APPROPRIATE TECHNOLOGY SELECTION FOR SEWAGE TREATMENT IN THE RURAL EASTERN CAPE

by

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A research project report submitted in partial fulfilment
of the requirements for the award of the degree of
Master of Science
of Loughborough University

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ABSTRACT

Waterborne sanitation is being proposed for many areas in South Africa, including the rural Eastern Cape. Legislation prescribes sewage treatment plants to produce a high quality effluent for discharging to water resources. This requirement effectively disqualifies low-technology options from being considered. Research was performed into selecting the most appropriate treatment technology for rural applications. An appropriate technology was defined as a technology with a suitable balance between the three spheres of sustainability (Environmental, Economic and Societal) while still complying with the BATNEEC principle (Best Available Technology Not Entailing Excessive Costs). A set of sustainability indicators for the study area was developed to select three realistic treatment options. Thereafter these were evaluated for local adaptation and a Multi-Criteria Decision Making (MCDM) process was used to select the preferred technology. It was determined that the Waste Stabilisation Pond system is the most appropriate technology, provided that effluent is re-used for agricultural purposes.

Keywords: Sustainable, Indicators; Low-Technology, Natural Treatment, Ponds

Distance Learning MSc Individual Research Project

EXECUTIVE SUMMARY

Individual Research Project Title:	Appropriate Technology Selection for Sewage Treatment in the Rural Eastern Cape
Author:	George Sebastiaan Nel
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EXECUTIVE SUMMARY

A. INTRODUCTION AND BACKGROUND

A.1. Subject Background

In South Africa, plans are in motion to eradicate the Bucket System and provide an improved level of sanitation service. The selection process for the appropriate level of service is, in some cases, influenced to motivate for a full waterborne sewerage system.

The South African National Water Act (NWA) specifies a very strict treated sewage effluent quality criteria (NWA (1998)). This can prevent or limit the use of low technology sewage treatment options such as Pond Systems.

Historically, Pond Systems have worked well in remote towns/communities (VD Merwe et al. (2012)). However, if the NWA requires strict compliance, then more advanced sewage treatment technologies might have to be considered. In such a remote setting, advanced technologies could pose problematic to implement, operate and maintain.

A.2. Study Area

The Study Area was selected as the Local Municipalities falling entirely within the old "Transkei" areas of the Eastern Cape. The Transkei was one of the traditional "Homelands" of the Xhosa-speaking ethnic groups in South Africa (SAHO (no date)). The area is characterised by rural villages clustered along main access routes, hilltops and near water sources. The area is mostly either state or communal land with very little European influence. Service delivery is also very basic at present.

A.3. Study Aims and Objectives

The aim of this study is to: **"Select the most appropriate technology for sewage treatment in the rural areas of the Eastern Cape (Study Area)."**

To achieve this aim, the following objectives needs to be achieved:

1. To understand the motivations behind current South African Policies.
2. To identify low-technology wastewater treatment options which can be used on a large scale.
3. To understand the O&M requirements and associated costs for the various treatment technology options available.
4. To address the applicability of such technologies to South Africa, with specific focus on the rural areas of the Eastern Cape.

5. To identify the social and competency challenges faced by the local community or water service providers in operating and maintaining sewage treatment works.

B. RESEARCH METHODOLOGY

B.1. Research Approach

Research was performed by means of four specific activities. The preceding activity created the platform and context for the next activity. These activities were:

i. Literature Review
ii. Stakeholder Engagement
iii. Field Investigations
iv. Options Analysis

The bulk of the research was a Desktop Study based on previous literature. Through Field Investigations and Stakeholder Engagement an attempt was made to improve the accuracy of the results and improve its relevance to the Study Area.

The Options Analysis was performed in three stages. The Status Quo and Local Preferences were first evaluated and three realistic technology options selected. The Environmental, Institutional and Economic Performance of these options were then evaluated. Thereafter the ability of these options to adapt to the local conditions were evaluated and a preferred technology selected.

During all stages, the appropriateness of the technologies were evaluated by considering the three spheres of sustainability (Societal, Economic and Environmental) (UWP (2012)). An integrated approach to al evaluations were followed by ensuring that all aspects according to SHTEFIE principle (Social, Health, Technical, Economic, Financial, Institutional and Environmental) was represented (Coates et al (2003)).

B.2. Accuracy of Results

Due to the Desktop approach to the research it was difficult to determine the accuracy of the research. The results were further influenced by:

i. Subjective responses from stakeholders
ii. Financial comparison of international case studies impacted by currency exchange rates
iii. Time limitations

A very low response rate to questionnaires and limited stakeholder engagement further impacted the accuracy of the results. Due to time limitations an attempt could not be made to improve this accuracy.

C. OPTIONS ANALYSIS AND RESULTS

C.1. Legislative Requirements

The most important legislative requirements revolve around the NWA. This study only considered a technology to be compliant with the NWA if it complies with the General Authorisation (GA). The GA is an in-principle approval, provided that certain conditions are met (NWA (2013)). The implementation of the GA varies between provinces. For Sewage Treatment, the following GA requirements (NWA (2013)) needs to be considered:

i. Maximum volume of treated effluent to be irrigation is 2 000 kl/d
ii. Maximum volume of treated effluent to be discharged to water resource: 2 000 kl/d
iii. Maximum volume of sewage to be stored in a pond system: 50 000 kl
iv. Maximum volume of sewage to be discharged into a pond system: 1 000 kl/d

C.2. Sustainability Scoring of Potential Technology Options

The South African Department of Water and Sanitation (DWS) performs a periodic assessment of the health of the Sewage treatment works in South Africa. These are reported on in the Green Drop Report. Technologies reported on in the Green Drop Report and through the initial literature review was consolidated into a list of potential technologies.

These technologies were then evaluated based on a Sustainability Scoring process recommended by Muga et al. (2007), but revised with recommendations from VD Merwe et al. (2012). The revision was required to adapt the approach for the South African context and specifically the Study Area. The results of the scoring is provided in Table 1.

Table 1: First Round Sustainability Scoring

Technology	Social Score	Enviro. Score	Econ. Score	Total Score
Waste Stabilisation Ponds (WSPo)	**24**	**24**	**30**	**78**
Settled Sewerage System (SSS)	14	12	20	46
Upflow Anaerobic Sludge Blankets (UASB)	**24**	**22**	**20**	**66**
Constructed Wetlands (CW)	**24**	**20**	**28**	**72**
Infiltration Percolation System with N-Basin	**20**	**24**	**18**	**62**
Activated Sludge Treatment (AS)	16	18	16	50
Biofiltration (Percolating filters)	16	24	18	58
Rotating Biological Contactors (Biodiscs)	22	14	18	54
Integrated Algal Pond System (IAPS)	**22**	**22**	**22**	**66**
PETRO System	14	28	18	60

The three realistic technologies for further evaluation was:

i. Waste Stabilisation Ponds (WSPo)
ii. Constructed Wetlands (CW)
iii. Integrated Algal Pond Systems (IAPS)

C.3. Performance Evaluation of Realistic Options

The performance evaluation considered the following aspects:

i. Physical Design Aspects
ii. Institutional Requirements
iii. Financial Considerations

It was found that the performance of the STPs were influenced by the strength of the raw sewage which had to be treated, as well as the disposal option (or Scenario) of the treated effluent. Three main effluent disposal scenarios were evaluated:

i. Scenario 01: Disposal of Effluent to a Water Resource. (This required strict effluent quality to be maintained)
ii. Scenario 02: Similar as for Scenario 01, but with relaxed nutrient removal requirements.
iii. Scenario 03: Local Irrigation of Effluent for Agricultural purposes (This permitted relaxed effluent quality requirements)

The performance aspects listed above all impact the overall Economic Performance of the STPs in some way, as can be seen from the figure below:

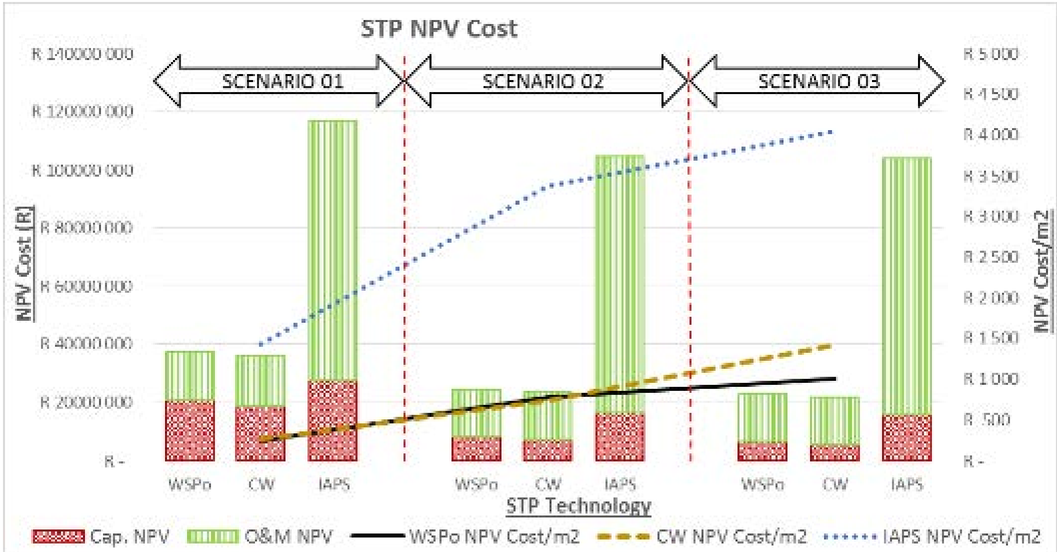

Figure 1: STP Economic Performance (Cost in ZAR; 1 US $ = 12.8 ZAR)

Through the economic performance it was concluded that:

i. Large areas of land are required to comply with Scenario 01
ii. When compared with the industry benchmark costs, no STP Option is economically viable to comply with Scenario 01.
iii. The IAPS is also not financially viable for any other Scenario.
iv. Staffing costs contribute the most over the lifecycle of the STPs

v. The WSPo uses land the most economically and has the lowest O&M costs.

C.4. Multi-Criteria Selection Process for Preferred Options

A multi-criteria decision making (MCDM) matrix was then developed based on the Analytical Hierarchy process developed by Saaty (1977). This process used pairwise comparison of the three realistic options, based on a standard set of criteria. The criteria was developed in consultation with a Water Services Provider and adjusted to allow for all spheres of sustainability.

The MCDM exercise corresponded well with the initial sustainability scoring in that the WSPo is the technology with the highest preference score.

D. CONCLUSIONS AND RECOMMENDATIONS

D.1. Selection of Preferred Technology

It was determined that the preferred technology is the WSPo system. This technology is the most appropriate since it has a good balance between the three spheres of overall sustainability, namely Economic, Environmental and Societal.

The selection of the WSPo as the most appropriate technology is however on condition that the effluent is re-used locally for agricultural purposes. Should these conditions remain true, then the WSPo is the BATNEEC (Best Available Technology Not Entailing Excessive Costs) (Smith(2011)).

It was further concluded that there is not one specific technology that will always be the most suitable in all circumstances. Should any deviation from the above assumptions occur, then the outcomes of this research will need to be revisited. The process followed above can however be used again, but with the revised boundary conditions.

D.2. Future Research Recommendations

This research has identified a few research gaps which should be researched in future, namely:

i. Revisit the South African effluent discharge standards to promote the sustainable development of all areas of South Africa
ii. Development of a universal STP performance coefficient to transcend socio-economic and political boundaries
iii. Standardised Criteria for Sustainability Calculations for the South African Industry
iv. Evaluation of the origin and motivation for the 1Ml/d limit to Pond-Systems in the NWA

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ABBREVIATIONS

AHP	Analytical Hierarchy Process
BPEO	Best Practical Environmental Option
CMA	Catchment Management Agency
COD	Chemical Oxygen Demand
COGTA	Cooperative Governance and Traditional Affairs
CRR	Cumulative Risk Rating
CSIR	Council for Scientific and Industrial Research
CW	Constructed Wetlands
DEDEAT	Department of Economic Development, Environmental Affairs and Tourism
DM	District Municipality
DOHS	Department of Human Settlements
DPW	Department of Public Works
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
ECA	Environmental Conservation Act
EIA	Environmental Impact Assessment
GA	General Authorisation
HRAP	High Rate Algal Pond
HSFCW	Horizontal Sub-surface Flow Constructed Wetlands
IAPS	Integrated Algal Pond System
IDP	Integrated Development Plan
IMESA	Institute for Municipal Engineers in South Africa
IPWMP	Integrated Pollution and Waste Management Policy
KPA	Key Performance Areas
KPI	Key Performance Indiators
LCP	Loughborough Catalogue Plus
LOS	Level of Service
MDG	Millennium Development Goals
MIG	Municipal Infrastructure Grant
MISA	Municipal Infrastructure Support Agency
Ml/d	Mega-litres per day
MW	Melbourne Water
N/C	Non-Compliance
NDP	National Development Plan

ABBREVIATIONS

NEMA	National Environmental Management Act
NEMWA	National Environmental Management: Waste Act
NFSD	National Framework for Sustainable Development
NGO	Non-Government Organisation
NI	No Information
NORAD	Norwegian Agency for Development Cooperation
NTS	Natural Treatment Systems
NPC	National Planning Commission
NPO	Non-Profit Organisation
NWA	National Water Act
NSP	National Sanitation Policy
NSAPSD	National Strategy and Action Plan for Sustainable Development
NWMS	National Waste Management Strategy
O&M	Operations and Maintenance
PE	Person Equivalent
PETRO	Pond Enhanced Treatment and Operation
PSP	Professional Service Provider
R	South African Rand (1 US$ = R12.80: 4 June 2017)
RWQO	Receiving Water Quality Objectives
RQIS	Resource Quality Information Service
SADC	Southern African Development Community
SALGA	South African Local Government Association
SH	Stakeholder
SHTEFIE	Social, Health, Technical, Economic, Financial, Institutional and Environmental
STP	Sewage Treatment Plant
SUSIT	Sustainability Indexing Tool
TSE	Treated Sewage Effluent
UASB	Up-flow Anaerobic Sludge Blankets
UESA	Uniform Effluent Standard Approach
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization
WMA	Water Management Area
WMI	Water Management Institute
WRC	Water Research Council

ABBREVIATIONS

WRR	Wastewater Risk Rating
WSA	Water Services Authority
WSAc	Water Services Act
WSDP	Water Services Development Plan
WSPo	Waste Stabilisation Pond
WSPr	Water Services Provider
WUL	Water Use License
ZAR	South African Rand (1 US$ = R12.80: 4 June 2017)

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1. INTRODUCTION

1.1 SUBJECT BACKGROUND

South Africa is undergoing a major drive to eradicate all service delivery backlogs. One of the regions with the biggest backlogs is the rural areas of the Eastern Cape, of which a portion was previously also known as the "Transkei".

A sanitation system being used in many of the remote areas mentioned above is the "Bucket System", whereby individuals defecate into an on-plot bucket and the contents of the buckets are then transported for treatment at a local sewage treatment works.

The Bucket System has been targeted for eradication and upgrading to a higher level of service. The selection process for the appropriate level of service is, in some cases, influenced by political pressure and community or institutional perspectives. In these instances the promoted solution for the replacement of the Bucket System is a full waterborne sewerage system, providing the highest sanitation level of service, irrespective of where the beneficiaries are located, whether in an urban or rural setting.

Full waterborne sewers require an increased and reliable water supply to flush the sewers and transport the wastes, and this increases the sewage inflows at the treatment works. Higher capacity sewage treatment works are thus required to accommodate the additional sewage volumes.

Figure 1-1: Location of Eastern Cape
(Image Source: Aurecon (2017(1)))

A typical treatment technology currently being employed in more remote areas of the Eastern Cape is a waste stabilisation pond (WSPo) system. This is a variety of the Pond System, which is a natural or low-technology sewage treatment option, characterised by sewage flowing through a series of ponds and in which treatment occurs by natural, biological processes over a period of several days.

Waste stabilisation ponds require simple operation and maintenance efforts and few (if any) electrical requirements. Unfortunately they require large areas of land. Further details on WSPo's are provided in Sections 2.7 and 4.4.

Remote towns/communities are well acquainted with Pond Systems and if sewage generation in these areas increases, more advanced sewage treatment technologies might have to be considered. In such a remote setting, advanced technologies could pose problematic to implement, operate and maintain.

South Africa also has a very high unemployment rate and low education level. The National Development Plan NPC (n.d.) has been created to assist in improving South Africa on various levels, including reducing unemployment and increasing the level of education of all. A key building block of this plan is to increase the volume of potable water to all households in South Africa, irrespective of their geographical location. These increased volumes of water will also further the goal of providing full waterborne sewerage to all.

1.2 DEFINING THE RURAL EASTERN CAPE

The Eastern Cape comprises three distinct types of land-uses. The first is the urban developmental areas, such as large towns, cities and industrial zones based on the European model. The second is the rural areas established through colonial farming activities, characterised by large areas of agricultural lands with formal farm dwellings or farm clusters between them. No rural villages for indigenous peoples dominate these rural areas.

The last area is the rural Eastern Cape in which the indigenous peoples established themselves over the years. This area is characterised by the grouping of people by ancestral heritage together on tribal lands. This latter type of area will comprise the study area, but to better understand its establishment, a short overview of its history is required.

During the Dutch colonisation of Southern Africa by the mid-1600's, the Xhosa peoples' ancestral lands were the Eastern Cape. They settled here after migration southwards, form higher up (further North) in Africa.

The transfer of Xhosa ancestral lands to European occupation started in 1770 when Dutch agricultural settlements started to expand eastward from the Cape of Good Hope. Following the British annexation of the Cape Colony in 1806, an aggressive expansion of the Cape boundaries occurred. The boundaries of the Cape expanded over time, with more and more of the Xhosa ancestral lands either taken by force or negotiated with the tribal leaders.

Under British rule an attempt was made to implement segregated districts for the Xhosa-peoples. This was referred to as the Glen Gray Act of 1894, in which these districts were governed by District Councils under the leadership of local Xhosa chiefs.

This Act also formed the basis of the 1913 Native's Land Act and the 1958 Bantustan Policy. In the Bantustan Policy the tribal lands identified in the Glen Grey Act were formalised as the "home lands" for the indigenous peoples of Southern Africa. In the Eastern Cape two "Home

Land" areas were identified. "Ciskei", meaning "this side of the Kei River" was established around the current Bhisho area and was the tribal lands of the Ngqika Xhosas. The other area was known as the "Transkei" meaning "beyond the Kei River". The latter was the home of the Gcaleka Xhosa people. Figure 1-2 shows the location of the historical "Ciskei" homelands in green, and the Transkei area in pink. Transkei was seven times the area of Ciskei at about 43,000 km^2, and predominantly consisted of villages with small holdings for subsistence maize farming. Communal cattle-herding also occurred.

On 27 April 1994 the Apartheid-era ended and the homelands were re-integrated into South Africa. The long absence from South Africa and the lack of investment in infrastructure and development for these areas did however cause a significant disparity in living conditions between these homelands and the rest of South Africa.

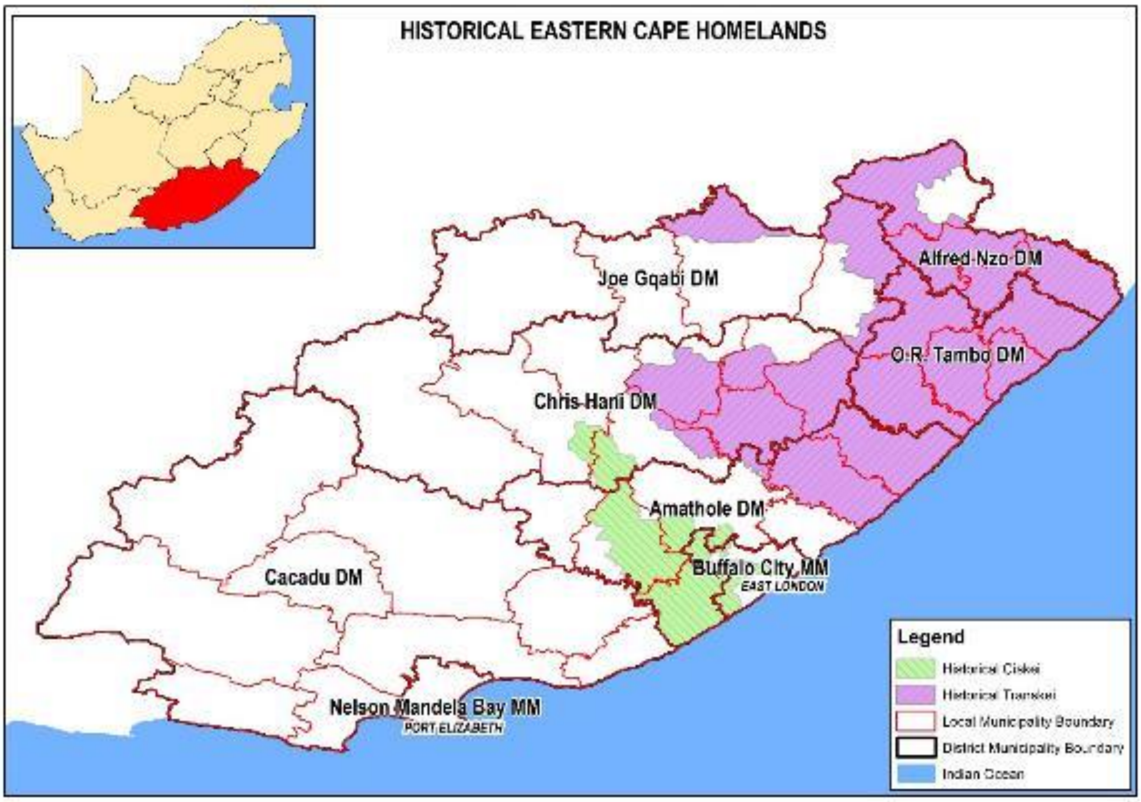


Figure 1-2: Historical "Home Land" Boundaries

(Image Source: Aurecon (2017(1)))

Material in this section is based on information obtained from SAHO (no date).

1.3 BOUNDARIES OF STUDY AREA

For the purpose of this study, the study area's boundaries were determined by overlapping the historical Transkei "Homelands" with the current municipal boundaries. It was decided to rather focus on the Transkei than on the Ciskei since the former was less influenced by European colonisation than the latter. The Transkei is thus more uniformly rural than Ciskei and low-technology sewage treatment technologies will be more appropriate in this area.

Figure 1-3 illustrates the study area boundaries and an enlarged image of Figure 1-3 is also provided in Annexure 1. The study area boundaries coincide with the boundaries of Local

Municipalities which fall entirely within the old "Transkei". This will improve the ease and accuracy of data collection without the need to filter information for areas which fall partly in the old Cape Colonies and partly in the old "Transkei".

Material in this section is based on information obtained from SAHO (no date).

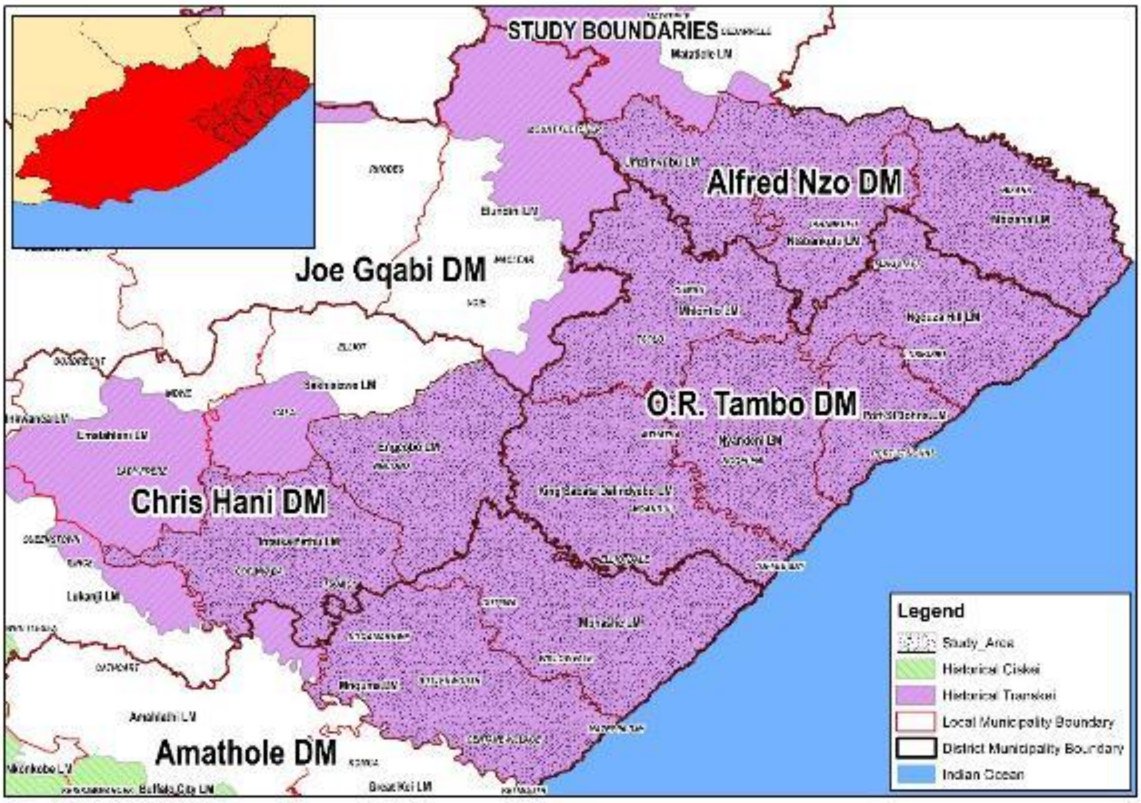


Figure 1-3: Study Boundaries
(Image Source: Aurecon (2017(1)))

1.4 PROBLEM STATEMENT

In the event full waterborne sewerage systems are to be provided in all rural areas of the Eastern Cape, sewage treatment works will have to be able to accommodate and safely treat the higher volumes. The local communities and service providers are more acquainted with simple technologies and it could be challenging for them to adjust to more complex technologies.

It is evident that an appropriate technology needs to be selected, which needs to address the following issues:

1. The selected treatment technology needs to be sustainable;
2. Treated sewage effluent needs to comply with the required discharge standards; and
3. Operation and maintenance of the sewage treatment technologies needs to be suitable for the local communities and local service providers.

This focus of the research can thus be summarised as follows:

"The selection of the most appropriate technology for sewage treatment in the rural areas of the Eastern Cape."

1.5 STUDY AIMS AND OBJECTIVES

The aim of this study is to:

Select the most appropriate technology for sewage treatment in the rural areas of the Eastern Cape (Study Area).

Specific attention will be given to the implementation of Pond Systems as this is currently the preferred option in rural areas of South Africa. Consideration will however be given to how well more advanced-technologies can be operated and maintained in a more rural environment, with emphasis given to training of the local community.

For all options considered, operation and maintenance requirements and challenges will be considered.

In order to achieve this aim, various objectives need to be achieved. The objectives of this study can be summarised as follows:

1. To understand the motivations behind current South African Policies.
2. To identify low-technology wastewater treatment options which can be used on a large scale.
3. To understand the O&M requirements and associated costs for the various treatment technology options available.
4. To address the applicability of such technologies to South Africa, with specific focus on the rural areas of the Eastern Cape.
5. To identify the social and competency challenges faced by the local community or water service providers in operating and maintaining sewage treatment works.

Research Questions to be answered

To achieve the above objectives, the following questions need to be answered:

1. What low-technology wastewater treatment options are available?
2. What advanced-technology wastewater treatment options can be considered for rural applications?
3. How applicable are these options to be used on a large scale?
4. Are there any success stories for these treatment options? (Local and/or International)
5. Why is the DWA so resistant to permitting high-volume low technologies to be used?
6. What community challenges are likely to be experienced in operating wastewater treatment works?
7. How effective are institutions currently at operating and maintaining wastewater treatment works?
8. What risks exist to the South African policies if high volume low technology options are used?
9. What are the financial implications for implementing such high volume low technology options?
10. How will the community benefit from the selected technology? (e.g. involvement in O&M and agricultural re-use of effluent)

Challenges to be addressed

Further to the above research questions, solutions to the following challenges will also need to be found:

1. How willing is DWA to change its policies?
2. Do local communities have the ability to learn new skills?

3. How willing are local authorities/service providers to transfer responsibilities for operating and maintaining treatment works to the local communities?
4. How could funding and cost recovery models be structured to suit the rural environment?

1.6 RESEARCH APPROACH

This study's research approach is very much dependent on literature reviews and desktop studies. These will be further refined by limited field work, which will include site inspections of existing plants and reviewing tests results of sampled sewage effluent. Interviews with plant operators and local decision makers will also be held to discuss the current shortcomings and successes in appropriate technology selection.

Section 3 describes the research approach in detail, but the basic approach is outlined below:

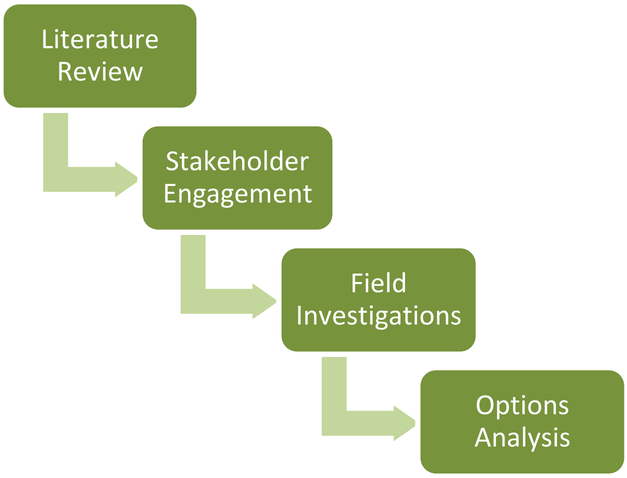


Figure 1-4: Research Approach Structure

Each research step depicted above will assist in executing the next research step. During the final options analysis stage, all information collected in preceding steps will be collated and used to compile a set of criteria from which the most appropriate technology will be selected.

1.7 LIMITS OF STUDY

Certain limitations to the scope and content of this study need to be defined as described below:

Geographic Location of Study Area

This study only focusses on the rural area of the Eastern Cape, thus is not representative of the entire Eastern Cape or South Africa. All findings needs to be read in this context and critically looked at for application in areas outside the Study Area.

The Study Area consists of many remote villages and communities. This can cause complications to reach them in time for consideration in the study. Some areas might have to be excluded from the study if insufficient time exists to incorporate all areas into the final analysis and findings.

Nature of Research

This research will only focus on treatment of sewage originating from human defecation and not industrial sewage or the management of solid waste.

The accuracy of the outcomes will only be based on findings from a desktop study and no pilot plants will be constructed to validate the findings.

Research analysis will be very much dependent on evaluation of available literature and interviews with various stakeholders. These interviews will assist in understanding the current context of the problem and what perceptions of the problem currently prevail.

Information on existing STPs and their operational records might also be limited, resulting in incomplete data-sets and requiring information to be assumed or synthesized.

Funding and Time Limitations

Limited time and the lack of funding will unfortunately prevent a pilot plant or any laboratory work from being performed.

Time limitations will also mean limited research will be done on sewage composition and effluent quality in the Study Area, and results from existing sewage treatment plants will form the basis of evaluation.

Availability of Information

Some role players and key informants will also be a bit difficult to reach for an interview or to acquire information from. There might even be reluctance on their part to disclose information.

Associated with limited time, it is plausible that some sources of literature or recent studies into new technologies were not consulted, meaning that some viable technologies were unintentionally overlooked in this research.

1.8 EXPECTED CONTRIBUTION OF RESEARCH

It is expected that this research will assist in providing a broad approach to selecting appropriate treatment technologies for the Rural Eastern Cape. While literature and generic approaches to technology selection do exist, the author was unable to identify any that have been adjusted to be appropriate for this Study Area.

This research will thus contribute to local industry best-practice through different avenues, namely:

1. The application of local legislation on the study area will be better understood
2. The local environmental and institutional challenges will be better defined
3. Preferred existing technologies for the area will be identified
4. The suitability of adapting new technologies for introduction to the study will be discussed
5. Potential challenges and successes in appropriate technology selection will also be discussed.

These will all be used to customize the generic approach of technology selection, to one which is specific and appropriate to the Rural Eastern Cape Environment.

The limitations discussed in Section 1.6 means that this research provides a broad approach, or baseline study, which can be used for further refinement by future studies.

1.9 REPORT OUTLINE

The report structure follows the research approach described in Section 1.6 and is graphically illustrated below in Figure 1-5:

Figure 1-5: Report Outline

Each section will start with an introduction to explain to the reader what will be addressed in that section. At the end of each section, a summary will be provided, which will review what has been achieved in the section and how it will be used in the rest of the research.

2. LITERATURE REVIEW

2.1 SECTION INTRODUCTION

A literature review was performed on available relevant information to understand the extent of the existing body of knowledge on this topic. To ensure the literature review was approached from an interdisciplinary perspective and thus covered all aspects that contributed to a holistic view of the topic, the literature research focussed on the SHTEFIE categories (Coates et al 2003), namely:

i. Social
ii. Health
iii. Technical
iv. Economic
v. Financial
vi. Institutional
vii. Environmental

The most important aspects in each of the above categories and which had bearing on this study were identified. With the literature review providing the necessary background information, it was possible to identify important role players for engagement during the study. Any appropriate research techniques which could be applied on this project could also be identified.

The final benefit of the literature review was to identify current knowledge gaps for future research opportunities, either as part of this research, or as part of future, independent research.

2.2 LITERATURE SEARCH AND REVIEW STRATEGY

Information was sourced from previous research papers, case studies on existing treatment plants, published industry guidelines and local legislation. The published industry guidelines and local legislation was either obtained directly from the institute's website or via interviews with key role players and industry colleagues.

Electronic publications and case studies were sourced by means of electronic search engines. The literature search was orientated towards the seven research categories mentioned in Section 2.1, with suitable keywords used to refine the search results to be relevant to the search category. Further details on the literature search and review strategy is provided further on in this section.

The literature search and review assisted in answering the various research questions and challenges identified in Section 1.5. Table 2-1 provides details on the various search methods utilised.

The author assessed the source reliability on the extent to which publications had been peer-reviewed. The reliability of information from interviews and institutional websites are considered to be low as it is difficult to prove that the information has been peer-reviewed. Research articles obtained through Google Scholar can be more reliable, but the certainty of the information having been peer reviewed first is still questionable and has thus a medium reliability.

Information obtained from Loughborough Catalogue Plus (LCP) and Science Direct can be selected based on its peer reviewed credibility. Further criteria which contributed to the reliability of an information source is the scientific approach to the research and ability of the research to be replicated, under similar circumstances and following the procedures set out in the research articles. Social and environmental aspects are considered "soft issues" since they are mostly intangible and the results are difficult to replicate, thus research on these aspects have been considered to be of medium reliability.

Table 2-1 : Search Methods Used

RESEARCH CATEGORY	INFORMATION SOURCE	SEARCH ENGINE USED	SOURCE RELIABILITY
Institutional / Health	Interviews	n/a	Low
	Institutional web-sites	None	Low
Technical / Economic / Financial	Electronic Publications	Loughborough Catalogue Plus (LCP) Google Scholar Science Direct	High Medium High
	Interviews	n/a	Low
Social	Electronic Publications	LCP Google Scholar Science Direct	Medium Medium High
Environmental	Electronic Publications	LCP Science Direct	Medium Medium

Table 2-1 above lists three electronic search engines used during the search for associated literature (LCP, Google Scholar and Science Direct). Searches on LCP however also covered the following databases:

i. T and F online
ii. Springerlink
iii. IWAP online
iv. Environmental Earth Sciences
v. Swetswise

Searches were performed by using selected keywords derived from the research questions which needed to be answered. The research area is quite broad thus a combination of keywords was required to be used to refine the search. The main keywords focussed on the research area while the secondary keywords focussed on the various research categories and questions needing to be addressed within the research area. Details on the Keyword search methodology can be found in Annexure 2. To identify the literature most applicable to this research, each article was evaluated using two sets of criteria. The first set provided a score out of a 100 for each article and tested its relevance to the current research, quality of work and recentness.

The second set of criteria evaluated the degree of correlation the literature had with the various research questions that this research need to help answer. It must be noted that the evaluation and scoring of the literature was based on the author's personal judgement and did not follow a prescribed approach outlined in previous literature. Further details on this method are provided in the text that follows and Table 2-2.

Once the highest scoring literature using both criteria was identified, the remaining literature was assessed using a third criterion. This focussed on identifying those literature sources which only addressed a few specific research aspects which were not readily available in any other literature identified during the literature search. This last criterion thus also helped to point out where the knowledge gaps in research were.

These three criteria formed the basis of the main body of literature which was sourced. From here, references in the text of the above literature base, and which contributed to the study, were further sourced to develop the body of knowledge even more. A 'snowball' technique therefore proved helpful, with references from one document suggesting other relevant publications.

Table 2-2 below shows how points were attributed to the research scoring and correlation respectively:

Table 2-2 : Literature Evaluation Criteria

RESEARCH SCORING		RESEARCH CORRELATION
Criteria	Max. points	Aspects Covered: (1 point per aspect)
Quality of Citation:	10	1. Ponds/ NTS
Peer Reviewed:	15	2. Large Scale STPs
Relevance to Topic	40	3. Institutional Aspects
Recentness	15	4. South African Policies
Objective Approach	20	5. Effluent Quality
		6. Rural Areas
Max Research Score which can be achieved: 100		7. Developing Countries
		8. O&M Aspects
		9. Cost considerations
		10. Community Involvement
		Highest Correlation Index score: 10

When scoring the research, greater weight was assigned to the relevance of the research than to the other factors. It should be pointed out that a document can have a low correlation index but a high scoring for relevance to the topic. This is because it can be very relevant to one aspect of the research, but does not address all facets which this study focusses on.

The correlation index thus refers more to the generality of research and overall comparison with the current research, than with the quality or subject depth the document had.

By applying the keyword search method and the above evaluation process of sourced literature, various pieces of useful literature were sourced for this study. The execution of this approach is further detailed in Annexure 2. Figure 2-1 illustrates which research category contributed most to the current body of knowledge, using the various search techniques.

From Figure 2-1 it can be seen that an increase in literature sources occur as the reliability of the source reduces. Only a few relevant resources with high reliability were able to be obtained. "Direct References" refers to publications obtained directly from organisations websites and include research papers as well as demographic information and strategic plans of which the reliability could not be verified. They therefore have a general “Low” reliability grading, but some very good technical documents was obtained through industry professionals.

Minimal research was obtainable on the Institutional, Health, Financial and Economic matters associated with the research using academic research engines. This either suggests that no quality research into these aspects have occurred to date, or research has been done but is such a way that the research technique could not identify it. In the event of Health the latter could be the case if Health issues were addressed in a broader view. The high volume of Institutional information obtainable by Direct Reference does indicate the information is available, but is not in an academic format.

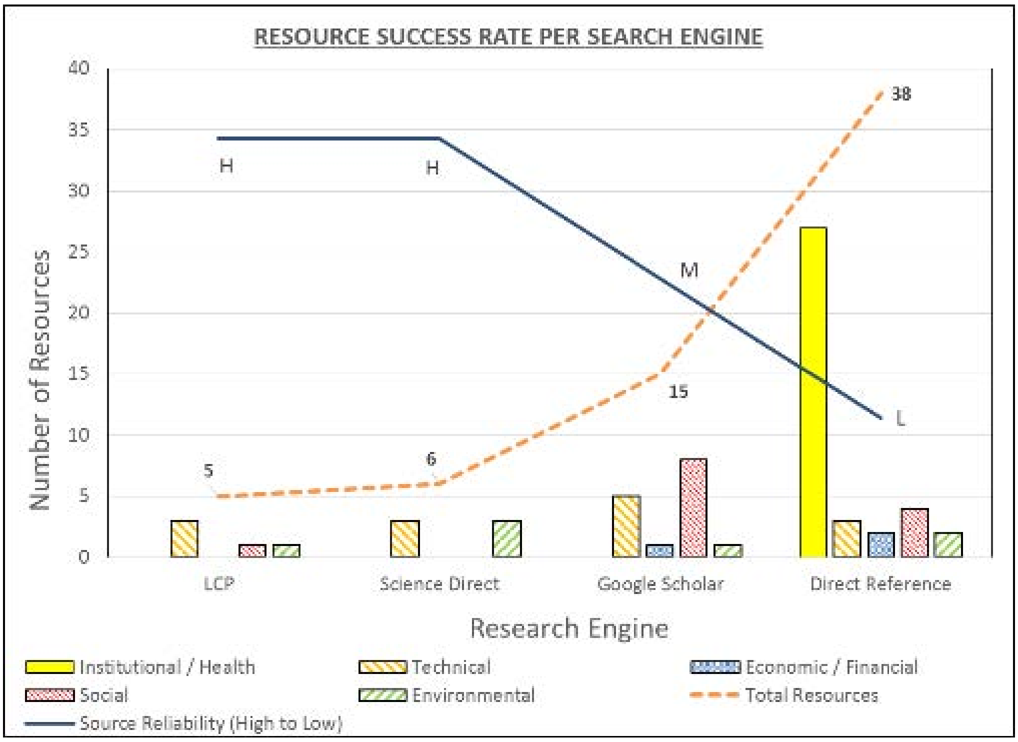


Figure 2-1: Resource Success Rate per Search Engine
(Image Source: Author)

It needs to be stressed that Institutional and Economic aspects are addressed in the other literature pieces reviewed and discussed below, but they do not form the core of the literature piece, thus is excluded from the figures below.

2.3 STATUS QUO OF LEVEL OF SERVICE IN THE STUDY AREA

The status quo of the study area’s sanitation Level of Service (LOS) needs to be understood in context of a Sanitation Ladder. A Sanitation Ladder is a multiple-step process or “ladder” with each higher step representing a better level of service than the lower step. The higher you move up the ladder, the more advanced and costly the level of service is. The number of steps in the ladder can be determined by the local institutions and community.

In the year 2000, world leaders signed the Millennium Declaration, from which the Millennium Development Goals (MDG) were developed. In 2002 a sanitation target was added to Goal 7 of the MDG, according to which the proportion of population without sustainable access to basic sanitation needed to be halved by 2015 (measured from 1990). (UNICEF/WHO, 2015, p.34)

A four step Sanitation Ladder was used to evaluate progress against (UNICEF/WHO, 2008, p.6), with each step representing the following level of service:

1. Practicing Open Defecation
2. Using unimproved sanitation facilities (Open pit latrines, Bucket Defecation)
3. Using shared sanitation facilities.
4. Using improved sanitation facilities (Ventilated Improved Pit Latrines, flushing toilets, etc.)

The intention was that by 2015, 77% of the world's population should achieve access to improved sanitation facilities. The 2015 assessment of the goals indicated that only 68% of the world population received the intended access. South Africa increased 15% from 51% in 1990 to 66% in 2015. The rural areas of South Africa increased from 38% in 1990 to 61% in 2015, suggesting a large investment in improving the rural living conditions.

According to the DWS database (DWS, 2015 (1)), approximately 7 million people live within the Eastern Cape of South Africa. Of the above population, 59% are living in 7,362 rural settlements, with an average density of 531 people per rural settlement/village and 4.5 people per household. The DWS database also provides information on the sanitation level of service (LOS), based on a 2.9million population sample size. The results are illustrated in Figure 2-2 below:

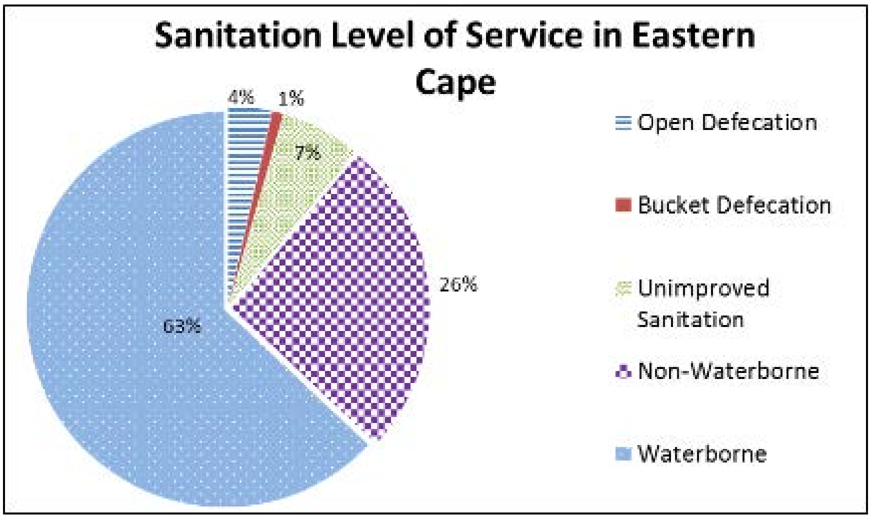


Figure 2-2: Sanitation LOS distribution in the Eastern Cape
(Image Source: DWS 2015 (1))

Figure 2-2 indicates that 12% of the sample population is not receiving Basic Sanitation and that 63% are receiving waterborne sanitation. No information is available on if the 26% Non-Waterborne sanitation is in fact of an improved level or below an acceptable standard and this will have to be confirmed. The first impression of the figure is that the Eastern Cape is equal-to-better than the rest of South Africa when it comes to sanitation service delivery and that they have achieved the MDGs.

The author's personal experience of the rural areas of the Eastern Cape contradicts the above summary of 63% waterborne sanitation coverage and believes that clarity from DWS needs to be sought on how representative this sample is of the rural Eastern Cape. More detail on the sanitation LOS can be obtained from the Water Services Authorities' (WSAs)

Integrated Development Plans (IDPs) and Water Services Development Plans (WSDPs) for the area.

WSAs also depend on the local municipalities' (LM's) own IDPs and these were also consulted in this study. With respect to level of service in the Study Area, Table 2-3 lists all the resources which were consulted. As mentioned in Section 1, the study boundaries were selected to coincide with Local Municipal boundaries which are wholly located within the borders of the old "Transkei". This was deliberately done in order to ensure that when the WSDP and IDP documents are consulted, the information would be well representative of the rural Eastern Cape.

It was found that only about 33% of the study area has an improved LOS (LOS definition as per the MDGs). Slight differences in quoted percentages were however found between the WSA's IDP and the LM's IDP. The general theme was however that sanitation services is inadequate and is a focus point for improvement over the next five years in all parts of the study area. The WSDPs and IDPs also noted that maintenance to existing sewage treatment works was also necessary, but due to high indigent populations that do not earn a salary, revenue collection was limited and resulted in funding shortfalls.

From the above literature review the following main stakeholders have been identified:

1. WSA: Responsible for planning and implementing sanitation LOS in their region
2. DWS: Responsible for monitoring compliance and enforcing policies and legislation.

Table 2-3 : LM and DM resources consulted

District Municipality	Local Municipality	Resource	Reference
Amathole District Municipality (ADM)	n/a n/a Mnquma LM Mbhashe LM	WSDP (ADM) IDP (ADM) IDP IDP	DWS, 2015 (3) ADM, 2015 MqLM, 2015 MbLM, 2015
Chris Hani District Municipality (CHDM)	n/a n/a Intsika Yethu LM Engcobo LM	WSDP (CHDM) IDP (CHDM) IDP IDP	DWS, 2015 (4) CHDM, 2015 IYLM, 2015 ELM, 2015
OR Tambo District Municipality (ORTDM)	n/a n/a King Sabata Dalindyebo LM Nyandeni LM Mhlontlo LM Port St Johns LM Inguza Hill LM	WSDP (ORTDM) IDP (ORTDM) IDP IDP IDP IDP IDP	DWS, 2015 (5) ORTDM, 2015 KSDLM, 2015 NyLM, 2015 MhLM, 2015 PSJLM, 2015 IHLM, 2015
Alfred Nzo District Municipality (ANDM)	n/a n/a Mbizana LM Ntabankulu LM Umzimvubu LM	WSDP (ANDM) IDP (ANDM) IDP IDP Not available	DWS, 2015 (2) ANDM, 2015 MzLM, 2015 NtLM, 2015 n/a

2.4 NATIONAL STRATEGIC PLANNING

In 2004 a National Sanitation Strategy was compiled for the then Department of Water Affairs and Forestry (DWAF). The document focussed on developing and action plan for sanitation service delivery and emphasized that the selected technology needed to be appropriate for the area in which it is to be implemented. MDK, 2004, p 47

Following this, the responsibility for sanitation services was transferred to the Department of Human Settlements (DOHS), but in 2014 it was returned to the newly structured Department of Water and Sanitation (DWS) (old DWAF). DWS has recently issued their 2015/2016 to 2019/2020 Strategic Plan in which they confirm their commitment to providing an improved quality of life to all and the provision of adequate sanitation services to all. DWS, 2015 (6), pp 19-20

The National Development Plan (NDP) is a strategic document developed by the Department of the Presidency National Planning Commission (NPC n.d.). Its focus is the elimination of poverty and reduction of inequality by 2030 through growing the economy and building capabilities and capacities. Focus is therefore given to the roll-out of infrastructure in the rural areas, as these areas are one of the major contributors of inequality in the country.

Emphasis is also placed on raising the income level in rural areas and it encourages community leaders to be involved in the country's development. The NDP further recommends that a long-term goal must be for the users to pay the bulk of the costs for infrastructure. The correct selection of sewage treatment technology could therefore assist in achieving the National Development Plan's goals. A 10 year plan is currently being developed to implement the ideals of the NDP. Petterson, 2004.

Amatola Water (AW) is a Water Board located in the Eastern Cape. In their 2015 – 2019 business plan they have indicated that DWS is contemplating realigning AW into a Water Utility for the Southern Region of South Africa. As a Water Utility they will be able to take over all Water Services from the Water Supply Authorities in the area. (AW, 2015, p23)

In order to support the goals of the NDP of providing running water to every household by 2030, they intend to increase their bulk water supply. AW has consulted the Guidelines for Human Settlement, Planning and Design (CSIR 2000, p9.20) and have concluded that a supply volume of 750 litres per household per day is an adequate level of supply to support the NDP's 2030 vision. AW intends to implement this larger supply volume over the next five years. AW, 2015, p31

From the above literature review the following main stakeholders have been identified:

1. AW: Water Board implementing infrastructure in the area and focussed on promoting the NDP in the Eastern Cape.
2. DWS: Promoting and implementing the goals set out in the NDP.

2.5 UNDERSTANDING LOCAL LEGISLATION AND POLICIES

NATIONAL WATER ACT (ACT 36 of 1998)

The National Water Act (NWA) of South Africa (NWA 1998) is used to regulate water use. This includes the disposal of sewage from a STP and prescribes that a person *"must return any seepage, run-off or water containing waste which emanates from that use, to the water resource from which the water was taken, unless the responsible authority directs otherwise or the relevant authorisation provides otherwise."*

Before the NWA, South Africa applied the Uniform Effluent Standard Approach (UESA), whereby effluent need to comply to either general discharge or special discharge standards.

These standards specifies certain indicator parameters that needs to be achieved. With the NWA, South Africa now applies the Receiving Water Quality Objectives (RWQO), which means that the discharged effluent must not impact on the quality of the receiving water resource.

The General and Special Limits still exist, are periodically updated as required and can only be applied under certain conditions specified in the General Authorisation. (NWA 2013). A copy of the latest discharge standards are provided in Annexure 3.

WATER SERVICES ACT (ACT 108 of 1997)

The Water Services Act (WSAc) of South Africa (WSAc 1997) outlines the roles and responsibilities of the various role players in the Water Sector and how water services are to be provided. The WSAc also makes allowance for authorised institutions to structure tariffs and collect payment for services rendered. Further detail on these roles and local dynamics are provided in section 2.6.

The WSAc also includes regulations for the classifications of Sewage Treatment Plants (STPs) and Operators, including their required qualifications. (WSAc 2013 and WSAc 2013(2))

ENVIRONMENTAL CONSERVATION ACT (ACT 73 of 1989)

The Environmental Conservation Act (ECA) of South Africa (ECA 1989) lists waste disposal as an activity which may be detrimental to the environmental. The ECA confirms that such activities may continue, provided that the Minister of Environmental Affairs or delegated competent authority approves the activity. Such approval can only be granted after consulting the necessary reports addressing the activity in detail. This process is called an Environmental Assessment, and can either be a full Environmental Impact Assessment (EIA) or Basic Assessment Report (BAR), depending on the degree of environmental impact. In the Eastern Cape, the delegated authority to monitor compliance with the ECA is the Department of Economic Development, Environmental Affairs and Tourism (DEDEAT).

NATIONAL ENVIRONMENTAL MANAGEMENT ACT (ACT 107 of 1998)

The EIA process must also comply with the provisions of the National Environmental Management Act (NEMA) of South Africa (NEMA 1998). The NEMA supports the principle of sustainability and that the Best Practical Environmental Option (BPEO) be selected. Wrt sustainability it specifically states: *"Development must be socially, environmentally and economically sustainable."* and "Sustainable development requires the consideration of all relevant factors". (NEMA 1998, p10)

NATIONAL ENVIRONMENTAL MANAGEMENT: WASTE ACT (ACT 59 of 2008)

The National Environmental Management: Waste Act (NEMWA) of South Africa (NEMWA 2008) focusses on protecting the health of the community as well as the environment. Wrt Sewage Treatment, the NEMWA emphasizes the following important objectives:

1. Minimising the consumption of natural resources;
2. Avoiding and minimising the generation of waste;
3. Reducing, re-using, recycling and recovering waste;
4. Treating and safely disposing of waste as a last resort;
5. Preventing pollution and ecological degradation;

6. Securing ecologically sustainable development, while promoting justifiable economic and social development;

According to Mambo et al (2014), the National Waste Management Strategy (NWMS), which is a legislative requirement of the NEMWA and seeks to achieve the objectives of the latter (NMWS 2011), any new sewage treatment technology which intends to be utilised in South Africa, needs to:

i. Demonstrate its proficiency
ii. Educate the various stakeholders of its abilities and limitations

SOUTH AFRICAN NATIONAL STRATEGY AND ACTION PLAN FOR SUSTAINABLE DEVELOPMENT (NSAPSD)

The NSAPSD was published in Government Gazette No 33187 on 14 May 2010. (NSAPSD, 2010) and provides an action plan for implementing the National Framework for Sustainable Development. The action plan sets out certain strategic goals and interventions in respect of the following strategic priorities:

- Priority 01: *Enhancing systems for integrated planning and implementation*
- Priority 02: *Sustaining our ecosystems and using natural resources efficiently*
- Priority 03: *Economic development via investing in sustainable infrastructure*
- Priority 04: *Creating sustainable human settlements*
- Priority 05: *Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)*

While this is still on a conceptual level, the importance of taking this strategy and action plan into consideration during future infrastructure planning will become increasingly important.

From the above literature review the following main stakeholders have been identified:

1. DWS: Responsible for implementing a whole range of water and waste related policies, legislation and issuing of authorisations.
2. DEDEAT: Monitors compliance with the ECA, NEMA and NEMWA.
3. Scientists: They advise clients on which legislation applies and usually applies for the authorisations and licenses on behof of the client.

2.6 LOCAL INSTITUTIONAL DYNAMICS

The NWA states in Clause 3 of Chapter 1 that "*As the public trustee of the nation's water resources the National Government, acting through the Minister, must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons and in accordance with its constitutional mandate.*" (NWA 1998)

The minister is held responsible in this regards and uses the Department of Water and Sanitation (DWS) to regulate all water related activities in South Africa (DWAF nd, p12), in accordance with the NWA. The Minister may delegate certain responsibilities to Catchment Management Agencies (CMA) and Water Management Institutions (WMI). The roles and responsibilities of the CMA is provided in the NWA, with the Water Services Act (WSAc) providing more detail on the WMI. In the study area, DWS is the CMA and the WMI is represented by various Water Services Authorities (WSAs), Water Services Providers (WSPrs) and Water Boards (also known as Water Services Utilities).

WSAs are responsible for the enforcement of regulations as well as the development and implementation of Water Services Development Plans. WSAs must also arrange for the provision of Water Services through either appointing a Water Services Provider, or acting in such a capacity themselves. (WSAc 1997)

The contract between the WSA and WSPr specifies which services are to be provided, but typically includes the operation and maintenance of existing water infrastructure and the process of revenue collection. Considering the WSDPs discussed in Section 2.3, Table 2-4 provides details on who the WSA and WSPr is in the study area.

Table 2-4 : WSA and WSP in the study area

LOCAL MUNICIPALITY	WSPr	WSA
Mnquma LM **Mbhashe LM**	ADM / AW	ADM
Intsika Yethu LM **Engcobo LM**	CHDM	CHDM
King Sabata Dalindyebo LM **Nyandeni LM** **Mhlontlo LM** **Port St Johns LM** **Inguza Hill LM**	ORTDM / AW	ORTDM
Mbizana LM **Ntabankulu LM** **Umzimvubu LM**	ANDM	ANDM

Amatola Water (AW) is a water board operating in the Eastern Cape. While it is fulfilling mostly the role of a WSPr, it is being used by DWS to implement certain projects in the province, on behalf of DWS. AW also owns and operates some infrastructure in the BCMM and western ADM areas, with Figure 2-3 providing further details on where Amatola Water is Operational.

Eskom is a South African Parastatal and generates approximately 95% of the electricity used in South Africa and 45% for that used in Africa. Eskom sells electricity to other African countries, mostly focussed on the Southern African Development Community (SADC). (ESKOM 2016) From 1988 to 2007, the electricity tarrif in South Africa was kept very low in order to ensure the affordability of low income communities. This however resulted in the electricity tariff increasing by only 223% compared to inflation's 335% over the same period. (POWEROPTIMAL 2016)

Following 2007, electricity price adjustments were implemented to recover costs and raise capital for maintaining aging assets and implementing new projects. This resulted in a tariff price increase of 300%, compared to a 45% increase inflation over the period from 2007 to 2015. It is foreseen that by 2017, the electricity tariff would have increased by 500%. Electricity in South Africa is not as expensive as in other parts of Africa and the world, but considering the high jobless figures in South Africa and slowing economy, it is too high for low income communities. Wage adjustments have also not been able to accommodate the increased costs of electricity. (POWEROPTIMAL 2016)

Some other stakeholders with vested interest in the Eastern Cape are:

- Cooperative Governance and Traditional Affairs (COGTA) – Assists with the development of good governance and promotion of service delivery. (COGTA 2016)
- Municipal Infrastructure Support Agency (MISA) – Provides technical support to municipalities with the intent to accelerate service delivery. (MISA 2016)
- Mvula Trust – A Non-Government Organisation (NGO) and Non-Profit Organisation (NPO) regulated by the Department of Social Development, focussing on the development of community infrastructure. (MVULA 2016)
- South African Local Government Association (SALGA) – Provides coordination between provincial and national government on political and administrative issues. (SALGA 2016)

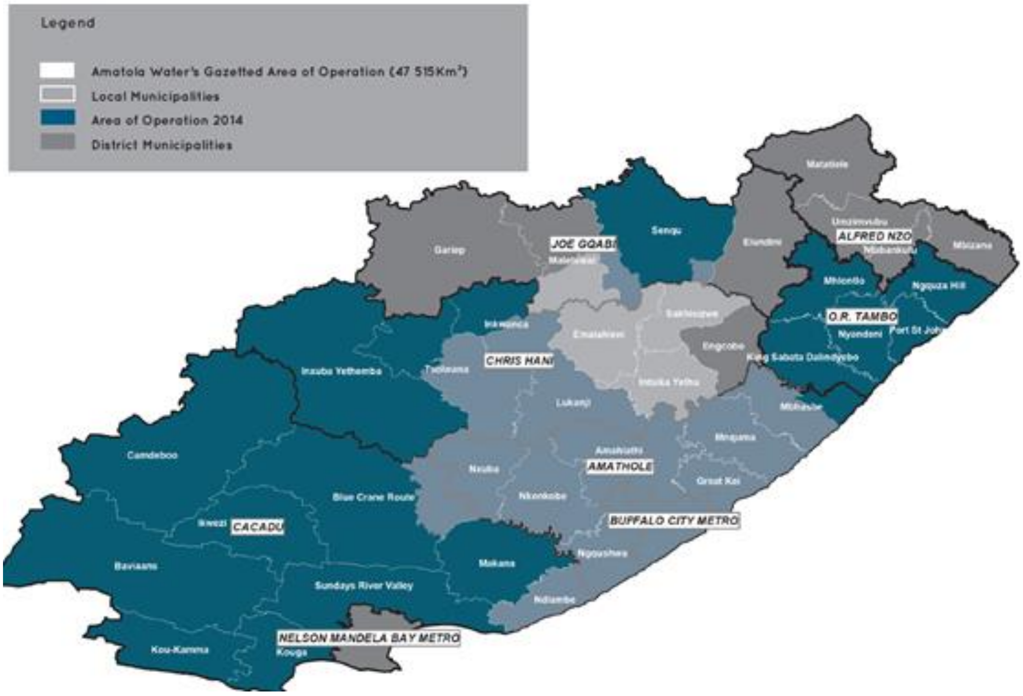


Figure 2-3: Amatola Water Area of Operation (Source: AW 2014, page 120)
(Image Source: AW (2014, pp 120))

From the above literature review the following main stakeholders have been identified:

1. DWS: Responsible for implementing the WSAc
2. District Municipalities (DMs): They are the WSA and the WSPr in the study area.
3. AW: They are also implementing water-related services in the study area.

2.7 SEWAGE TREATMENT PRACTICES IN SOUTH AFRICA

The South African Water Research Commission (WRC) performed a study in 2012 in which they evaluated the drivers for sewage treatment technology selection in the country (VD Merwe et al. 2012). They found that insufficient focus is given to investigating sustainable low to medium level alternatives and O&M limitations of each technology and implementation environment.

They determined that 44% of the technologies implemented in South Africa are inappropriate, with about a further 33% being questionable (possibly inappropriate). Sewage treatment systems in the Eastern Cape are also predominantly either questionable or inappropriate, with treated effluent mostly being discharged into rivers.

The study also indicated that the effluent discharge policies are too strict for poor municipalities. Politicians exacerbate this by interfering in the technology selection process. A trend was perceived that planning for future treatment plants will move away from pond systems in favour of activated sludge plants. The authors however noted that activated sludge plants will not be sustainable within 7 years due to increasing electrical costs. Research into green economics was consequently recommended.

A research technique applied by VD Merwe et al. (2012) and which could be applied to the current project is to consult the Department of Water and Sanitation (DWS) sewage treatment works license database, as well as their river classification database, to obtain information on existing sewage treatment works and the limitations placed on effluent to be discharged into rivers in the Study Area. Questionnaires or interviews with decision makers should be performed to understand their technology preferences.

DWS has a Green Drop Programme which assesses the health of sewage treatment plants throughout South Africa. The latest available Green Drop Report is the 2012 Progress Report (DWS 2013). According to the report, microbial contamination is a major issue, with the most preferred solution being disinfection using chlorine. The Eastern Cape has a high risk rating, with most plants being oxidation ponds (Waste Stabilisation Ponds) with a small capacity (0.5 - 2Ml/d). Other technologies being used in South Africa include:

- Activated sludge plants
- Biofilters
- Aerated oxidation ponds with facultative ponds
- Anaerobic digesters
- “Petro” systems
- Rotating biological contactors
- Sea outfall

DWS also lists other technologies on their website not listed above. These are contained in a Technical Brief published by Water And Environmental Health at London and Loughborough (WELL, nd).

From the above literature review the following main stakeholders have been identified:

1. DWS: Responsible for performing the Green Drop Assessment and managing a STP and River Quality database.
2. Decision Makers: Responsible for the selection of treatment technologies (eg WSAs)
3. Policy makers: Responsible for defining the effluent discharge criteria which needs to be complied with.
4. WRC: Performed a lot of ground work already in appropriate technology selection.

2.8 APPLICATION OF SOUTH AFRICAN DESIGN GUIDELINES

For small scale sewage treatment facilities, Freese and Nozaic (2009) compiled a process design manual on behalf of the Water Research Commission (WRC) of South Africa. This is an update of two previous versions of the same guideline and intends to assist engineers and scientists in the design of treatment works.

The report draws on many previous studies and textbooks and is considered in South Africa as the main publication to follow when designing a treatment facility. The guideline addresses the preliminary planning of a STP as well as the most prominent treatment technologies applied in South Africa.

Limited information is however provided on how the most appropriate technology for a situation is to be selected and no examples of the selection process is provided. The guideline is very technical in nature and does not focus on the soft issues such as sustainability, community involvement and environmental impacts.

The South African Department of Public Works (DPW) has also compiled guidelines for the design of small waste water treatment works, DPW (2012). This guideline is much more simplistic than Freese and Nozaic (2009) and only permits the designer to select between rotating bio-reactors or bio-filters, depending on the effluent standards required.

The effluent standards and permissible effluent discharge practices is however based on outdated DWS guidelines and will have to be read in conjunction with the NWA 2013 amendment. No comment is provided in the study on community involvement or other soft issues, but this is mostly because their STP are predominantly at correctional facilities where access is limited to authorised personnel only.

The design guidelines take the following into consideration:

i. Legislation
ii. Environmental aspects
iii. Critical design and planning criteria
iv. Reliability and power consumption
v. Best practice and operations
vi. Health and safety
vii. Maintenance requirements

An interesting issue which was raised is that the effluent quality in activated sludge plants is immediately affected in the event of power failures. Activated sludge plants require a continuous and reliable source of power. This is a major concern especially in rural areas where the remote location can increase the waiting period between failure-event and repairs. The risk of pollution to water courses that receive effluents from activated sludge treatment plants is therefore increased.

From the above literature review the following main stakeholders have been identified:

1. Decision Makers: Responsible for the selection of treatment technologies (eg WSAs)
2. Engineers/Scientists: Responsible for the design of the STP
3. WSPr: Responsible for operation and maintenance of the STP
4. Community: Possible involvement during operation of the STP
5. Environmental Practitioners: Need to be involved in the selection of the technology and impact on the environment

2.9 SEWAGE EFFLUENT DISCHARGE INTO RECEIVING RIVERS

Saneago et al. (2013) attempted to quantify the effect of sewage effluent discharges on the Limpopo River's ecology. Saneago et al. (2013) established that eutrophication occurs if effluent is not properly treated, and that this is a common problem in South Africa. The situation is further complicated if the river flows very slowly, as this enriches the water body leading to an increased oxygen deficit and eutrophication. Each river has a self-cleansing potential, but this is unique for each river and changes along the length of a river. However, if the self-cleansing potential could be accurately determined, the degree to which effluent discharge standards can be relaxed could be determined.

DWS has a Resource Quality Information Services (RQIS) (DWS 2016) directorate which focusses on monitoring the water quality in natural resources, such as rivers, dams and estuaries. Water monitoring sites are spread throughout South Africa and grouped together per Water Management Area (WMA). Once the water samples have been obtained and tests results received, this information is placed on their database. This information is freely provided to the public and can be imported into Google Earth.

Figure 2-4 illustrates the distribution of river water sampling points across the Study Area. Information is available across a 40 year period, but the sampling periods at each specific location varies, with some having been taken only once. Annexure 4 provides an example of what water sampling information is provided at each sampling point.

Eddy (2003) commented on the impact sewage discharge has on the receiving water quality. Three zones of pollution, downstream of the pollution point, has been identified namely “Zone 1: Recent Pollution”, “Zone 2: Active Decomposition” and “Zone 3: Recovery”, The ecosystem is the most severely effected by Zone 2, with ecosystem recovery occurring in Zone 3.

Eddy (2003) also compared the NWA with other international standards and concluded that the adoption of a RWQO approach places South Africa on the same par as other developed countries in the world. RWQO follows a holistic approach when determining the discharge standards and takes into consideration the receiving water quality and quantity.

RWQO evaluates the assimilative capacity (or self cleansing ability) of the river and Eddy (2003) clarified the evaluation process by summarising the various aspects that needs to be considered, namely:

i. Defining hydrological characteristics of the catchment
ii. Defining water quality of the catchment and determining the point source
iii. Estimating the effects on non-point sources in the catchment
iv. Estimating the effects of natural features on the catchment
v. Predicting the effects of the potential discharge on the catchment
vi. Conducting a Reserve Determination

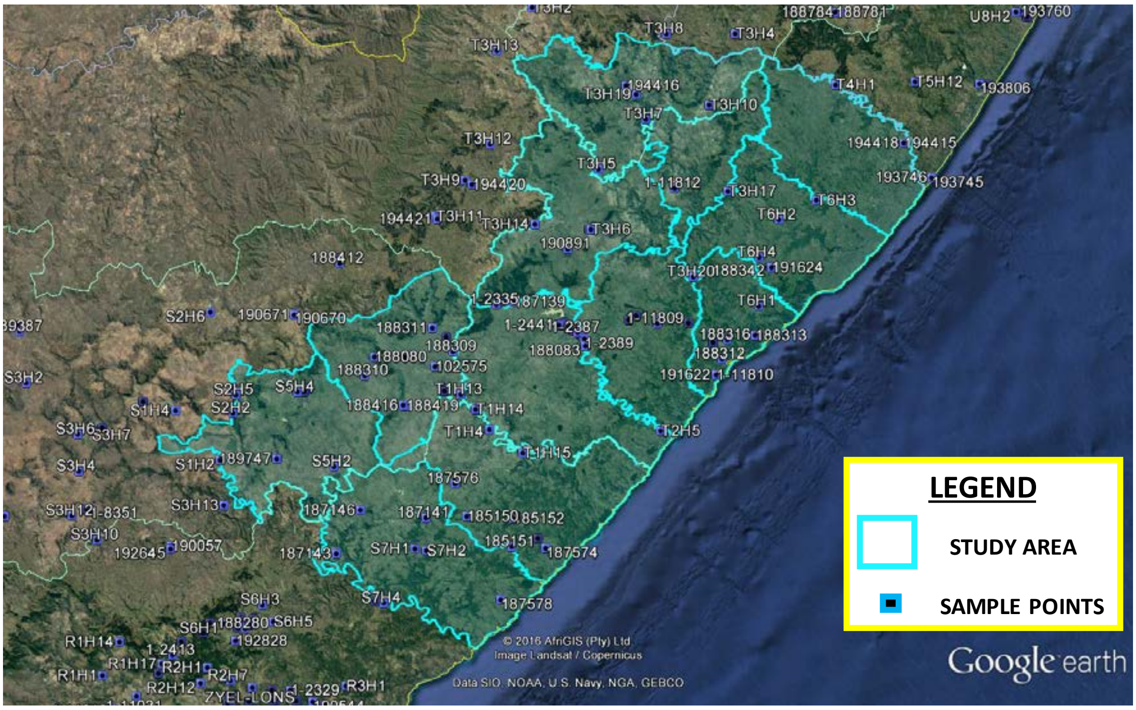


Figure 2-4: RQIS information on Study Area
(Image Source: DWS (2016) superimposed on Google Earth)

DWS has also issued a General Authorisation for certain sewage storage and disposal activities, provided that they comply with a specific set of criteria. The General Authorisation has recently been amended in 2013 (NWA 2013), providing minimum requirements for the following:

i. Irrigation with sewage up to a maximum volume of 1Ml/d
ii. Disposal of treated sewage into a water resource, up to 2Ml/d.
iii. Disposal of sewage to a sewage treatment pond system with maximum capacity of 1Ml/d

Consultations with DWS is required to approve the various disposal methods. For irrigation, DWS also needs to be approached to identify the location of major aquifers where irrigation will not be permitted.

Depending on where in South Africa discharge into a water resource is planned, according to the General Authorisation the effluent must either comply with General or Special Discharge Limits. These standards are just for discharge into a water body and separate standards apply for irrigation with treated sewage. Annexure 3 provides the parameters to be complied with for General and Special Standards, as well as for irrigation.

Figure 2-5 below indicates the location in the Study Area where General and Special Standards apply. Figure 2-6 indicates the location where pond systems in the Study Area, up to a capacity of 1Ml/d, will be permitted based on the General Authorisation.

As part of the General Authorisation, NWA (2013) also specified certain minimum monitoring criteria which varies between WWTW of max capacities of 0.1Ml/d, 1Ml/d and 2 Ml/d, respectively. The various monitoring criteria is provided in Annexure 5. Deviations and Exemptions from these standards can be applied for, but this will have to be done in consultation with DWS.

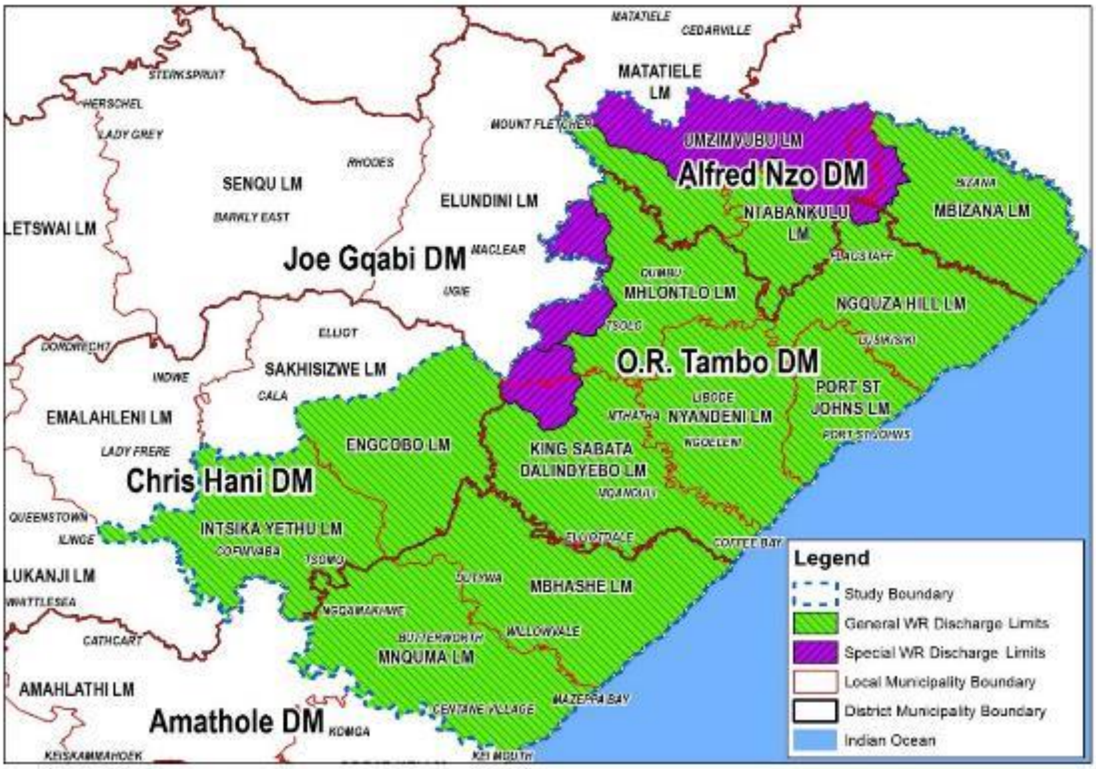


Figure 2-5: Demarcations where General and Special Discharge Limits apply
(Image Source: Aurecon (2017(2))

From the above literature review the following main stakeholders have been identified:

1. WSPr: Responsible for routine sampling of effluent being discharged into the water resource.
2. DWS: Maintaining the RQIS database and acting against any transgressions of RWQO.
3. Designers/Engineers: Need to take RWQO and local discharge environment into consideration when designing the STP.

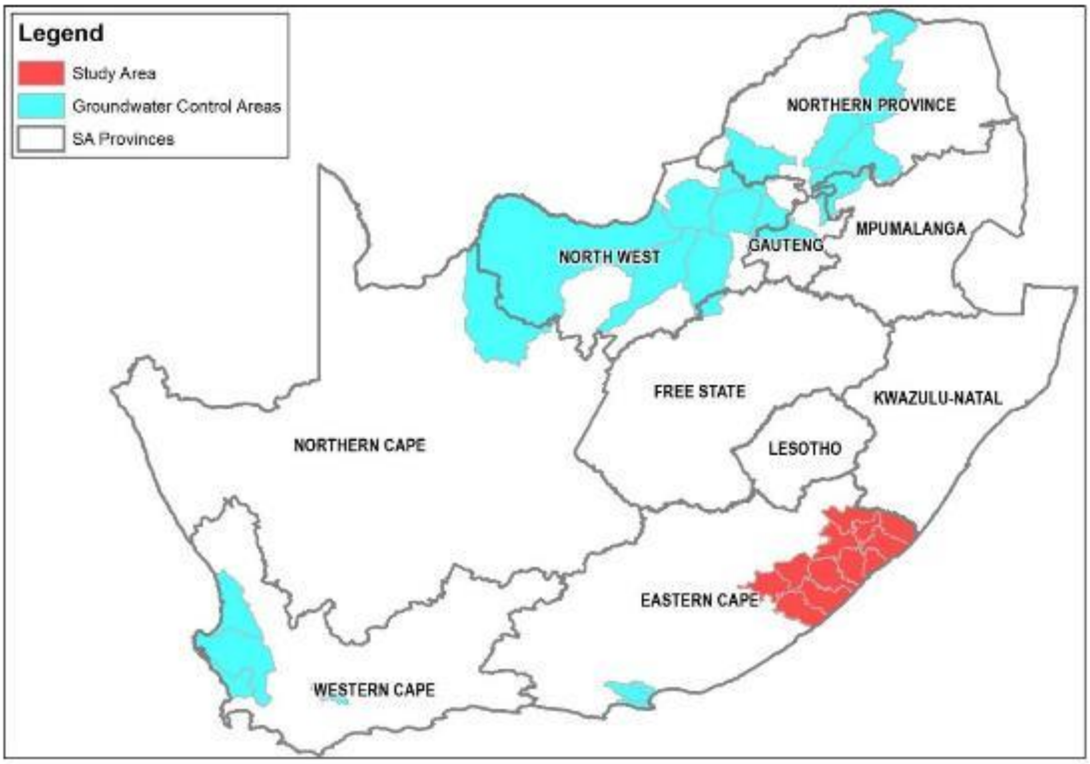


Figure 2-6: Groundwater Control Areas (Where ponds are not permitted under the GA)
(Image Source: Aurecon (2017(2))

2.10 STAKEHOLDER PARTICIPATION IN TECHNOLOGY SELECTION

Martin et al. (2009) researched the drivers for sanitation technology selection in dense areas of South Africa. While the current research project focusses on rural areas, and thus does not focus on the same target group as Martin et al. (2009), the National Development Plan's focus on equity throughout South Africa could mean that similar technologies will have to be considered for rural areas as well. In addition, the research performed by Martin et al. (2009) could be valuable in understanding how to approach stakeholders and in identifying what alternative technologies could be considered by the communities.

Martin et al. (2009) had to obtain information using questionnaires focussing on four stakeholder groups: Political, Technical, Community and Individual. At the start of the research, most respondents wanted waterborne sewers, with very few wanting composting toilets. Following an integrated affordability approach, it was concluded that while most of the community wanted a water borne sewer, they were willing to accept a lower technology when faced with the necessity to pay. Composting toilets were, however, still the least favoured option.

If an integrated affordability approach was not used, then the wrong technology selection would have occurred. It could be considered that a similar integrated affordability approach should be used for the selection of the most appropriate sewage treatment technology. It was interesting to see that people with social grants were willing to make a longer term financial commitment than those with limited funds. Involving the beneficiaries in the technology selection process can impact the sewage technology selection.

Rose (2015, p 16) recommended that if the local community is to participate in the operation of the treatment works, the roles and responsibilities needs to be well defined upfront. He indicated that remote/decentralised systems can work well if the community participates in the operation, but warns that friction could occur between them, the local government and leaders due to a fear of loss of work or benefaction. A broad cross-section of stakeholder involvement is thus recommended.

Breslin (n.d.) highlighted the challenges capacity constrained local governments have, to operate completed water schemes. Breslin suggested that village-level O&M could be considered for remote/decentralised schemes but that it needs to be supported by the local government and villages.

From the above literature review the following main stakeholders have been identified:

1. Local Authorities: Need to decide if community will be for sanitation services and if they will be involved in the operations of the STP
2. Local communities: Willingness to pay and involvement during operation of the STP needs to be understood.

2.11 TECHNOLOGY COMPARISON STUDIES

Sato et al. (2006) compared up-flow anaerobic sludge blankets (UASBs) with Waste Stabilisation Ponds (WSPos) in India. While the focus was mainly on economic comparisons, effluent quality was also looked at. The operational capacities of the plants used in the study varied between 1 and 32.5 Ml/d.

It was concluded that WSPos are only more cost effective in areas where land costs are low. UASBs however only provide anaerobic treatment, which is only one step in the treatment process, thus further treatment is still required to ensure effluent quality is acceptable for safe discharge. Information was, however, not provided on which effluent constituent failed the quality test, and this will require some further investigation.

An interesting point to consider in further research is that, with rising land costs, WSPos have a time limit before they become too expensive. If land is acquired now, then they can be retrofitted at a later stage and perhaps be combined with other land requirements. Natural treatment systems (NTS), which require little or no electricity, reduce the demand on electricity generation and this keeps Carbon Dioxide Emissions low. NTSs therefore comply with the emission reduction principles of the Kyoto Protocol.

The research by Sato et al. (2006) utilised costs which they acquired from past reports. Information on treatment plants was further obtained from the local plant operators, and effluent sampling was done to verify the information obtained from the plants. This current research project will attempt to emulate a similar approach.

Mburu et al. (2013) compared the performance of WSPos with Horizontal Sub-Surface Flow Constructed Wetlands, both being NTS. They found that the appropriateness of the technology is dependent on population size, land value and available construction materials. It is interesting to note that the latter research did not delve deeper into the local soft issues (community interaction, preferences and institutional dynamics), such as those that VD Merwe et al. (2012) and Muga et al. (2007) did.

Mburu et al. (2013) indicated that such NTS do not require skilled labour, and need little to no electricity. The probability of a NTS to malfunction, if properly designed, constructed, operated and maintained, is very low.

The research by Mburu et al. (2013) was based on field analysis they performed themselves on existing and pilot plants. Field analysis will also be performed on the current research.

From the above literature review the following main stakeholders have been identified:

1. Local Authorities: Availability of local land and associated value as well as electricity. Size of local communities
2. Local communities: Available local construction materials and population sizes.
3. Decision makers, Designers and Engineers: Selection of most appropriate technology for the area.

2.12 SUSTAINABILITY OF TREATMENT TECHNOLOGIES

The United Nations Economic Commission for Europe (UNECE) defines a green economy as one which can sustain social equity and improved human well-being, while reducing both ecological scarcities and environmental risks. Sustained economic development is thus achieved by promoting environmentally friendly and socially equitable practices. A Green Economy has many of the characteristics listed under Section 2.1 which was used as search parameters for literature reviews, but also looks further than this to the outcomes of the Rio+20 UN conference on Sustainable development, which was held in Rio de Janeiro in June 2012. (UNECE, 2016)

South Africa’s National Strategy and Action Plan for Sustainable Development (NSAPSD) states that healthy ecosystems and natural resources are preconditions to human wellbeing and that there are limits on the goods and services that they can provide. Human beings are also considered as part of nature and thus ecological sustainability needs to acknowledge the inclusion of human existence in its definition.

According to the NSAPSD, Sustainable Development implies the selection and implementation of a development option which allows for the achievement of appropriate and justifiable social and economic goals without compromising the natural system on which it is based. (NSAPSD, 2010)

These aspects are reflected in the three dimensions of mainstream sustainability thinking (UWP, 2012), namely Economic, Environment and Society. These are also the main aspects which Muga et al. (2007) focusses on in their sustainability evaluation.

Muga et al. (2007) investigated the sustainability of technology selection by evaluating various treatment technologies against a certain set of indicators which covered environmental, societal and economic aspects. This could be compared with the multi-criteria selection approach which VD Merwe et al. (2012) referred to in their research. The technologies which their study focussed on was mechanical (eg WAS), lagoon systems and land applications and focussed on a capacity less than 19Ml/d.

Muga et al. (2007) determined that high-technology solutions consume much more energy during their operational life than other technologies. They recommended that, should a life cycle assessment be performed on the technology, the operational life stage of the plant needs specific attention as it is used to determine affordability in developing countries and low income communities.

It was interesting to note in their research that the cost savings which can be realised through low-tech options, could be used to improve water supply, which will have a consequential cost saving on medical health due to reduced illnesses.

The research by Muga et al. (2007) was performed by means of a desk-based review on available information of existing plants. A similar approach will be used for this research project.

DWS has compiled a tool called the "Sustainability Indexing Tool" (SusIT) in partnership with the Norwegian Agency for Development Cooperation (NORAD). This tool evaluates the sustainability of water schemes in the South African context using a multitude of factors, including Community acceptance, involvement and support. (DWS, 2015 (7))

Breslin (n.d.) reported in his study on water supply schemes that O&M was not focussed sufficiently enough on during the design stage, leading to remote schemes which could not be well operated and eventually falling into disrepair. He noted that for rural schemes it is important for the communities to participate in the technology selection and eventual operation of the scheme. The success stories of rural schemes were attributed to the ownership which the local communities took in operating and maintaining the scheme.

From the above literature review the following main stakeholders have been identified:

1. WSA: Promoting sustainable technologies
2. WSP: Involved in technology selection from a end-user / O&M perspective.
3. Local communities: Possible involvement in O&M and technology selection
4. Decision Makers, Designers and Engineers: Design and selection of sustainable technologies.

2.13 APPROPRIATE TECHNOLOGY SELECTION

Mburu et al. (2013) indicated that Capital Costs, O&M Costs and procurement of land are important parameters when selecting appropriate technologies. They further suggested that appropriate technologies need to be:

- Affordable
- Efficient in complying with local effluent standards
- Have low O&M Costs
- Be publicly acceptable
- Environmentally friendly

Mburu et al. (2013) concluded that considering the above requirements, natural treatment systems can be considered as appropriate technologies for developing countries.

In Muga et al. (2007)'s development of sustainability indicators, they suggested that an appropriate technology is balanced by environmental, economic and societal sustainability. This balanced sustainability is also reflected in the list of factors which Vd Merwe et al (2012) recommends needs to be considered when selecting a suitable technology. Vd Merwe further recommends that option selection principles such as BATNEEC (Best Available Technology Not Entailing Excessive Costs) needs to be considered.

A similar list of factors which vd Merwe et al recommended, is listed in Smith(2011). Smith further indicated that in the European Eunion the Interated Pollution Prevention and Control legislation requires use of the Best Available Technology (BAT) principle. In earlier legislation, BATNEEC and BPEO, was referred to.

Mara (2003) indicated that where the value of land is low and sufficient land is available, natural treatment systems are usually the most appropriate technologies. NTSs only becomes inappropriate when the required effluent quality becomes too strict. In the latter case a more mechanised process needs to be selected, which will incur additional energy costs.

2.14 TECHNOLOGY ADAPTATION FOR REMOTE/RURAL AREAS

Research performed by Choukr-Allah et al. (2003) focussed on adapting a low-technology sewage treatment works (lagoons) with effluent polishing processes to improve effluent quality with the hope of re-using effluent for agricultural irrigation purposes. The STP serves a population of about 17,600 people and polishing was done by means of recirculating sand filters and constructed wetlands.

Their results indicated that an infiltration-percolation treatment system needed a nitrification basin in order to bring effluent quality in-line with WHO guidelines for wastewater re-use, and permit unrestricted irrigation for agricultural purposes. A site selection criteria was defined, which could be evaluated for application in other research.

A concern Choukr-Allah et al. (2003) raised was that the concentration of contaminants will increase in future due to accumulation over time in the ground water, as larger volumes of sewage are treated over an extended period of time. This could pose a limitation on the volume of effluent which could be re-used and will have to be taken into consideration in this research project. It was also interesting to note that, for the research by Choukr-Allah et al. (2003), effluent was used for the irrigation of corn, which is also the dominant agricultural crop in the Study Area.

Massoud et al. (2008) compared centralised sewage treatment systems with decentralised systems. They determined that centralised systems are expensive to build in rural and low-density areas, and recommended decentralised or cluster systems, which are more cost effective and sustainable in a rural setting. Cluster systems are decentralised systems linked to each other in logical groupings without excessive costs. Decentralised systems include septic tanks or conservancy tanks, lagoons and constructed wetlands.

The research recommended that management strategies need to be site specific and consider the social, cultural, environmental and economic setting in the target areas. Decentralised systems are more suitable where communities have improper zoning and are low density. They are less resource intensive and more ecologically sustainable.

From the above literature review the following main stakeholder category has been identified:

1. WSA / Decision Makers: Selection of service delivery approach (centralised or decentralised) and project-specific management strategies.

2.15 LOW-TECHNOLOGY OPTIONS IN OPERATION GLOBALLY

Mambo et al. (2014) evaluated the performance of a pilot Integrated Algal Pond System (IAPS) and compared it to the current practices and industry challenges in South Africa. The pilot plant was built at the Belmont Valley WWTW in Grahamstown in 1996. It consists of an in-pond digester, an advanced facultative pond, high-rate algae oxidation pond, algae settling ponds and maturation ponds.

The IAPS is ideally suited for warmer climates and uses less land area than conventional pond systems. The study concluded that the effluent did not comply to South African discharge standards and it was also observed that no mention is made of E.coli removal from the effluent (no treatment was provided for this step). While their research approach is very scientific, no attempt was made to address the “soft issues” such as institutional capacity or community involvement. The performance of algae in comparison with other biological media such as water lettuce, water hyacinth or wetlands are also not discussed.

Wells et al. (n.d.) also evaluated the performance of the above system over a nine year period. They acknowledge the operational ease of WSPs and that there has been recent improvements to them. They furthermore indicated that the algae in the IAPS is high in nutrients and could be used for fertiliser. They noted that the effluent had a high COD but this was in fact the algae biomass still in the effluent and could be released into the downstream receiving watercourse.

The author is however of the opinion that the downstream ecology must first be researched before such a release can be done. This is still a high risk since if the ecology changes then the treatment technology or process must be quickly adjusted. Wells et al. (n.d.) further indicated that Ammonia removal by IAPS is better than for Activated Sludge Systems and recommend such a system for smaller communities due to the simplicity of design and that the effluent can be used for irrigation.

An artificial wetland system, used for treating domestic sewage, was evaluated by Rousseau et al. (2005). The system was designed for 47 Person Equivalents (PE) and consisted of a septic tank followed by two horizontal subsurface flow beds in series. Thereafter the effluent was discharged into a river.

Laboratory tests were performed on the effluent and it was determined that the system had effective removal of most indicators, except for phosphorus and suspended solids. No testing however was performed for Ecoli. The study further concluded that wetland system had a very good buffering potential for varying hydraulic loading during the day.

Huibers et al (2004) investigated the use of wastewater being discharged from an Oxidation Pond system in Cochabamba, Bolivia. The plant has a capacity of 1.4Ml/d, but due to weak institutional capacity the waste treatment process is not performing adequately. Local farmers are also by-passing the treatment process to use the sewage for irrigation purposes. The continuous use of sewage has required that farmers start using crops with a high salt tolerance, such as fodder grass (Lolium).

Huibers et al (2004) highlighted the importance of appropriate technologies for financial and managerially restrained areas needs to be selected. The study concludes that while decentralised systems can work, if they are dependent on interactions with the community, the latter needs to benefit from the system in some way.

It was interesting to note that Huibers et al (2004) refers in his study to the widespread use of UASB systems in Brazil, Columbia and India and promotes it as a technology that does not require electricity, with adequate contaminant reduction and minimal maintenance requirements.

In Melbourne Australia, sewage from the city and surrounds is treated at two Waste Water Treatment Plants: Eastern and Western Treatment Plant. MW (n.d.). Both these plants are large scale pond systems. The Western Plant began operation in 1897 and the treatment technology developed over time from land filtration to grass filtration to the current lagoon treatment system with a capacity of more than 100Ml/d. It is surrounded with man-made wetlands which attract a range of birdlife and it is thus important to maintain effluent standard.

A system of 10 ponds (Anaerobic and Aerobic) is used to treat the sewage with a combined retention time of 30 - 35 days. The treated effluent is then used for recycled irrigation. Methane from the anaerobic ponds are used to generate electricity to run the plant. No information is however available on the quality of the effluent, and this will have to be sourced if requried.

According to Norman (2009), In Francophone West Africa, 108 of the 155 non-industrial WWTW are in Ivory Coast. The predominant technologies being use are WAS systems, pre-treatment only (settling tanks, sand filtration and sea outfall) and pond-based systems. Rufisque, a suburb of Dakar, Senegal has a 2.86Ml/d pond system.

Norman concluded that settled sewerage systems (a small bore system connected to a septic tank at household level) have been able to access poor areas relatively effectively. He further hypothesizes that low technologies with suitable technical strategies to include the local community is critical for success.

The pond system used Water lettuce (Pistia Stratiotes) to remove sediment and purify water. This has been used in Sudan for over 1000 years and is low cost, appropriate and ecologically sound. Other WWTW in the area uses micro algae for the same purpose.

The implementation of the settled sewerage system in Dakar was not fully succesfull due to multiple reasons. Weisburd et al (nd) indicated that the construction work was not up to standard, but also that the community would prefer not to clean out the septic tanks. Weisburd et al (nd) further provided advantages and disadvantaged of the settled sewerage system.

Weisburd et al (nd) concluded that decentralised anaerobic digesters, acting as points of sludge collection, can still work but clear lines of responsibility ito who maintains what is important. Up-front negotiations between the parties ito O&M and method of waste disposal is also important.

From the above literature review the following main stakeholders have been identified:

1. WSA / Decision Makers: Selection of most suitable technology for the area, and willingness to consider alternative technologies. Up-front land-use planning also needs to be taken into consideration when selecting the site and technology. The managerial and financial capabilities of the area where the technology must be implemented needs to be considered.
2. Designers / Engineers: Technology needs to be designed to fully comply with discharge standards set by DWS
3. Farmers – Involved in land-use planning and STP siting. The crops they farm with should also be taken into consideration when designing the STP.
4. Local community – Possibly involved in O&M and should thus be involved in technology selection and upfront agreement of O&M strategies, roles and responsibilities.

2.16 INFORMATION SHORTFALLS

Limited information of the Economics of the Technologies

While limited information was obtained through the various literatures consulted, no main body of knowledge on the matter could be obtained. It will therefore be important to discuss this in more detail at interview level with those parties responsible for financial decisions in this regard.

Community Involvement in Technology Selection

None of the literature referred to in Section 2.10 addressed the issue of sewage treatment technology selection and how the various stakeholders, specifically the community, needs to be approached. The local government's response to the community's involvement during O&M has also not been addressed anywhere. These matters will be addressed as part of the Stakeholder Interview process discussed in Sections 3 to follow.

Sustainability

VD Merwe et al.(2012) made reference to "Green Economics" although no detail on this or how to implement it is provided. UNECE also provides a definition of "Green Economics" but provides a lot more criteria than could be considered for this study. The NDP made reference to unlocking the agricultural capacity in rural areas and the possibility of sustainable sewage treatment to make this possible should be considered.

VD Merwe et al.(2012) further indicated that there appears to be a lack of a multi-criteria selection process in selecting the most appropriate technology. Muga et al.(2007) made reference to a set of sustainability indicators which should be considered when selecting the most appropriate technology selection. It would appear a multi-criteria selection approach which emphasizes the importance of sustainability will require further deliberation in this study. Muga et al. (2007) have, however, indicated that information on local indicators is not always easily obtainable.

Accurate Demographic Information

The discrepancies between the DWS, WSA and LMs on population sizes and distribution, as well as level of service makes it difficult to select the base data on which the Eastern Cape context will be evaluated. For purposes of consistency, the WSA information will be selected as the basis for evaluation going forward. This is further substantiated in Section 4.

Amendment of the Discharge Standards in Rural Areas.

It was observed that previous literature commented on the fact that the effluent discharge standards are too strict for use in rural areas, forcing a more advanced technology to be used. DWS has not issued any clarity on this and based on the literature available from them, no attempt has been made to consider the local institutional and social challenges when selecting the technology. Without sufficient flexibility in the guideline, the ability of the NDP to be implemented and rural areas to prosper, can be hampered.

Guidance on Appropriate Technology Selection/Comparison in the South African Context

While local legislation provides criteria according to which the treatment technology needs to be selected, there is no standard approach which lists the various technologies available or approach to be adapted to evaluate "appropriateness" in the South African context. Even the design guidelines which exist, are mostly technical in nature and does not follow a interdisciplinary approach. Some technologies, such as the IAPS, has good merit for application in South African, but its compliance to local legislation and local conditions has not been fully evaluated. Should a guideline of comparison have existed, it would have made it much easier to evaluate the performance of the IAPS.

Comprehensiveness of River Quality Data in South Africa.

While the RQIS provides a wide spectrum of information, the historical data is in some places only limited to one year. No biological parameters are tested for and when considering the parameter listed in the General and Special Discharge Limits, it can be seen that the RQIS does not test for all these chemical parameters as well. Therefore applying either the UESA or the RWQO approach can be problematic without performing some further long-term testing of the water resources. Failure to do so could lead to the incorrect treatment process/technology being selected.

Treatment and Disposal Capacity Limitations

No reason was found for the selection of the specific capacity limitations on certain technologies and discharge methods (eg irrigation or discharge water resource). The differences could be based on firm research, but considering the South African context with large rural and poor areas, these limitations can be restrictive to the selection of the most appropriate technology for the area and will have to be further investigated in this study.

2.17 SECTION SUMMARY

The purpose of the literature review was to determine the extent of the Study's current body of knowledge and evaluate how it can assist in achieving the research objectives. To make sure the literature search was as comprehensive as possible, it was structured using the SHTEFIE categories (Social, Health, Technical, Economic, Financial, Institutional and Environmental)

Firstly, it was attempted to understand the local demographics, political and institutional environment before looking at the current sewage treatment practices applied in South Africa and the Eastern Cape. It was then attempted to understand how the treatment technologies are selected and who is involved in the selection process. Lastly, other treatment technologies being used elsewhere in the world was looked at and how they compare with each other. Focus was mostly on low-technology and natural treatment systems.

It was found that there is a drive from National Government to improve the living conditions in the rural areas, thus making it very possible that at some point waterborne sewerage will have to be provided to all areas. Local legislation is however very prescriptive, which could limit the treatment technology selection in rural areas and leading to a less-appropriate system being selected. South African legislation currently places limitations on Natural Treatment and Low-technology Systems, mostly due to the risk of contamination of water resources.

This section has assisted in answering the following research questions:

- Question 01: *What low-technology wastewater treatment options are available?*
- Question 02: *What advanced-technology wastewater treatment options can be considered for rural applications?*
- Question 03: *How applicable are these options to be used on a large scale?*
- Question 04: *Are there any success stories for these treatment options? (Local and/or International)*

- Question 07: *How effective are institutions currently at operating and maintaining wastewater treatment works?*

Through this literature review, the major stakeholders have been identified which will now be contacted to answer a questionnaire and possibly participate in an interview. This engagement will form the basis for further engagement on matters such as O&M, alternative technology options and community involvement, all of which will be required to determine the most appropriate technology for the rural areas of the Eastern Cape.

3. RESEARCH METHODOLOGY

3.1 SECTION INTRODUCTION

In this section the research methodology is discussed. A general overview of the research approach is firstly provided, summarising the research activities and how they assisted the various analysis stages.

Thereafter, some of the main research activities are further elaborated on, providing more detail on how they were approached and what was expected to be achieved through them. The applicable research questions, described in Section 1.5 and which were to be answered by the specific research activity, are also listed.

Emphasis was placed on the Sustainability Evaluation approach, which was required to assist in assessing each treatment technology's appropriateness for use in the study area.

3.2 OVERVIEW OF RESEARCH APPROACH

The topic of this research makes it clear that the selected technology needs to be appropriate. Through Section 2.13 it could be seen that the term "appropriate" is closely related with sustainability. For the purpose of this research, it was thus decided that the most appropriate technology needed to have a balance between environmental, economic and societal sustainability.

Furthermore, due to the finite nature of funding, the selected technology also needed to comply with BATNEEC. By combining sustainability and BATNEEC, the BPEO principle was also complied with. The research approach considered appropriateness during all activities performed. As mentioned in Section 1.6, research was performed by means of four specific activities. The preceding activity created the platform and context for the next activity. These activities were:

i. Literature Review
ii. Stakeholder Engagement
iii. Field Investigations
iv. Options Analysis

The different research activities assisted in answering the various research questions, all focussed on understanding how best to approach technology selection in the rural Eastern Cape. The literature review, stakeholder engagement and field investigations all assisted in understanding the local challenges and what technologies could be considered as the best options for the local setting.

The last activity (Option Analysis) collated all the findings of the previous activities and attempted to structure a selection process for appropriateness. This Options Analysis was done in three stages, namely:

Stage 1: Status Quo and Technology Options

The current situation in the study area was determined ito spatial data, legislation, service delivery and existing STP operating conditions. All possible technology options, identified through literature reviews and stakeholder engagement, were evaluated and the three most realistic options were taken forward to Stage 3. An initial sustainability evaluation formed the cornerstone of the Stage 1 evaluation process.

Stage 2: Performance Evaluation of Technology Options

The most appropriate technologies identified in Stage 1 were further evaluated using a comparative case study format in which specific aspects were compared.

Stage 3: Challenges and Solutions

The three realistic technology options identified in Stage 1 were then further compared for local application and possible problems and solutions discussed. A more in-depth sustainability evaluation was used to critically assess the three realistic options in order to provide support in identifying the preferred technology. The various research activities played important roles during the different Analysis Stages. Some specific aspects of the research, requiring further discussion, are detailed further in this section.

3.3 DESKTOP STUDY

The type of literature and method by which they contributed to the overall research, are summarised in Table 3-1.

This research mostly followed a desktop study approach, focussing on literature reviews and case studies. Through such an approach the boundary conditions within which a solution needed to be found was determined and a hypothetical selection approach proposed. It needs to be emphasized that since the research was mostly by means of a desktop study, no actual testing of the solution in a "real world" scenario could have been performed.

Further detail on the case studies are provided in Section 3.4 that follows.

3.4 PERFORMANCE EVALUATION

During the Stage 1 Analysis, the most likely technologies which could be used in the study area were selected. These included technologies which could be appropriate for the study area but are currently not being utilised due to any of the following reasons:

- The technology is not familiar to the South African Industry
- The technology's application does not comply with the NWA General Authorisation's limitations
- The low technology solution has historically not been applied on a similar scale

These technology options were further scrutinised in the Performance Evaluation (Stage 2 Analysis), by evaluating their overall performance based on the following parameters:

i. Institutional Requirements
ii. Effluent Quality
iii. Operation and Maintenance Requirements
iv. Economic Performance
v. Social Aspects
vi. Environmental Impacts
vii. Overall Sustainability

The degree of sustainability for each selected technology was measured against a standard set of criteria, as described in Section 3.7. The purpose of the Case Study was to evaluate which of the selected technologies will be the most appropriate for the study area, for further deliberation in the Stage 3 Analysis.

Table 3-1 : Literature Review Approach

LITERATURE TYPE	ANALYSIS DESCRIPTION	ANALYSIS STAGE		
		St 1	St 2	St 3
Industry Guidelines, Legislation and Policies	***Analysis Techniques:*** Qualitative Data was reviewed and reported on narratively, with the most critical items summed in a table format or similar. ***Expected Outcomes:*** This assisted in understanding the current policies, design principles and decision making frameworks currently being implemented in the study area. This analysis contributed to answering research questions 1, 4, 8 and 9.	X		X
Published Papers and Technical Reports	***Analysis Techniques:*** Analytical coding was used on the Qualitative Data to group data into meaningful categories. Meta-analysis was performed on the Quantitative Data to create databases and GIS was used to graphically present data and identify any trends/problem areas. Statistical analysis was used on databases to ascertain any trends or grouping of information. Data Sets was grouped to assist in processing information. ***Expected Outcomes:*** An understanding on the operational conditions of existing treatment works and typical problems experienced was developed. The local demographics, level of service, current effluent quality and spatial distribution of existing treatment works, were also be determined. This analysis contributed to answering research questions 1, 5 and 6.	X	X	
Case Studies	***Analysis Techniques:*** Data was reviewed and reported on narratively, with the most critical items summed in a table format or similar. ***Expected Outcomes:*** Past experiences on similar and alternative technologies were evaluated for implementation in the study area. Specific success stories for large scale low-technologies were also specifically evaluated. This analysis contributed to answering research questions 1, 2, 3, 7, 8 and 9.	X	X	X

3.5 INTERVIEWS WITH STAKEHOLDERS AND POLICY MAKERS

Stakeholders were engaged to better understand local soft issues, such as:

i. Local operational, social and institutional challenges and what changes were desired
ii. Understanding institutional capabilities to operate and maintain the various treatment technologies
iii. Obtain local opinions, including perceived strengths and weaknesses of technologies being focussed on in this study.

Based on the literature review, it was considered to engage with the following stakeholders:

- Social Facilitators: They have a good understanding of local social dynamics
- WSA: Responsible for the planning of sanitation service delivery
- WSP: Responsible for the operation and maintenance of the STP
- Policymakers/Decision makers: Responsible for the implementation of policies
- STP Designers: Responsible for the consultation with WSAs on STP technology and final design of the selected technology
- Scientists/Researchers: Individuals with good background information on previous studies and who understands the environmental impact the various technologies can have.

The following table summarises how the various stakeholders were engaged and how their input contributed to the research:

Table 3-2 : Stakeholder Engagement Approach

STAKEHOLDER	ANALYSIS DESCRIPTION
Social Facilitators, Designers and Operators	***Analysis Techniques:*** Data coding, with specific attention to Numeric Coding, was used on the Qualitative Data to rank data in order of importance. Highly structured questions were used with Numeric Coding implemented to identify preferences. ***Expected Outcomes:*** An understanding on the operational conditions of existing treatment works and typical problems experienced was developed. Local designers and operators were given the opportunity to provide recommendations on what options they would like to be seen implemented, as well as their recommendations to overcome certain challenges. Low-technology options, identified through the literature review, were also presented to the interviewee to record their responses. This analysis contributed to answering research questions 1, 2, 4, 5 , 6, 8, 9 and 10.
Authors of Previous Publications	***Analysis Techniques:*** Data was reported on narratively, with specific focus on challenges and recommendations from the previous authors which could not have been introduced in their own published literature. ***Expected Outcomes:*** By consulting the authors of previous work, an understanding of challenges they faced was received. Low-technology options, identified through the literature review, were also presented to the interviewee to record their responses. Their experiences also assisted in guiding this research in acquiring further research which was specific to this study. The analysis contributed to answering research questions 1, 2, 3, 5, 6, 7 and 10.
Key Decision Makers	***Analysis Techniques:*** Purposive sampling, substituted with convenience sampling was done. Analytical data coding was used to group thinking patterns together. Data coding also employed the use of themes, common phrases and keywords. ***Expected Outcomes:*** To understand the thinking behind the various role players' stance on policies and the acceptance or rejection of the various technologies. Low-technology options identified through the literature review, were also presented to the interviewee to record their responses. This analysis contributed to answering research questions 3, 4, 6, 7 and 10.

HONEY (2017), LOWIES (2017, OOSTHUYSEN (2017), NQWEMESHE (2017) and NASH (2017) were the stakeholders interviewed for this research and are collectively referred to as Interviewed Stakeholders. The inputs received from the various stakeholders assisted across all three Analysis Stages, varying in relevance depending on what type of input was required.

3.6 FIELD INVESTIGATIONS

Due to time and financial limitations, it was not possible to visit all the existing sewage treatment works in the Study Area. Convenience sampling was performed on some of the sewage treatment works previously assessed as part of the DWS Green Drop assessment (DWS (2013)). By doing this, the findings of the Green Drop assessors was thus verified.

Prior to the field investigation, the site's Green Drop Assessment was reviewed and a site checklist compiled. Permission from the WSPr was obtained to visit the site and the contact details of the operators acquired.The field investigations assisted in the Stage 1 and Stage 3 Analysis. For Stage 1, the local context was better understood and the relevance of previous literature on the condition of existing STPs confirmed. Preferences to specific sewage treatment technologies was also recorded.

In Stage 3, the local challenges and proposed solutions helped guide selecting the most appropriate technology and how it should be adapted for the local conditions.

3.7 SUSTAINABILITY EVALUATION

As mentioned earlier in this section, the sustainability evaluation formed an integral part of selecting the most appropriate technology. Since this research is considering the hypothetical scenario of providing waterborne sanitation to the rural Eastern Cape, it was important that selection of the most appropriate technology be considered within the context of the South African National Strategy and Action Plan for Sustainable Development (NSAPSD).

A two-stage approach was used in evaluating the various technology options and selecting the most appropriate technology, as illustrated below:

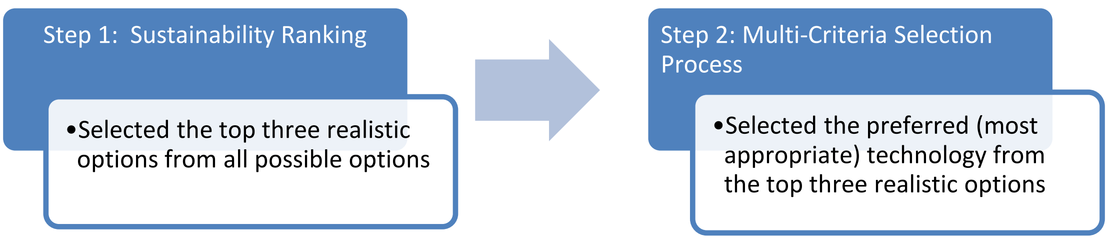


Figure 3-1 : Sustainability Evaluation Process
(Image Source: Author)

Research performed by Muga et al. (2007) formed the basis of Step 1, but their methods were adapted for the South African context. The NSAPSD, Green Drop Report (DWS, 2013) and the findings from VD Merwe et al. (2012) all assisted in conceptualising the South African concept. In order to make it as comprehensive as possible, the three dimensions of sustainability (Economic, Environmental and Society) and which forms part of SHTEFIE, were further expanded on to include all categories of SHTEFIE.

Figure 3-2 is an example of the Sustainability diagrams used by Muga et al. (2007). The closer the scoring is to the centre of the diagram, the more sustainable is the proposed technology.

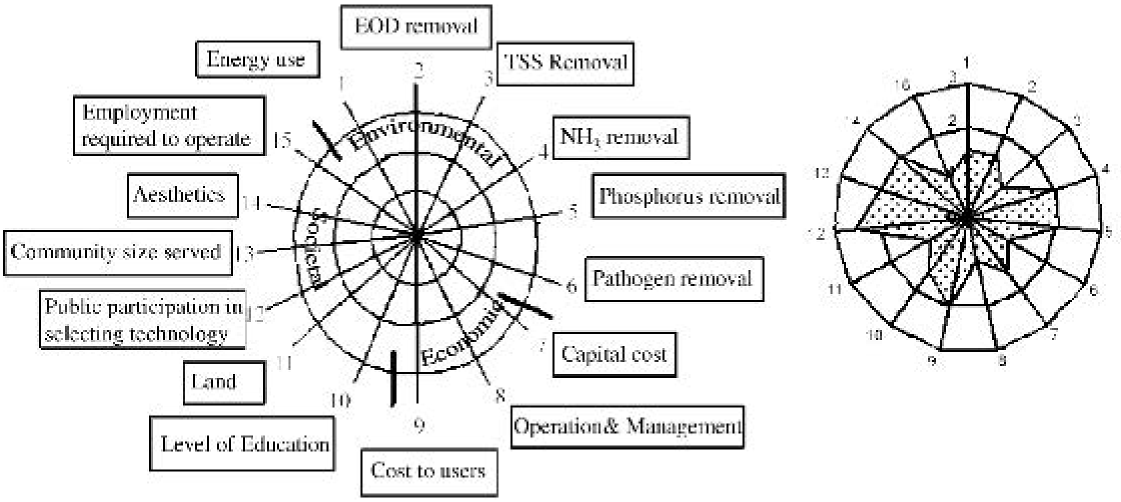


Figure 3-2 : Sustainability Spider Diagram Example
(Image Source: Muga et al. 2007)

The standard Venn diagram for sustainability (UWP, 2012), was thus expanded to allow for these other categories:

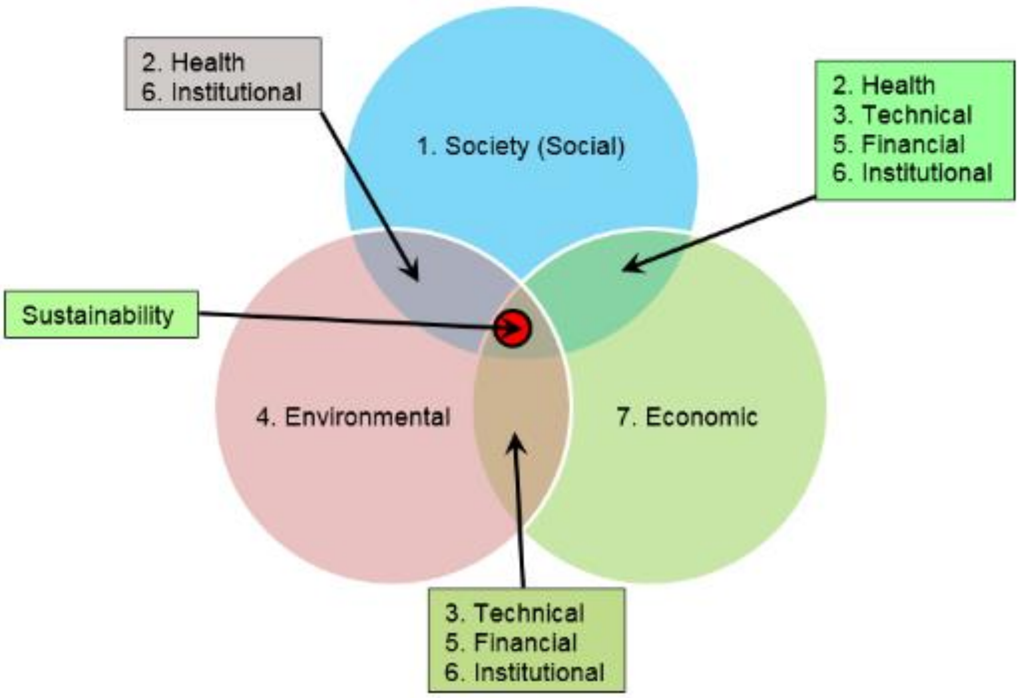


Figure 3-3: Expanded VENN Diagram
(Image source: UWP (2012) and adapted by author for this study)

From Figure 3-3 above it can be seen that where two of the main dimensions of Sustainability overlap with each other, interactions with certain other SHTEFIE categories are triggered. The SHTEFIE categories are also combined in unique ways at each of these overlaps. Where all three dimensions overlap, Sustainability is achieved.

For the purpose of this study, the Sustainability Ranking (Step 1) was done by evaluating each technology in three Key Performance Areas (KPAs). These KPAs are equal to the three main dimensions of Sustainability. Each KPA has six Key Performance Indicators (KPIs), which are associated with the other SHTEFIE categories, but considered in context of the KPA.

As mentioned, the KPIs are based on research done by Muga et al. (2007), but customised for the South African context. Annexure 6 provides details on how the final KPIs were selected. The three most realistic technology options, best suited for the study area, were selected from all possible options based on their ability to address all aspects of sustainability.

The sustainability ranking performed in Step 1 was very high-level since it only provided an indication on if a technology covers certain sustainability aspects, and to what degree. It however did not provide any weighting on the various sustainability parameters. Weighting is a very subjective issue and in order to approach this as objectively as possible, while maintaining the relevance to the local context, a multi-criteria selection process was followed as part of Step 2.

This approach was based on the Analytical Hierarchy Process (AHP), as developed by developed by Saaty (1977). Mann et al. (1995) provides some background to the AHP and illustrates the Ideal AHP as follows:

		Criterion			
	C_1	C_2	C_3	…	C_N
Alt.	W_1	W_2	W_3	…	W_N
A_1	a_{11}	a_{12}	a_{13}	…	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	…	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	…	a_{3N}
⋮	⋮	⋮	⋮	⋮	⋮
A_M	a_{M1}	a_{M2}	a_{M3}	…	a_{MN}

Figure 3-4: Structure of AHP Decision Matrix
(Figure Source: Mann et al. 1995)

Where: *A_i = All alternative options being considered*
a_{ij} = performance value of the i-th alternative (A_i) in terms of the j-th criterion (C_j)
C_j = Evaluation Criteria applied to the various alternatives
W_j = Weight of the evaluation criteria C_j

Pairwise comparison was first used to evaluate the various technology options against a pre-determined set of evaluation criterion. Following this, pairwise comparison was again used, but to evaluate the importance of the various criterion when compared with each other. The comparison was executed by using a scale of 9 integers assigned to a qualitative evaluation approach. An allocated value of 9 represented the highest level of importance a criteria can have.

Mann et al. 1995 does not recommend using a scale of more than 9, since *"Psychological experiments have also shown that individuals cannot simultaneously compare more than seven objects (plus or minus two)*". The author therefore limited the evaluation criterion to a maximum of 9 criteria, which was developed during Step 1, engagements with stakeholders and after reviewing the returned questionnaires.

In practice, the AHP process is an interactive process with all stakeholders, but due to time restrictions this was not comprehensively possible in this research. The author therefore only engaged with select, key stakeholders on this topic and thereafter synthesized further AHP exercises by using the feedback obtained from the questionnaires. This is therefore a gap in the research which needs to be considered in future, follow-up research.

3.8 LIMITATIONS OF THE METHODOLOGY

Considering the “Desktop” approach to this research, there were certain limitations to it. These limitations are explained below, and can be summarised as follows:

- Predominantly academic approach to Technology Selection
- One dimensional engagement with Stakeholders
- Time and Financial limitations
- Simplification of available technology options
- Lack of field testing of results

The approach to this research mostly followed an academic approach whereby previous literature was reviewed and a hypothesis on the appropriate technology for the area structured. The follow-up engagements with stakeholders, required to improve the research’s relevance, was also limited due to time restrictions.

Stakeholders were engaged during the different Analysis Stages in order to verify what was previously understood and to test conclusions which were drawn. Continuous engagement with them also assisted in refining the outcomes and addressing any consequential issues they identified through the solution finding process.

Had sufficient time and funding been available, a detailed stakeholder engagement and field investigation could have been possible. The larger field investigation would also have helped to increase the sample size and accuracy of the findings.

Another consequence of limited time is that not all possible treatment technologies could be evaluated for appropriateness. Only the most prominent technologies in their basic formats were considered. A possible future research topic could be to evaluate the performance of “new” technologies. These new technologies could be identified by combining the best aspects of the most realistic technologies identified in this research.

It is also always important to field test your hypothesis, if possible. This research methodology unfortunately did not allow for it due to time and financial limits. It is recommended that a pilot plant in future be constructed, in partnership with a WSA and WSP. Decision makers and designers should partake in this pilot plant study in order to perform all required tests and hence develop the research into a credible case study.

3.9 ACCURACY OF RESULTS

It is difficult to determine the accuracy of the results due to the desktop approach to the research. The largest influences on the accuracy of the results were as follows:

- Subjective responses from stakeholders
- Financial comparison of international case studies impacted by currency exchange rates
- Lack of pilot plant to test sewage effluent and impact on ecology

Interviews with stakeholders mostly provided subjective answers which, if not evaluated against facts or input from other stakeholders, could have caused the overall research to be influenced in an undesirable way. During the case study comparison (Stage 2 Analysis), it was important to evaluate the various technologies against the same set of criteria. This included O&M costs as well as construction and land costs. These costs were all influenced by the local country's economic system, policies and foreign exchange rates. Furthermore, the current global financial climate made it difficult to perform a comparison on an equitable basis.

There is no certainty what the quality of the effluent will be (except through academic means) or to exactly understand the O&M needs of the recommended technology. Thus there is some uncertainty as to the level of confidence that can be given to the suitability of the final recommended technology.

It was attempted to improve the accuracy of the results by performing the following activities:

i. Have overlapping questions for various stakeholders
ii. Triangulate of feedback from Stakeholders
iii. Follow-up interviews

The questionnaires were structured to have overlapping topics, thus the answers of one stakeholder group could be compared with the same answers of another stakeholder group. This helped with inter-stakeholder triangulation. Similarly, within the same stakeholder group, answers were also compared to determine whether or not any common themes surfaced.

Follow-up interviews were held on the questionnaires and on the Case Studies if any interesting findings were identified.

3.10 SECTION SUMMARY

This section describes how the analysis of collated information was performed and outlines the research methodology applied. This research is predominantly a Desktop Study of previous literature and evaluation of local dynamics in the study area. It was attempted to improve and refine the research by performing Case Studies on existing technologies and evaluating how well they will be able to perform in the study area.

Stakeholder engagement and limited field investigations was also used to further improve the accuracy of the research. The testing of the technology options with Stakeholders formed one of the critical components of the research. The other critical component was the sustainability evaluation which was performed on the most likely treatment technologies.

A sustainability evaluation fulfilled the critical role for selecting the most appropriate technology. To be as thorough as possible, this was done in two stages, or steps, whereby a general check on all-round sustainability was first done on all probable solutions. The top three most probable solutions, or realistic solutions, was then further interrogated in a formal analytical process to determine the most preferred option.

Due to the nature of the research there were some concerns as to the accuracy of the research, but as discussed above some attempts were made to improve it.

The research approach was structured in such a way to help answer the different research questions. The correlation between which research activities helped answer which research question is summarised in Table 3-3.

Table 3-3 : Research Activity and Question Correlation

RESEARCH QUESTIONS	RESEARCH ACTIVITY										
	LR: Industry Guidelines	LR: Legislation and Policies	LR: Published Papers	LR: Technical Reports	LR: Case Studies	SE: Social Facilitators	SE: STP Designers	SE: STP Operations	SE: Researchers	SE: Decision Makers	Field Investigations
1. What low-technology wastewater treatment options are available?	X	X	X	X	X	X	X	X	X		X
2. What advanced-technology wastewater treatment options can be considered for rural applications?					X	X	X	X	X		
3. How applicable are these options to be used on a large scale?					X				X	X	
4. Are there any success stories for these treatment options? (Local and/or International)	X	X				X	X	X		X	
5. Why is the DWA so resistant to permitting high-volume low technologies to be used?			X	X		X	X	X	X		
6. What community challenges are likely to be experienced in operating wastewater treatment works?			X	X		X	X	X	X	X	X
7. How effective are institutions currently at operating and maintaining wastewater treatment works?					X				X	X	
8. What risks exist to the South African policies if high volume low technology options are used?	X	X			X	X	X	X			
9. What are the financial implications for implementing such high volume low technology options?	X	X			X	X	X	X			
10. How will the community benefit from the selected technology? (e.g. involvement in O&M and agricultural re-use of effluent)						X	X		X	X	X

Note: "LR" : Literature Review
"SE" : Stakeholder Engagement (eg Questionnaires and Interviews)
"X" : A link between the Research Question and Research Activity exists

4. STAGE 1 ANALYSIS: STATUS QUO AND TECHNOLOGY OPTIONS

4.1 SECTION INTRODUCTION

This section forms the first part of a three step process to evaluate the various technology options and select the most appropriate technology.

An overview of the study area's current sanitation level of service is first provided, after which the local legislative framework is briefly described, which governs the selection of sewage treatment technologies. This information helps describe the status quo and context within which sewage treatment technologies need to be selected.

The different, potential technologies are then briefly described and listed for further evaluation as part of the selection of the three most realistic technologies. The selection process depended heavily on a first round sustainability evaluation, as mentioned in Section 3.7, and further informed by local considerations.

4.2 SERVICE DELIVERY IN THE STUDY AREA

Section 2.6 describes the various roles of Water Services Authorities (WSAs) and Water Services Provider (WSPr). Within the Study Area, the WSA is also the WSPr, and their footprints are illustrated in Figure 4-1.

Various sources of information exist on which the Study Area's current Level of Service (LOS) could have been based. The two main sources of information is the DWS database and the WSDPs for the various WSAs in the study area.

With reference to Section 2.3, the author's own experience of the Study Area would suggest that the information provided by the WSDPs are more accurate since it is developed by the WSAs and needs to be routinely updated.

Moving forward, this study will be based on the information provided in the WSDPs, supplemented with information provided in the IDPs and the information provided by DWS database will be discarded. It is however a concern that the DWS information provides such an incorrect representation of the actual situation, and might require further deliberation in future, but outside of this research.

Information obtained from the various WSDPs have been collated and is summarised in Table 4-1. Detail on how this information has been obtained is provided in Annexure 7. Comparing this information with that provided by DWS in Section 2.3, it would indicate that the average village size (DWS: 531 people per village) and household size (DWS: 4.5 people per household, refer to Annexure 7) corresponds very well. The study area's population is, however, much less than what has been quoted by DWS (7 million for whole Eastern Cape). However it must be kept in mind that the study area is only a part of the larger Eastern Cape.

WSA Name:	LM Names:
Amathole DM	Mnquma LM Mbhashe LM
Chris Hani DM	Intsika Yethu LM Engcobo LM
OR Tambo DM	King Sabat Dalin. LM Nyandeni LM Port St Johns LM Mhlontlo LM Ingquza Hill LM
Alfred Nzo DM	Mbizana LM Ntabankulu LM

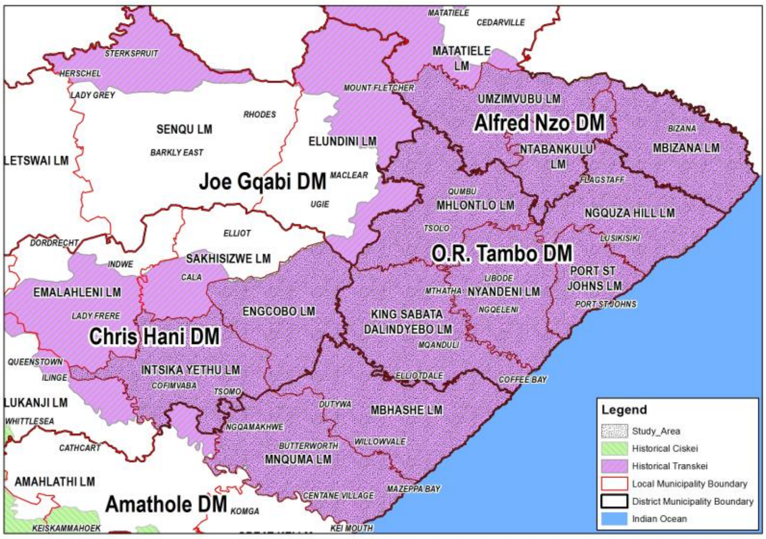


Figure 4-1: WSA Area of Operation in the Study Area
(Image Source: Aurecon 2017(1))

Table 4-1: Rural Demographics in the Study Area

Local Municipality (LM) Name	Land Area (sq.km)	Tot. Population	Tot no of Villages	Average Village Size (pax / village)	Ave. Village Distribution (sq.km / village)
Mnquma LM	3 270	252 390	565	447	6
Mbhashe LM	3 169	254 909	653	390	5
Intsika Yethu LM	2 711	145 725	364	400	7
Engcobo LM	2 484	156 309	440	355	6
King Sabata Dalindyebo LM	3 027	267 151	482	554	6
Nyandeni LM	2 474	284 711	336	847	7
Mhlontlo LM	2 826	206 529	327	632	9
Port St Johns LM	1 291	180 003	221	814	6
Inguza Hill LM	2 477	256 643	331	775	7
Mbizana LM	2 417	281 905	389	725	6
Ntabankulu LM	1 385	123 976	154	805	9
Umzimvubu LM	2 506	191 620	238	805	11
TOTAL	**30 037**	**2 601 871**	**4 500**	**578**	**7**

(Refer to Annexure 7 for references to source material)

Table 4-1 would suggest that the villages are very small and sparsely distributed. While the village itself can be very small, it is the author's experience of the study area that the rural villages are usually clustered together along main access routes, near water supplies or larger urban nodes, and also along the crest of hilltops. The author has experienced that in some places, up to 7 villages can be clustered together.

Figure 4-2 shows a good example of this clustering. Figure 4-2 is an aerial photograph of the Port St Johns' area (GPS Location: Lat: 31°37'44.13"S. Long: 29°32'13.21"E) within the Alfred Nzo District Municipality. While it would appear as if there are only a few villages around the urban settlement of Port St Johns, these are in fact clusters of smaller villages, each with their own leadership, and it is important that these community dynamics are always considered when planning service delivery in the area.

Figure 4-2: Example of Village Clusters in the Study Area

(Image Source: Aurecon (2017(1))

Table 4-2 provides a summary of the service delivery in the study area, with more detail provided in Annexure 7 and summarised in Figure 4-3.

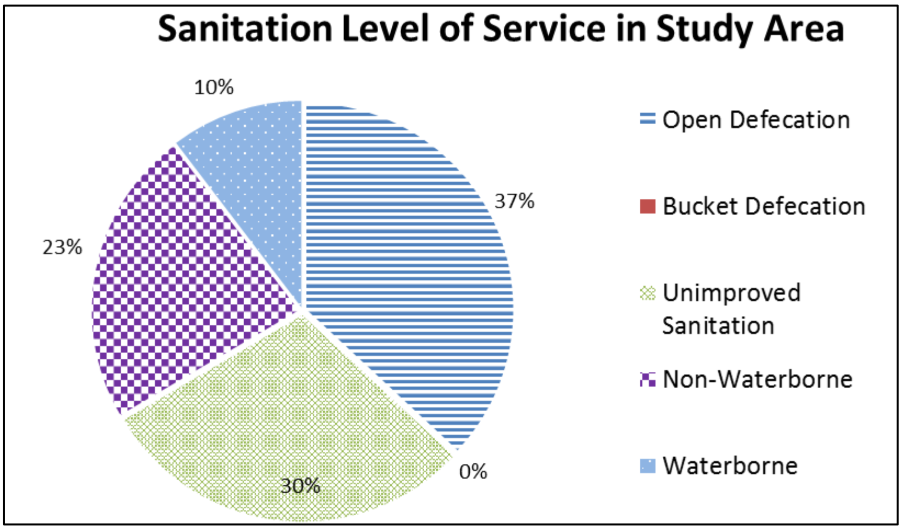


Figure 4-3: Sanitation Level of Service in the Study Area

(Image Source: Various, refer to Annexure 7 for references to source material)

The information provided in Table 4-2 and Figure 4-3 indicates that the Study Area has not achieved the MDG of 77% for improved sanitation as it is currently at only 33%. This is also much lower than the information, provided by DWS in section 2.3, of 63% waterborne sanitation in the rural Eastern Cape. Table 4-2 also indicates that large scale STP establishment will occur if waterborne sanitation is to be provided to all areas.

Table 4-2: Summary of Service Delivery in the Study Area

WSA	LM	Tot no of Villages	% Improved Sanitation	% Off-Site Sanitation
ADM	Mnquma LM	565	19%	12%
ADM	Mbhashe LM	653	22%	4%
CHDM	Intsika Yethu LM	364	30%	4%
CHDM	Engcobo LM	440	34%	5%
ORTDM	King Sabata Dalindyebo	482	58%	34%
ORTDM	Nyandeni LM	336	42%	6%
ORTDM	Mhlontlo LM	327	35%	9%
ORTDM	Port St Johns LM	221	37%	13%
ORTDM	Inguza Hill LM	331	37%	13%
ANDM	Mbizana LM	389	40%	2%
ANDM	Ntabankulu LM	154	16%	2%
ANDM	Umzimvubu LM	238	34%	17%
TOTAL		4 500	33%	10%

(Refer to Annexure 7 for references to source material)

4.3 LEGISLATIVE FRAMEWORK FOR TECHNOLOGY SELECTION

With reference to Sections 2.5 and 2.9 the following pieces of legislation have been identified as being the cornerstones when it comes to defining the framework within which the most appropriate technology must be selected:

- National Water Act (NWA) (Act of 1998, as amended in 2013. (NWA 1998, NWA 2013)
- National Environmental Management Act, including the NEMA: Waste Act. (NEMA 1998, NEMWA 2008)
- The South African National Strategy and Action Plan for Sustainable Development (NSAPSD). (NSAPSD, 2010)

Figure 4-4 illustrates a general approach to how technologies are selected in South Africa and how the above legislation and stakeholder engagement plays a role during the process. Annexure 8 provides further detail on how the legislation influences the technology selection process. The STP Development Process is also further elaborated on.

Some challenges with the implementation and enforcement of the legislation have been experienced in the past. As an example, Figure 4-4 illustrates that the NSAPSD should basically be applied throughout the whole project lifecycle, however the ability to enforce and monitor its implementation is difficult.

According to VD Merwe et al. (2012), the NWA does set out the principle that water use must promote social and economic development. This is also emphasized in the NEMA. The challenge is that there exists no effective mechanism to monitor the compliance with these principles in the most sustainable manner.

Further challenges with the legislation is that the need for technically competent staff is not a legislated requirement, thus a technology can be selected for which no competent staff can be provided by the WSPr to operate the selected technology.

STP DEVELOPMENT PROCESS

The process described below is a very high-level approach and based on VDMERWE and the author's own experience in the industry. This is a typical approach for the implementation of a STP for a WSA and can deviate if it is for another institution.

STP DEVELOPMENT PROCESS	STAKEHOLDER ENGAGEMENT: WSAs	WSPr	DWS	DEDEAT	Community	Eskom	Municipal Council	Funder	PSP: Technical	PSP: Environmental	Construction Contractor	CONSULTED LEGISLATION: NWA	NEMA	NEMWA	ECA	NSAPSD
1. IDENTIFY THE NEED FOR A NEW STP The need for a SDP is usually derived from a Sanitation Masterplan, IDP and WSDP documents.	X				X		X									X
2. APPOINT PSP TO DESIGN THE STP A consulting engineer is usually appointed to execute the design and assist with delivery, but alternative models also exist.	X								X							
3. DETERMINE PARAMETERS WITHIN WHICH THE STP NEED TO OPERATE This includes available electricity, the applicability of the General Authorisation or need to comply with RWQO.	X	X	X		X	X		X	X			X	X	X		X
4. SELECT THE STP TECHNOLOGY TO BE APPLIED Environmental restraints, community involvement, effluent disposal and WSPr requirements must be considered	X	X	X		X				X	X		X	X	X		X
5. OBTAIN INSTITUTIONAL AUTHORISATION An Environmental Authorisation and Water Use License needs to be obtained before the STP can be built.	X		X	X		X		X	X	X		X	X	X	X	X
6. IMPLEMENT THE PROJECT A Contractor is appointed for construction and must follow an Environmental Management Plan.	X	X		X	X	X		X	X	X	X				X	
7. REGISTER STP AND BEGIN COMPLIANCE MONITORING The completed STP needs to be registered at DWS and an effluent compliance monitoring programme implemented.	X	X	X	X					X	X		X	X	X		

Figure 4-4: Current STP development process in South Africa
(Image Source: Developed by the author based on VD Merwe et al. (2012))

Lastly, according to VD Merwe et al. (2012), some stakeholders they interviewed during their research criticized the effluent standards which DWS prescribes, as being too strict and only capable of being achieved through the most advanced, and sometimes very inappropriate, technology. Their study recommended that DWS needs to set clear and scientifically defendable parameters which need to be complied with.

The Water Services Act (WSAc) has provided regulations according to which a STP will be classified using a point scoring method (WSAc 2013). STP Classes vary from Class A (High volume and complex technology) to Class E (Small and simplistic treatment). Further details are provided in Annexure 8. The WSAc also classifies Process Controllers based on required qualifications (WSAc 2013) and what Class of STP they may be involved with. (WSAc 2013(2)). Table 4-3 summarises the correlation between Process Controller and STP.

Table 4-3 : Operator and STP Class Correlation

Works Class	Class of Process Controller per shift	Supervision*	Operations and maintenance support services :
E	Class I	Class V*	Must be available at all times, either from PSP or In-House: - electrician - fitter - instrumentation technician
D	Class II	Class V*	
C	Class III	Class V*	
B	Class IV	Class V	
A	Class IV	Class V	

* Note: *Does not have to be at the works at all times but must be available at all times*

4.4 CONDITION ASSESSMENT OF SEWAGE TREATMENT WORKS

A condition assessment, complying with the process illustrated in Figure 4-5, was performed on existing STPs in the study area, to:

1. Determine how well the various technologies are being operated
2. Verify the findings of the Green Drop Assessment
3. Develop a better understanding of when the different technologies can be applied

To establish the condition of the existing STPs, the following literature was consulted:

i. 2012 Green Drop Assessment, as prepared by DWS (DWS 2013)
ii. “Drivers for Wastewater Technology Selection”, as compiled by VD Merwe et al. (2012)
iii. “Rapid Assessment Report of the Waste Water Treatment Facilities”, compiled by Aurecon South Africa (Pty) Ltd, for Amatola Water. (Aurecon 2017)

Condition assessment items 1 and 2 have been reported on in Section 2.7. Item 3 was an assessment report which Amatola Water commissioned to be done after they were appointed as the WSPr for the Department of Public Works (DPW). The DPW is responsible for all sewage treatment facilities at Correctional Facilities.

It was decided to include Item 3 as part of the assessment in order to increase the data sample size. STPs at the correctional facilities are also typically smaller than elsewhere, which means simpler technologies are required. With reference to the 2012 Green Drop Report (DWS 2013), the following parameters were identified to be reported on:

- Design Capacity of Plant
- Operational Flow
- Non-compliance to effluent quality

➢ Technical skills compliance

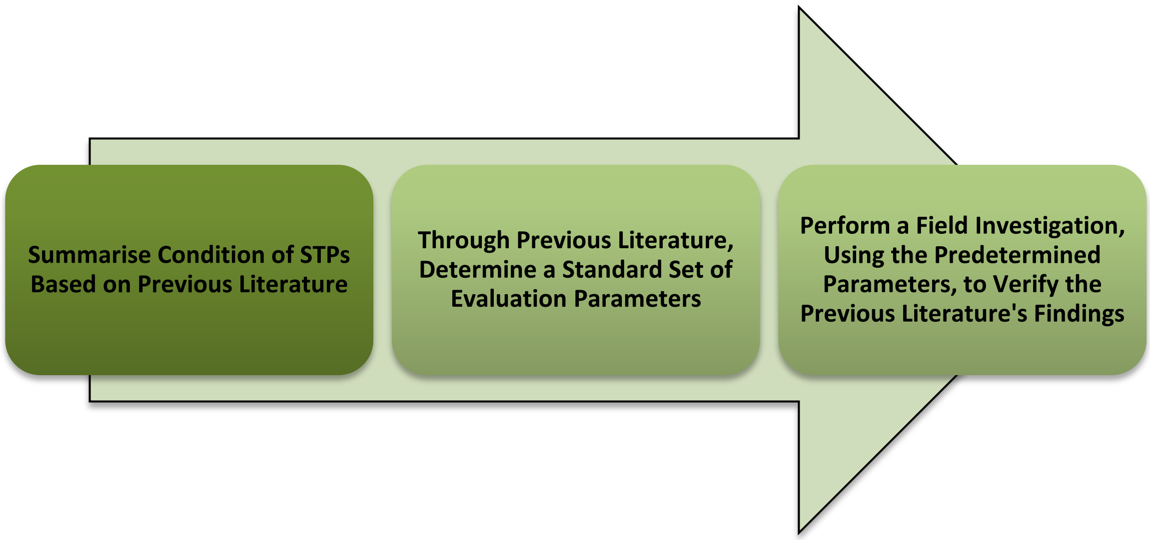


Figure 4-5 : Condition Assessment Process

(Image Source: Author)

These are the parameters used to calculate the Cumulative Risk Rating (CRR) and eventual Wastewater Risk Rating (WRR). The WRR is the ratio between current CRR and the maximum CRR which can be achieved. Annexure 10 provides an excerpt from the Green Drop Report (DWS 2013), explaining how this is calculated, but should only be seen as a quick reference.

The higher the WRR, the higher the likelihood of failure, with the following ranges reflecting the overall risk ranges of STPs:

- 90 – 100%: Critical risk
- 70 - <90%: High Risk
- 50-<70%: Medium risk
- <50%: Low Risk

The findings of all STPs in the study area are summarised in Table 4-4. Through evaluating this information the following can be concluded:

1. Very little information is available to perform an adequate assessment of the status quo
2. Limited reporting and compliance monitoring is being implemented
3. There is a general non-compliance in the skills empowerment to operate the applicable plants
4. No trend is evident between increasing Risk Rating and Type of technology.
5. All STPs are for formal urban areas
6. 75% of all STPs in the study area are oxidation ponds, with capacities below 1.1Ml/d
7. Biofilters are being used for large treatment volumes (above 10Ml/d)
8. The WRR has reduced at those Oxidation ponds where evaporation ponds have been implemented in-lieu of discharging effluent into the receiving water courses

The STPs belonging to the Department of Public Works (DPW) at Correctional facilities were assessed as part of an AW study (Aurecon 2017) and are summarised in Table 4-5. In this study it was attempted to report on the same parameters as for the Green Drop Report, however the study was a rapid assessment and not all WRR parameters were reported on.

Table 4-4 : Condition of STPs in Study Area, according to 2012 Green Drop Report

WSA	Plant Location	STP Type	Design Capacity (Ml/d)	Opera-tional %	Actual Flow (Ml/d)	Effluent Quality	Staff Skills:	WRR
ANDM	Mount Ayliff	Activated Sludge	1.2	14%	0.2	32.1%	N/C	64.7%
	Mount Frere	Activated Sludge	2	70%	1.4	55.0%	N/C	58.8%
	Bizana	Oxidation Ponds	NI	NI	NI	NMR	N/C	52.9%
	Ntabankulu	Oxidation Ponds	NI	NI	NI	NMR	N/C	52.9%
ADM	Butterworth	Biofilters	12.6	39.7%	5.0	NI	N/C	63.6%
	Cintsa East	Oxidation Ponds	0.3	NI	NI	65.6%	N/C	88.2%
	Idutywa	Oxidation Ponds	1.1	NI	NI	NI	N/C	88.2%
	Kei Mouth	Oxidation Ponds	0.69	NI	NI	65.6%	N/C	88.2%
CH-DM	Cofimvaba	NI	NI	NI	NI	NI	NI	100.0%
	Engcobo	NI	NI	NI	NI	NI	NI	100.0%
	Tsomo	NI	NI	NI	NI	NI	NI	100.0%
ORTDM	Flagstaff	Oxidation Ponds	NI	NI	NI	NI	N/C	100.0%
	Lusikisiki	Oxidation Ponds	NI	NI	NI	NI	N/C	94.1%
	Mqanduli	Oxidation Ponds	NI	NI	NI	NI	N/C	94.1%
	Mthatha	Biofilters	12	116.7%	14.0	NI	NI	81.8%
	Ngqeleni	Oxidation Ponds	NI	NI	NI	NMR	N/C	52.9%
	Port St Johns	Oxidation Ponds	NI	NI	NI	NMR	N/C	52.9%
	Qumbu	Oxidation Ponds	NI	NI	NI	NMR	N/C	52.9%
	Tsolo	Oxidation Ponds	NI	NI	NI	NI	N/C	94.1%

Note: NI = No Information N/C = Non-Compliant
(Table Source: DWS 2013)

Table 4-5 : Condition assessment of DPW STPs in the Study Area

Plant Location	STP Type	Design Capacity (Ml/d)	Operational %	Actual Flow (Ml/d)	Person Eq (PE)
Willowvale Correctional Centre	Oxidation Ponds	0.012	500%	0.060	696
Ntabankulu Correctional Centre	Oxidation Ponds	0.042	476%	0.200	2 319
Ncgqamakwe Correctional Centre	Oxidation Ponds	0.027	148%	0.040	464
Mqanduli Correctional Centre	Oxidation Ponds	0.039	256%	0.100	1 159
Mount Fletcher Correctional Centre	Oxidation Ponds	0.062	NI	NI	NI
Flagstaff Correctional Centre	Oxidation Ponds	0.026	42%	0.011	128
Cofimvaba Correctional Centre	Oxidation Ponds	0.034	59%	0.020	232
Mthatha 14 SAI Army Base	Oxidation Ponds	0.255	NI	NI	NI
Lusikisiki Correctional Centre	Oxidation Ponds	0.072	65%	0.047	545
Qunu Museum	Lilliput System	NI	NI	NI	NI
Elliotdale SAPS	Activated Sludge	NI	NI	NI	NI
Engcobo Correctional Centre	Oxidation Ponds	0.018	167%	0.030	348

(Table Source: Aurecon 2017)

From the assessment performed, the following conclusions were drawn:

1. Chlorine dosing is done at all STPs, but by hand and using granular chlorine, without accurate estimation of how much is required.
2. Effluent testing is reportedly done, but no proof of frequency and results can be provided
3. Septic tanks are provided at some STPs for primary treatment
4. Effluent is discharged to open fields, from where it drains to the nearest watercourse. At some STPs evidence existed that the effluent was previously used for irrigation, but this practice has been abandoned
5. Pond seepage is occurring at some ponds and some ponds require a lining
6. Even though fencing has been provided, there is no access control and it has been reported that animals have gained access to the ponds for grazing and drinking
7. Maintenance is done from time to time, but no fixed frequency is evident
8. Pipe blockages have been reported and these occur mostly at STPs where screenings are not removed
9. Not all STPs were provided with an inlet works and formal hand raked screen.
10. No proof of is available to show that formal training is provided to the STP staff

For the DPW STPs, it can be seen that the Person Equivalents (PEs) vary between 130 and 2300 persons per STP, which compares well with the average size of villages in the study area (Table 4-1).

4.4.1 FIELD INVESTIGATION RESULTS

The following tables summarise the findings of the STP Field Investigation which was performed by the author as part of the study:

Table 4-6 : Stutterheim STP

<table>
<tr><td rowspan="5">
STP Layout (Image Source: Google Earth)</td><td><u>Location:</u> Stutterheim, Amathole District Municipality
Latt: 32°34'14.92"S ; Long: 27°26'6.81"E</td></tr>
<tr><td><u>Technology Description:</u> Waste Activated Sludge Treatment, with secondary settlement and tertiary treatment to reduce phosphates. Sludge drying beds are used after which the sludge is disposed of on-site in old abandoned oxidation ponds.</td></tr>
<tr><td><u>Capacity:</u> 3 Ml/d
<u>Flow:</u> 1.82 Ml/d</td></tr>
<tr><td><u>Staff:</u> 1 Supervisor that rotates between the various STPs.
3 Process Controllers (1 Senior and Two Juniors – Class I,II and III)
4 General Staff for basic maintenance and plant up-keep
The WSPr has a central maintenance team that visits the various STPs as and when required.</td></tr>
<tr><td><u>Effluent Comment:</u> TSE is gas chlorinated and discharged into the local water course. Not all TSE parameters are tested and no information is available of what the final effluent quality should be, but based on the NWA General Standards (DWS 2013), the effluent's Ammonia and Nitrogen levels are compliant, but the free Chlorine and Electrical Conductivity do not comply, and Dissolved Oxygen seems a bit low.</td></tr>
<tr><td colspan="2"><u>General Comments:</u> Previously a pond system was used, but this was replaced by a Waste Activated Sludge System and the pond system fully abandoned except for sludge storage. The phosphate removal process failed after the commissioning of the STP and was never repaired. Operators also commented that they never received training on how to operate the process. Faulty components are replaced within 30 days. DWS samples effluent once a month, but no sampling of influent is done by any party. Water is abstracted downstream for treatment and domestic use. Annexure 11 provides further information obtained</td></tr>
</table>

during the field investigation.

Table 4-7 : Cintsa East STP

<table>
<tr><td rowspan="5">
STP Layout (Image Source: Google Earth)</td><td><u>Location:</u> Cintsa, Amathole District Municipality
Latt: 32°48'53.77"S ; Long: 28° 6'7.51"E</td></tr>
<tr><td><u>Technology Description:</u> Mechanically aerated oxidation pond, followed by Facultative and Maturation Ponds. Sludge is only removed as and when required, and stored in holding ponds. Treated effluent is discharged into the nearby river.</td></tr>
<tr><td><u>Capacity:</u> 0.3Ml/d
<u>Flow:</u> 0.28 Ml/d</td></tr>
<tr><td><u>Staff:</u> 1 Supervisor that rotates between the various STPs.
2 Process Controllers (Both Class II), only one on-site and only during day shifts. No staff present in evenings
The WSPr has a central maintenance team that visits the various STPs as and when required.</td></tr>
<tr><td><u>Effluent Comment:</u> TSE is disinfected using Sodium Hypochlorite solution and discharged into the local water course. Not all TSE parameters are tested and no information is available of what the final effluent quality should be, but based on the NWA General Standards (DWS 2013), most effluent parameters are compliant, but the free Chlorine does not comply and Dissolved Oxygen seems a bit low.</td></tr>
<tr><td colspan="2"><u>General Comments:</u> The STP Supervisor indicated the effluent quality of the pond system only complied with DWS requirements after the first pond (Anaerobic Pond) was converted to a Mechanically Aerated Oxidation Pond. In order to assist in the treatment process, some effluent is pumped back from the maturation ponds to the first pond. DWS does sample effluent once a month, but no sampling of influent is done by any party. Sludge removal from the pond systems has in the past been a problem. Annexure 11 provides further information obtained during the field investigation.</td></tr>
</table>

Table 4-8 : Kei Mouth STP

STP Layout (Image Source: Google Earth)

Location: Kei Mouth, Amathole District Municipality
Latt: 32°41'59.51"S ; Long: 28°21'45.56"E

Technology Description: Two Facultative ponds followed by two Maturation Ponds. No sludge removal has historically occurred and treated effluent is discharged into the nearby river. The local golf course also uses some effluent for irrigation purposes

Capacity: 0.8 Ml/d
Flow: Unknown (No flow meters are installed)

Staff: 1 Supervisor that rotates between the various STPs.
4 Process Controllers (Classes I - IV), only two on-site at any time and only during day shifts. No staff present in evenings
The WSPr has a central maintenance team that visits the various STPs as and when required.

Effluent Comment: TSE is disinfected using Sodium Hypochlorite tablets and discharged into the local water course. Not all TSE parameters are tested, and no information is available of what the final effluent quality should be, but based on the NWA General Standards (DWS 2013), none of the effluent parameters are compliant.

General Comments: The pond system is in a good condition and works fully under gravity flow. The irrigation abstraction is erratic, thus no guaranteed abstraction can be assumed. Even though the effluent quality is not compliant, the effluent seems clear and there is no bad smells emanating from the pond system. Limited space is available for future STP upgrade/expansion. DWS samples effluent once a month, but no sampling of influent is done by any party. Annexure 11 provides further information obtained during the field investigation.

The results of the field investigation compare well with the findings of the Green Drop report. The most significant findings from the field investigation, for application to this study, are:

- Effluent sampling is not comprehensive enough
- Effluent quality does not comply with the NWA General Discharge Limits
- Staffing levels do not comply with the Water Services Act Regulations (WSAc 2013)
- The WSPr prefers their STP Supervisors to rotate between facilities
- Basic maintenance is done by the local STP team, with more complex maintenance being performed by a central O&M team which is on stand-by.

4.5 TECHNOLOGY PERFORMANCE FRAMEWORK

In order to select the three realistic technology options for further consideration, certain boundary conditions, or a performance framework, had to be compiled to ensure all technologies are evaluated on a similar basis. The following operational parameters were selected:

1. Only domestic sewage to be treated
2. According to the NWA, a General Authorisation with General Discharge Limits will apply.
3. With reference to Section 4.2, one STP could possibly have to treat a cluster of villages. A maximum cluster size of 10 villages, or 5 780 people, or about 500kl/d of raw sewage (at 75 l/c/d and 15% wet weather infiltration) has been selected.
4. Ample land is available for the establishment of a STP

4.6 SUMMARY OF POTENTIAL SEWAGE TREATMENT TECHNOLOGIES

During the literature review, technologies being implemented in South Africa and abroad were identified. Section 2.7 lists those technologies being utilised within the Eastern Cape, while sections 2.11, 2.14 and 2.15 list technologies being applied in other parts of the world.

All of these technologies were consolidated into a list of potential options for the study area, and are summarised below:

- Waste Stabilisation Ponds (WSPo)
- Settled Sewerage Systems
- Upflow Anaerobic Sludge Blankets (UASB)
- Constructed Wetlands
- Infiltration Percolation System with Nitrification Basin
- Activated Sludge Treatment
- Biofiltration (Percolating filters)
- Rotating Biological Contactors (Biodiscs)
- Integrated Algal Pond System
- PETRO System

Two technologies currently being applied in the study area, but which were not selected for consideration, are:

- Sea outfalls
- Aerated oxidation ponds with facultative ponds

These technologies were excluded since only a portion of the study area runs along the coast for sea outfalls to be considered. Aerated oxidation ponds are also a combination between a WSPo and a Activated Sludge Plant, thus is already represented in their basic forms for consideration.

Questionnaires were issued to stakeholders and included the above list of technologies to gauge responses from them on any preferences or additional technologies which should also be considered. Copies of the BLANK questionnaires are provided in Annexure 9. In no returned questionnaires was any other technology suggested to be included for further consideration in addition to those already listed above.

The following technologies will thus be taken through a first round sustainability ranking (described in Section 3.7) and selection process in order to identify the three most realistic technologies for the study area:

Table 4-9 : Low Technology Options

Technology Description	Used Globally?	Used in RSA?	Used in Study Area?
Waste Stabilisation Ponds (WSPo)	Y	Y	Y
Settled Sewerage Systems	Y	Y	Y
Upflow Anaerobic Sludge Blankets (UASB)	Y	N	N
Constructed Wetlands	Y	N	N
Infiltration Percolation System with Nitrification Basin	Y	N	N

The Table 4-9 technologies have been grouped together as Low-Technologies as they typically are more dependent on gravity and natural treatment, requiring minimal electricity and medium to low-skilled operating staff.

Table 4-10 : Advanced Technology Options

Technology Description	Used Globally?	Used in RSA?	Used in Study Area?
Activated Sludge Treatment	Y	Y	Y
Biofiltration (Percolating filters)	Y	Y	Y
Rotating Biological Contactors (Biodiscs)	Y	Y	N
Integrated Algal Pond System	Y	Y	N
PETRO System	N	Y	N

As can be seen from the tables above, no other combination of technologies have been included, such as combining WSPo and Constructed Wetlands. The reason for this is that limited research into the effectiveness of these hybrid technologies exists. In addition, by evaluating the different technologies listed above as is, which have been well researched and applied consistently up to the present, this can create the basis for future research into combining the best aspects of the preferred technologies, to form a new hybrid for application in the study area (or similar other applications).

In order to better understand the different treatment technologies evaluated in this study, some background on conventional sewage treatment is first provided.

According to Smith (2011) the three main wastewater treatment techniques are:

- Physical: Separation of water from solids and other liquids
- Biological: Breaking organic matter down into stable chemicals, using bacteria or other micro organisms
- Chemical: Converting chemicals into compounds which are either safe or which can be separated from the water.

Table 4-11 summarises the various conventional sewage treatment stages and typically which treatment technique is used during the different stages. Chemical treatment is generally only used if chemical disinfection is required.

Table 4-11 : Conventional Sewage Treatment Stages

Stage Name	Stage Description	Treatment Technique:
0. Preliminary	Removal of easily separated solids (e.g. paper, plastics, faeces). Removal of dense suspended solids (e.g. grit, grease, fruit pips).	Physical
1. Primary	Removal of some suspended solids through settlement and sedimentation. Sludge and scum can also be removed (e.g. food waste, faecal matter, fats and greases.)	Physical
2. Secondary	a) Biological Treatment (Biological Decomposition or Oxidation) of settled sewage. b) Secondary settlement of suspended solids.	a) Biological b) Physical
3. Tertiary	Optional Stage. Further treatment to improve effluent quality.	Dependent on the influent composition, preceding treatment techniques and required effluent quality.
4. Complementary	a) Treatment (Stabilisation) and disposal of Sludge b) Treatment and disposal of solid waste	a) Biological / Physical b) Physical

(Table Source: Smith 2011)

A brief description of each of this study's potential technologies are provided below. Details on typical O&M activities for each of these technologies area provided in Annexure 9, as part of the issued questionnaires.

Waste Stabilisation Ponds

A system of ponds, preceded by primary treatment (Screens and Grit Removal) consisting of three types of ponds. These are Anaerobic, Facultative and Maturation Ponds. The ponds can be lined and sewage treatment occurs through encouraging natural processes by means of gravity and solar radiation. (Smith (2011). Figure 4-6 shows an example of a series of ponds.

Settled Sewerage Systems (also termed "Small Bore Sewerage")

A sewer drainage system connected to an Anaerobic Digester (septic tank) and discharging of effluent at a centralised location for further treatment. Figure 4-7 shows an example of a septic tank connected to a small-bore sewer. Various treatment technologies exist. (Reed (2008)).

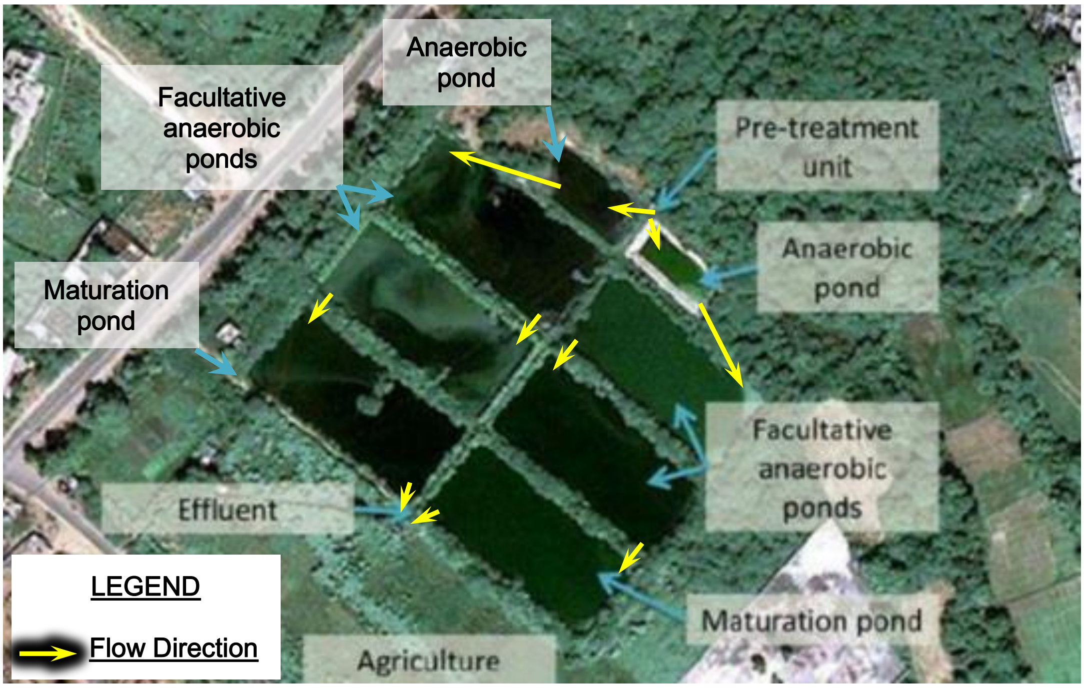


Figure 4-6 : Typical WSP layout

(Image Source: Adapted by author from ResearchGate (2016))

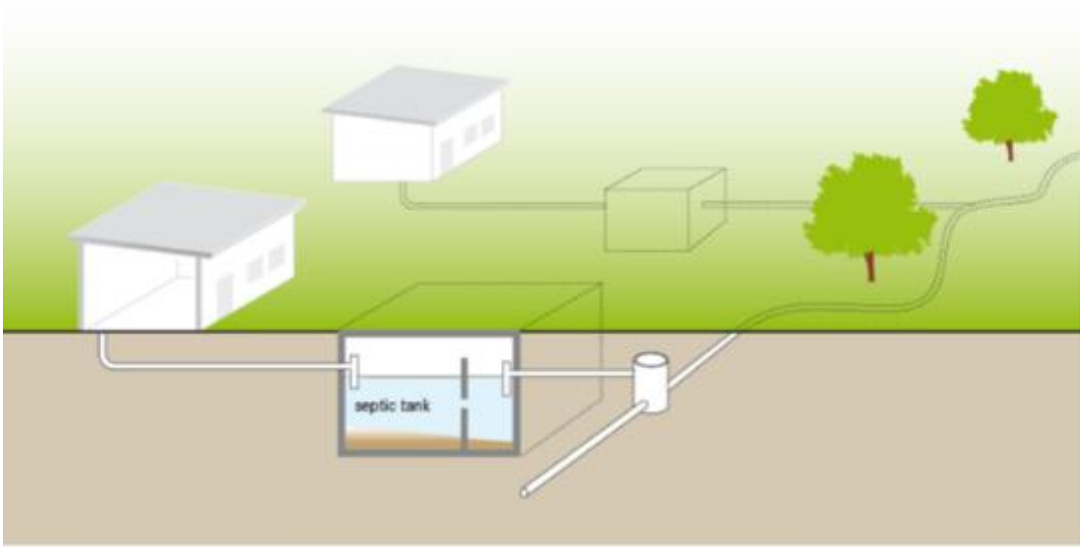


Figure 4-7 : Typical Settled Sewerage System Design

(Image Source: SSWM *(2016))*

Upflow Anaerobic Sludge Blankets (UASB) (Figure 4-8)

Primary treatment (Screens and Grit Removal) followed by a UASB reactor. Anaerobic processes occur in a reinforced concrete structure. Raw sewage flows upwards through the base of the structure, through a suspended sludge layer. Polishing ponds with an approximate depth of 1.25m are thereafter required for improving the effluent quality. (Mara (2003)).

Figure 4-8 : Typical UASB example

(Image Source: Mara (2003))

Constructed Wetlands (Figure 4-9)

Following primary treatment, effluent trickles through the reed bed. In the root zone sewage is treated by the biological action of micro-organisms. The granular growth medium allows for aerobic, anaerobic and anoxic treatment. Horizontal, Vertical and Floating Wetlands are different types of Constructed Wetland technologies being used over the world. (Freese and Nozaic (2009)).

Figure 4-9 : Typical Constructed Wetland (Still under construction)

(Image Source: FREESE and NOZAIC (2009))

Infiltration Percolation System with Nitrification Basin (IPSNB) (Figure 4-10)

Following primary treatment and an anaerobic pond, sewage is further treated in a denitrification basin where nitrogen is removed by heterotrophic bacteria operating in an anoxic environment (an environment having very little free oxygen available).

This effluent is then dosed onto recirculating sand filters to remove ammonia. Some effluent will need to be recirculated via pumping. (*CHOUKR-ALLAH et al. (2003)*))

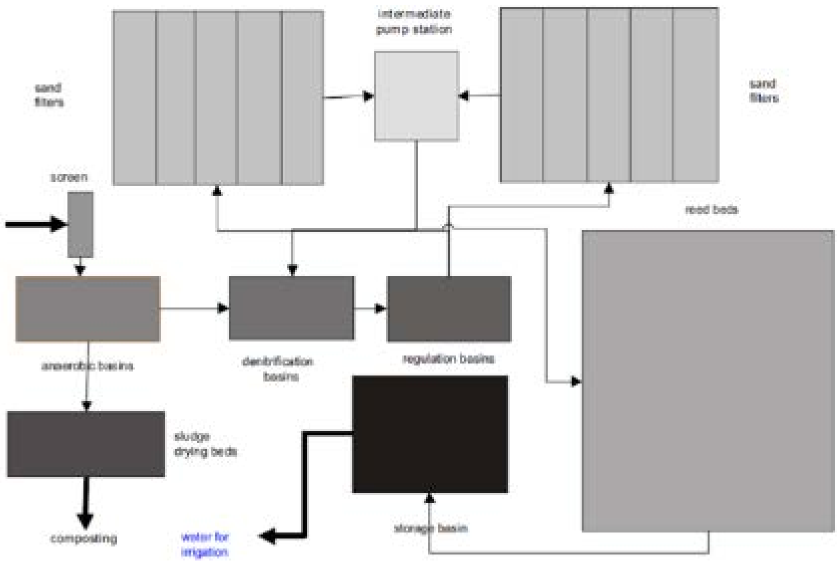


Figure 4-10 : Typical Infiltration Percolation System with Nitrification Basin

(Image Source: CHOUKR-ALLAH et al. (2003))

Activated Sludge Treatment (Figure 4-11)

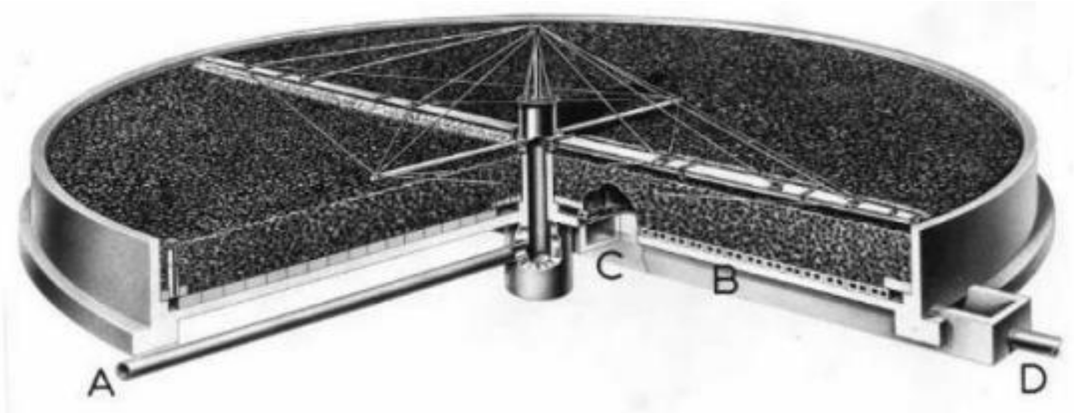
Sewage and sludge (containing active aerobic bacteria) is aerated by means of surface aeration, diffused air aeration, or a combination of the two. This promotes bacterial growth which accelerates the decomposition of the sewage. Following this process, the effluent is discharged to a settling tank where the sludge is either recycled back to the aeration tank, or pumped away for final treatment and disposal. Examples of such technologies include Waste Activated Sludge and the Sequencing Batch Reactor systems. (Smith (2011)) and (Freese and Nozaic (2009))

Biofiltration (Percolating filters) (Figure 4-12)

Wastewater is sprinkled on the top of either a circular or rectangular structure containing coarse media (eg gravel). The media supports a biological film which assists in the purification of the sewage as it gravitates downwards through the media. These systems are used together with primary treatment, settling tanks and tertiary treatment. (Smith (2011)) and (Mara (2003)).

Figure 4-11 : Typical Waste Activated Sludge Treatment Plant

(Image Source: FREESE and NOZAIC (2009))



Note: A, inlet pipe; B, underdrain blocks; C, effluent channel; D, outlet pipe.

Figure 4-12 : Typical Biofiltration System

(Image Source: Mara (2003))

Rotating Biological Contactors (Biodiscs) (Figure 4-13)

A mechanical secondary treatment system similar to the Biofiltration system, except that the biofilm develops on mechanically rotated discs. They require smaller land area and less electricity than biofilters. Primary treatment and further treatment of the effluent will still be required. (Smith (2011))

Integrated Algal Pond System (Figure 4-14)

After preliminary treatment, sewage flows into a facultative pond via an "Anaerobic Fermentation Pit". Then effluent is conveyed to a High Rate Algal Pond (HRAP) which is a concrete oval shaped raceway in which algal growth is promoted through a paddle wheel. From there, effluent flows into an algal settling pond before being discharged. (Wells et al. (n.d.))

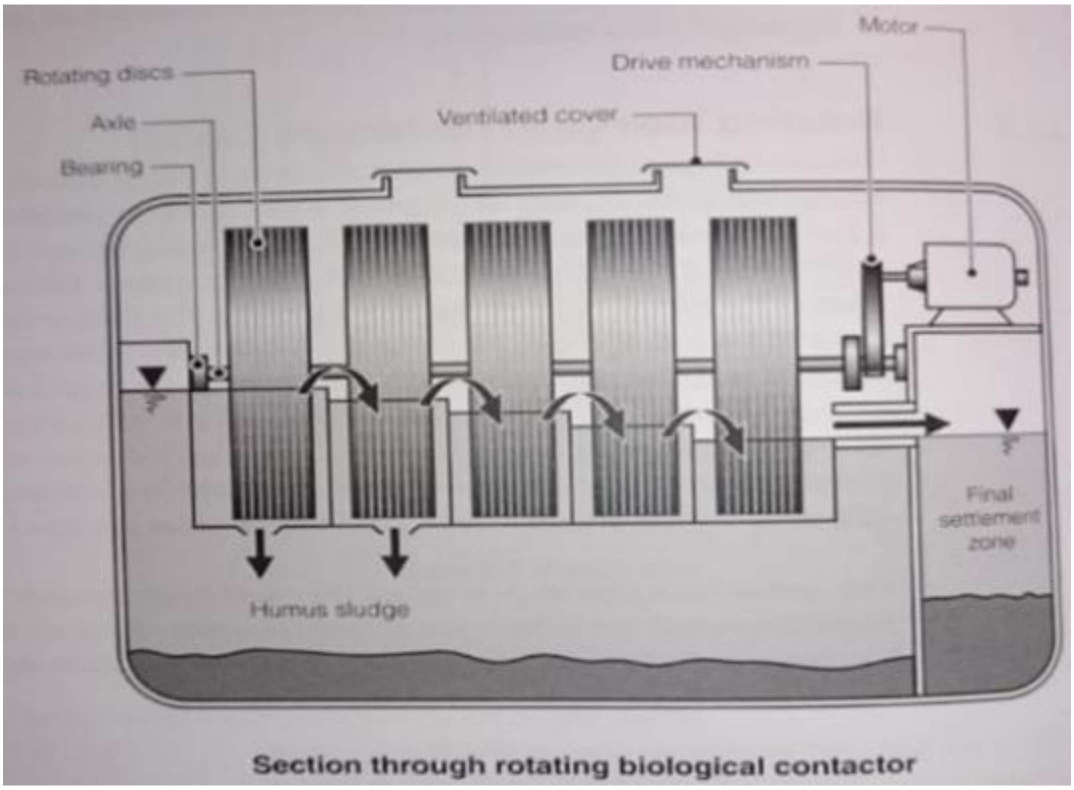


Figure 4-13 : Example of Rotating Biological Contactor

(Image Source: Smith (2011))

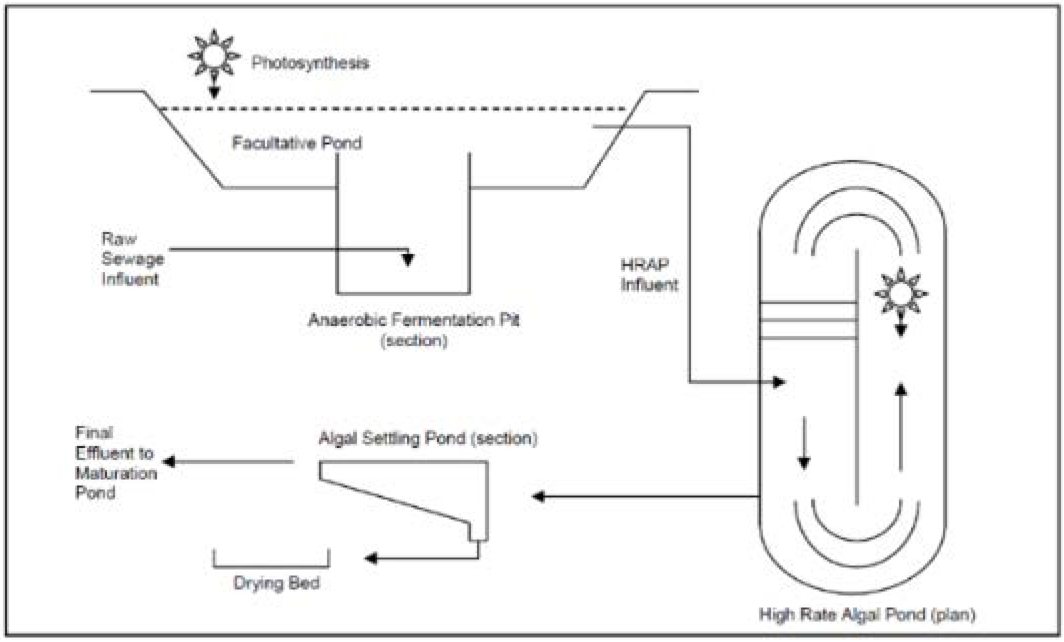


Figure 4-14 : Indicative Process for an Integrated Algal Pond System

(Image Source: Wells et al (nd))

PETRO System (Figure 4-15)

PETRO is an acronym for "Pond Enhanced Treatment and Operation" (PETRO) and is basically a waste stabilisation system followed by Biofiltration. Anaerobic and Aerobic biodegradation occurs in the pond system, after which polishing occurs in the Biofilter.

Primary treatment (screens etc.) and disinfection is however still recommended. (Shipin et al (1998))

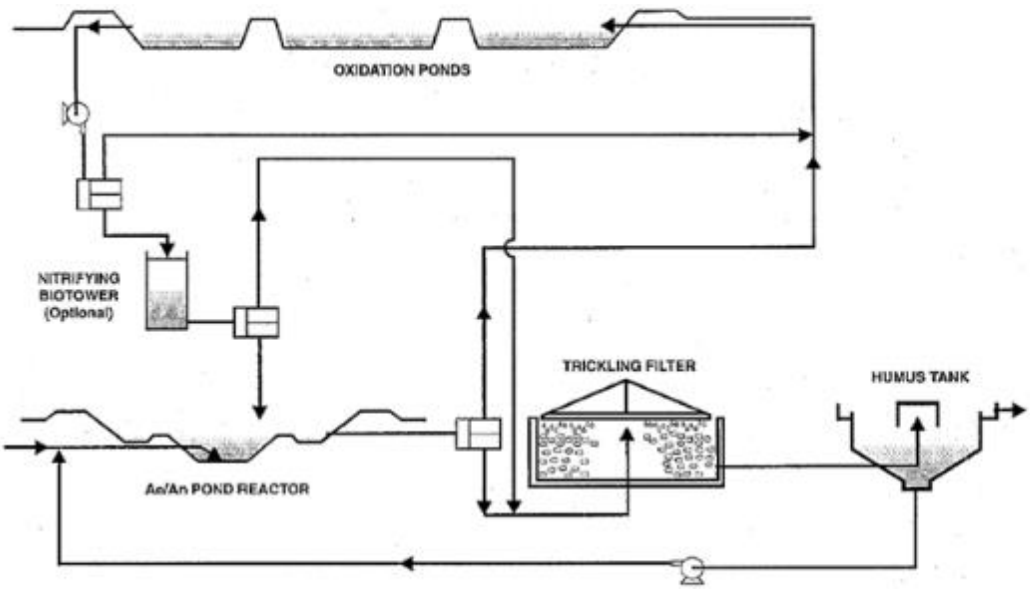


Figure 4-15 : Schematic PETRO System

(Image Source: Shipin et al (1998))

4.7 EVALUATION OF TECHNOLOGY OPTIONS

The top three realistic technologies were selected based on a three-filter evaluation process, as illustrated in Figure 4-16:

Figure 4-16 : Realistic Technology Evaluation Process

(Image Source: Author)

This filter process is further described below:

Filter 1: Sustainability Ranking

This ranking is performed as per Step 1 in Section 3.7 and only the top 5 technologies proceed to Filter 2.

Filter 2: Local Legislative Conditions

The five selected technologies will need to comply with the NWA's General Authorisation and STP Operating Regulations (WSAc (2013) and WSAc (2013(2))).

Filter 3: Stakeholder Preferences

Stakeholder preferences, identified through the issued questionnaires, will be used to evaluate the remaining technologies. Three main areas will be looked at:

- Preferred technologies to operate
- Preferred O&M activities to be involved with
- Any critical issues which the technologies must be able to address/comply with

Only the top three remaining technologies will be selected as the Realistic Technologies which will proceed to the next stage of evaluation.

4.7.1 SUSTAINABILITY SCORING

The sustainability scoring process has been performed in detail in Annexure 10 with the results provided in Table 4-12. The Social, Environmental and Economic category each have a maximum score of 30 points. The higher the overall score, the more sustainable the technology is likely to be.

Table 4-12 : Sustainability Scoring

Technology	Social Score	Enviro. Score	Econ. Score	Total Score
Waste Stabilisation Ponds (WSPo)	**24**	**24**	**30**	**78**
Settled Sewerage System (SSS)	14	12	20	46
Upflow Anaerobic Sludge Blankets (UASB)	**24**	**22**	**20**	**66**
Constructed Wetlands (CW)	**24**	**20**	**28**	**72**
Infiltration Percolation System with N-Basin	**20**	**24**	**18**	**62**
Activated Sludge Treatment (AS)	16	18	16	50
Biofiltration (Percolating filters)	16	24	18	58
Rotating Biological Contactors (Biodiscs)	22	14	18	54
Integrated Algal Pond System (IAPS)	**22**	**22**	**22**	**66**
PETRO System	14	28	18	60

The research performed by Muga et al. (2007) was used to calibrate the scoring provided above. Based on the above exercise, the top 5 technologies, ranked from best to worst, are:

1. Waste Stabilisation Ponds (WSPo)
2. Constructed Wetlands (CW)
3. Upflow Anaerobic Sludge Blankets (UASB)
4. Integrated Algal Pond System (IAPS)
5. Infiltration Percolation System with Nitrification Basin

While both the UASB and the IAPS received the same overall score, the UASB received a higher Social Score, while the IASP a higher Economic Score. It has been assumed that all aspects of sustainability carry the same weight, but should this not be the case, then the above scoring could be affected.

4.7.2 LOCAL LEGISLATIVE CONDITIONS

Based on the findings reported on in Section 4.4, the dominant technologies applied in the study area illustrated in Figure 4-17. Insufficient information is available to accurately determine these STPs' Classification (Class A, B, C, D or E as per Section 4.3), as defined by (WSAc, 2013), Based on the regulations provided in Annexure 8, it is believed the following classes apply:

- Activated Sludge: Class B / C
- Bio-filters: Class C / D
- Oxidation Ponds: Class D / E

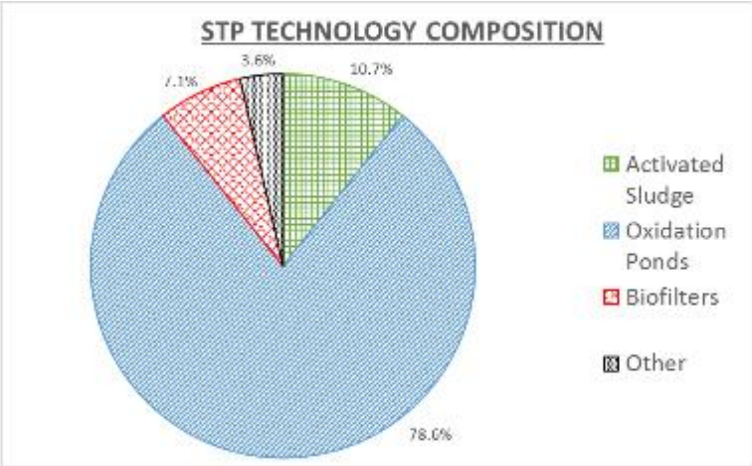


Figure 4-17 : STP Technology Composition

By applying the operational framework provided in Section 4.5 to the STP Operational Regulations (Section 4.3 and Annexure 8), the STP class for the top 5 realistic technologies are as follows:

Table 4-13 : Realistic Technology STP Classification

Technology	STP Score	STP Class
Waste Stabilisation Ponds (WSPo)	29	E
Constructed Wetlands (CW)	29	E
Upflow Anaerobic Sludge Blankets (UASB)	41	C
Integrated Algal Pond System (IAPS)	36	D
Infiltration Percolation System with Nitrification Basin	44	C

Note: Detailed calculations are provided in Annexure 11

With reference to the field investigations reported on in Section 4.4, the WSPrs in the study area are showing a preference for their supervisors to rotate between the different plants. Considering Table 4-3, this would mean only a STP classified as either a C, D or E (ie where the supervisor does not have to be on-site permanently) will be able to comply with the current technical support approach.

According to the IDP Documents for the different DMs in the study area, approximately 10% of the population older than 15 are illiterate, with only 70% of the same population group having a matric certificate. VD Merwe et al (2012) also indicated the retention of scarce skills is a major concern for adequate staffing of STPs in the Eastern Cape.

The challenge of illiteracy is being addressed through various institutions and initiatives, but this will take a while to bear fruit. In the interim, an appropriate technology needs to utilise the various resources available at present. It is thus proposed that the STP operators need to have at least a Grade 10 schooling certificate and will be able to be proficient in his duties within a period of 2 to 5 years.

Considering the educational requirements provided in Annexure 8 and qualifications and competencies proposed by the author in this section, it can be reasoned that only Class I and Class II Operators can be provided locally. This also means that only a Class D and E STP should be selected.

Assuming that the selected technologies should at least comply with a General Authorisation as detailed in the NWA, the following operational parameters can be determined in consultation with the GA:

Table 4-14 : Legislative Limitations on STP Technologies

Water Use Aspect	Legislative GA Limit[1]	Requirement for this study[2]
Irrigation of any land	2 000 kl/d[3]	500 kl/d
Discharge into a Water Resource	2 000 kl/d	500 kl/d
Storage of effluent for disposal	50 000 kl[4]	Varies[5]
Disposal of Sewage to a Pond System	1 000 kl/d	500 kl/d

Notes: 1: *The GA limits are provided in the NWA (NWA (2013))*
2: *The requirements were calculated based on the technology performance framework provided in Section 4.5*
3: *This is the maximum irrigation volume permitted within the GA. Further details on the irrigation volumes and associated effluent quality is provided in Section 2.5 and Annexure 3*
4: *This is the volume for storage in a pond system*
5: *The requirement for this study is a function of the final design, which is discussed in the Stage 2 Analysis. Different storage volumes are further discussed in Section 5.4*

The top 5 technology options all require ponds in the final treatment process. Thus by reviewing Table 4-14, it would suggest that all options comply with the GA, except when it comes to storage capacities. This issue is further discussed in Section 5.

4.7.3 STAKEHOLDER PREFERENCE

For the purpose of this evaluation, it was assumed that equal weighting is provided between social, institutional and technical issues and that each of the three areas being evaluated (Technology Preference, O&M Activities, Critical Issues) are equally important. The scoring will work as follows:

- Technology Preference: 30 points
- O&M Activities: 30 Points
- Critical Issues: 30 Points

A maximum score of 90 is thus possible, with the three technologies with the highest score advancing forward. It must be pointed out that the issue of weighting is very subjective, but still important and will be addressed as part of the Step 2 Sustainability Evaluation. The top three technologies selected in this Stage could thus be challenged and will be verified with stakeholders as part of the interview process.

Technology Preference

These technologies were listed and provided as part of a questionnaire which was issued to stakeholders for comment on and ranking. Separate questionnaires were issued to stakeholders who were either Community (Social), Technical or Institutionally orientated. Copies of the blank questionnaires are provided in Ann. 8.

The 10 possible technologies were ranked by the various stakeholders in Annexure 11, with scoring for the top 5 realistic options (Section 4.7.1) being provided in Table 4-15.

Table 4-15 : Stakeholder Technology Rank

Technology	Tech SH Rank	Instit. SH Rank	Social SH Rank	Comb. Score
Waste Stabilisation Ponds	1	1	2	26
Constructed Wetlands	3	6	2	19
Upflow Anaerobic Sludge Blankets (UASB)	7	1	2	20
Integrated Algal Pond System	5	8	8	9
Infiltration Percolation System with Nitrification Basin (IPSNB)	9	5	8	8

O&M Activities

The top six O&M activities which the stakeholders believed the community could be involved with, were identified as part of the Questionnaires and summarised in Annexure 11. The likelihood (High, Medium or Low) for the top 5 technologies to support and promote these activities, were assigned and scored. These are summarised in Table 4-16.

Table 4-16 : O&M Activity Scoring

O&M ACITIVTY	WSPo	CW	UASB	IAPS	IPSNB
Cutting of grass on embankments	H	H	H	H	H
Removal and burying of screenings	H	H	H	H	H
Routine removal of sludge from STP	L	M	M	L	L
Weed and insect control.	H	H	H	H	H
Trimming/replacement of reeds	H	H	H	H	H
Repair of damage to embankments, external fences and gates	M	M	M	M	M
TOTAL SCORE	24	26	26	24	24

Critical Issues

The top six critical issues which the preferred STP technology in the study area needs to address, were identified as part of the Questionnaires, and are summarised in Annexure 12. The likelihoods for the top 5 technologies to address these issues, were assigned and scored. These are summarised in Table 4-17.

Table 4-17 : Critical Issue Scoring

CRITICAL ISSUES	WSPo	CW	UASB	IAPS	IPSNB
Effluent quality always complies with discharge standards	M	L	H	M	H
Wastewater Treatment Works cannot easily be overloaded	H	M	M	H	M
Operation and Maintenance is easily and routinely performed	H	H	M	M	M
Job creation and skills development is possible	H	H	M	M	M
Re-use potential of effluent for agricultural purposes	H	H	H	H	H
Comprehensive financial contribution by local communities for O&M	M	H	M	M	L
TOTAL SCORE	26	24	22	22	20

Final Technology Scoring

By combining the scoring of the various aspects discussed above, the final combined scores are achieved:

Table 4-18 : Combined Realistic Technology Scoring and Ranking

Technology	Tech. Score	O&M Activity Score	Critical Issue Score	Total Score	Final Rank
Waste Stabilisation Ponds	26	24	26	76	1
Constructed Wetlands	19	26	24	69	2
Upflow Anaerobic Sludge Blankets (UASB)	20	26	22	68	3
Integrated Algal Pond System	9	24	22	55	4
Infiltration Percolation System with Nitrification Basin	8	24	20	52	5

Even though only the top 5 possible technologies were evaluated using stakeholder preferences, it is interesting to note that their ranking is in exactly the same order as what the sustainability ranking determined in Section 4.7.1.

While this does confirm some correlation of results, it must be remembered that the scoring in both exercises was mostly dependent on the author's judgement, thus some subjectivity did influence the final scoring. It would have been preferred to involve more stakeholders in the scoring process, but due to time limitations this was not possible.

4.8 SELECTION OF REALISTIC TECHNOLOGIES FOR FURTHER CONSIDERATION

With reference to Table 4-13 and Table 4-18, the following three technologies will be taken forward to the next stage of evaluation, during which the preferred technology will be selected:

- Waste Stabilisation Ponds
- Constructed Wetlands
- Integrated Algal Pond System (IAPS)

While the Upflow Anaerobic Sludge Blanket (UASB) had a better ranking than the IAPS, the UASB had a more complex STP Classification (Class C - Table 4-13), requiring operating staff who cannot easily be sourced from the local community, and so not making it viable. The IAPS is a Class D STP with staffing requirements which can be more easily sourced from the local community.

These technologies all have similar attributes to those already being applied in the Study Area, thus the author is of the opinion that the WSPr should be able to adapt easily to the technology.

4.9 SECTION SUMMARY

In Section 4.2, the level of service in the study area was confirmed as being much lower than what the DWS database suggested in Section 2.3. Major infrastructure investment will be required to establish flushing toilets in the study area. The average size of rural villages, and their geographic distribution were also determined. This is required to determine the size of STPs in the study area. This assisted in answering research questions 6 and 10.

Through Sections 4.3 to 4.6, the type of STP technology applied in the study area has been determined and a better understanding was developed into how it must comply to local legislation. In general STPs are not complying with the effluent discharge standards and staffing requirements. There is also a preference for senior support staff (Supervisors and specialist maintenance), to be provided from a central location to all surrounding STPs, with daily activities being addressed by local teams. It was also identified that oxidation ponds are the dominant technology currently being applied. This assisted in answering research questions 1, 4, 5 and 8.

A first-round sustainability ranking was performed in Section 4.7 to identify the top five realistic technologies. By evaluating these technologies using local legislation and preferences, they were further reduced to only three technologies for further evaluation in Section 5 & 6. The three technologies are:

- Waste Stabilisation Ponds
- Constructed Wetlands
- Integrated Algal Pond System (IAPS)

This assisted in answering research questions 1, 4, 6 and 10. The table below summarises which sections have assisted in answering which research questions:

Table 4-19 : Section Question and Research Question Correlation

RESEARCH QUESTIONS	SECTION REFERENCE						
	Section 4.2	Section 4.3	Section 4.4	Section 4.5	Section 4.6	Section 4.7	Section 4.8
1. What low-technology wastewater treatment options are available?		X	X		X	X	X
4. Are there any success stories for these treatment options? (Local and/or International)		X	X		X	X	
5. Why is the DWA so resistant to permitting high-volume low technologies to be used?		X	X				
6. What community challenges are likely to be experienced in operating wastewater treatment works?	X					X	
8. What risks exist to the South African policies if high volume low technology options are used?		X	X	X			
10. How will the community benefit from the selected technology? (e.g. involvement in O&M and agricultural re-use of effluent)	X				X	X	

5. STAGE 2 ANALYSIS: PERFORMANCE COMPARISON OF REALISTIC OPTIONS

5.1 SECTION INTRODUCTION

In this section, the performance of the three realistic options will be evaluated and compared to each other. The main focus will be on Technical, Institutional and Financial aspects, using a standard set of criteria for comparative purposes.

Operation and maintenance aspects will be given attention as well as what level of staffing each of the technologies will be required to be operated effectively. An economic performance evaluation over the entire lifecycle of the STP will also be performed and the Net Present Values (NPV) of these technologies compared.

This performance evaluation is important as it will assist in developing the context within which the Stage 3 Analysis (Challenges and Solutions) will be constructed.

5.2 COMPLIANCE CRITERIA DESCRIPTION

In order to compare the technologies on an equitable basis, the following criteria will be used to conceptualise the technologies and evaluate their performance:

Table 5-1 : Compliance Criteria

CRITERIA	DESCRIPTION
Raw Sewage Composition	As per Table 5-2.
Population Size	5 780 (Section 4.5)
Per Capita Water Demand	75 l/c/d (Section 4.5 and Cotton(2011))
Wet Weather Infiltration Rate	15%
Mean Annual Evaporation	1278mm/a
Mean air temp of coldest month.	23 degrees Celsius
STP Design Guidelines / Principles	Freese and Nozaic (2009) will form the basis of all designs, supplemented with information from Mara (2003) and Smith (2011).
Facility Staffing Requirements	Should at least comply with DWS requirements (WSAc 2013(2)). Also refer to Section 4.3 and Annexure 8.
Sludge Disposal	Burying close-by STP, or use in local agricultural activities (Fodder Grass / Maize). According to "Guidelines for the Utilisation and Disposal of Wastewater Sludge" Volumes 2&3. (Herselman and Snyman (2006) and Herselman and Snyman (2009)).
Effluent Quality	Two options will be considered: ➢ Quality to comply with irrigation up to 500kl/d (NWA(2013)) ➢ Quality to comply with disposal to a Water Resource according to the DWS General Standards (NWA(2013))

Freese and Nozaic (2009) recommends a higher sewer strength for lower income areas. Their recommended design loads were compared with the recommendations provided by Smith (2011) to develop the design loads for this study. These are summarised in Table 5-2.

Table 5-2 : Raw Sewage Design Loads

Sewage Characteristic	Design Loads
BOD	50 g/person.d
COD	100 g/person.d
Settleable Solids	60 g/person.d
Suspended Solids	30 g/person.d
Nitrogen*	7.5 g/person.d
Ammonia (NH_4^+ – N)	15 g/person.d
Phosphate (P)	4 g/person.d
Thermotolerant Coliforms	5.8 x 10^6 FC/person.d
Helminth Eggs*	1000 Eggs/Litre

*(Table Source: Freese and Nozaic (2009), where indicated with * it was assumed)*

5.3 TREATMENT PROCESS DESCRIPTIONS FOR REALISTIC OPTIONS

The general treatment processes for each of the technologies, as prescribed in Table 5-1, is illustrated below:

Table 5-3 : Waste Stabilisation Pond Process Description

WASTE STABILISATION PONDS

Process Flow Diagram:

INLET WORKS	ANAEROBIC POND	FACULTATIVE PONDS	MATURATION PONDS
Treatment Stage & Type:			
Preliminary Stage Physical Treatment	Primary Stage Physical Treatment Secondary Stage Biological Treatment	Secondary Stage Biological Treatment	Tertiary Stage Biological Treatment
Additional Notes:			
Manual Screens with degritting channels important	Settlement of sludge and suspended solids occur. Some BOD removal also occurs. Routine desludging is important	BOD and nutrient removal removal occurs. Routine desludging is important	Pathogen removal occurs. No chemical disinfection required. Effluent to be discharged to either rivers or used for irrigation

(Table Source: Freese and Nozaic (2009) and Smith (2011), with photos provided by author)

Table 5-4 : Constructed Wetland Process Description

CONSTRUCTED WETLANDS

Process Flow Diagram:

INLET WORKS	ANAEROBIC POND	ARTIFICAL WETLANDS	MATURATION PONDS
Treatment Stage & Type:			
Preliminary Stage Physical Treatment	Primary Stage Physical Treatment Secondary Stage Biological Treatment	Secondary Stage Biological Treatment	Tertiary/Optional Stage Biological Treatment
Additional Notes:			
Manual Screens with degritting channels important	Settlement of sludge and suspended solids occur. Some BOD removal also occurs. Routine desludging is important	BOD, nutrient and Pathogen removal occurs. Plant-care is important	Pathogen removal occurs. No chemical disinfection required. Effluent to be discharged to either rivers or used for irrigation

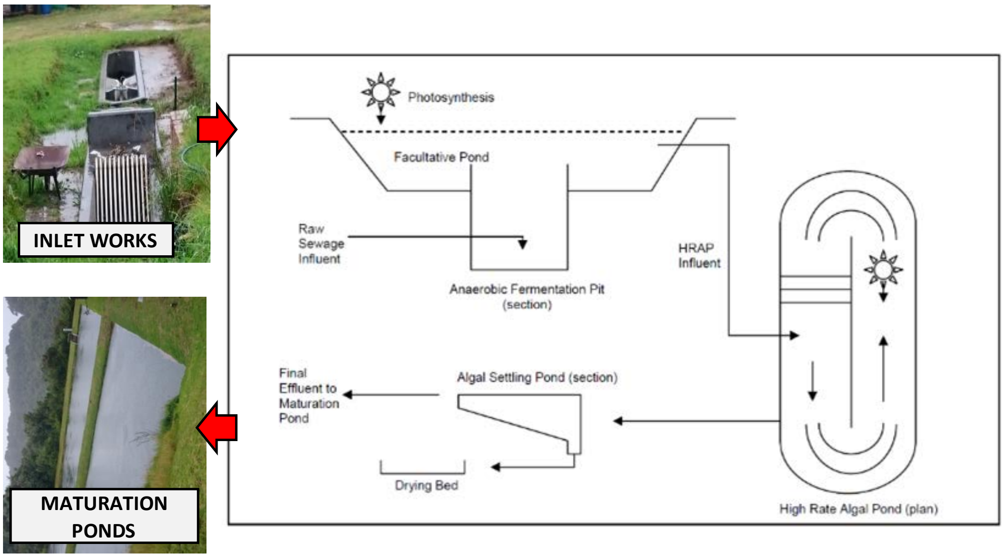
(Table Source: Freese and Nozaic (2009) and Smith (2011), with photos provided by author and Freese and Nozaic (2009))

For all components of the various STP processes, the number of each of these components are a function of the required final effluent as well as the degree of safety that needs to be built into the STP in the event of component failure / maintenance.

Table 5-5 : IAPS Process Description

INTEGRATED ALGAL POND SYSTEM

Process Flow Diagram:



INLET WORKS	FACULTATIVE POND WITH ANAEROBIC PIT	HIGH RATE ALGAL POND	ALGAL SETTLING POND AND DRYING BEDS	MATURATION PONDS
Treatment Stage & Type:				
Preliminary Stage Physical Treatment	Primary Stage Physical Treatment Secondary Stage Biological Treatment	Secondary Stage Biological Treatment	Tertiary Stage Physical Treatment	Tertiary Stage Biological Treatment
Additional Notes:				
Manual Screens with degritting channels important	Settlement of sludge and suspended solids occur. BOD and nutrient removal also occurs. Routine desludging is important	BOD and nutrient removal removal occurs.	Algae removed to drying beds	Pathogen removal occurs. No chemical disinfection required. Effluent to be discharged to either rivers or used for irrigation

(Table Source: Wells et al. (nd) and Mara (2003), with photos provided by author and Wells et al. (nd))

5.4 PHYSICAL DESIGN CONSIDERATIONS

The following main design aspects can influence the suitability of the realistic technologies for the study area:

- Electricity requirements
- Construction Materials
- STP Footprint (Land Area)

Electricity Requirements

The dependable supply of sufficient electricity can influence the selection of the preferred technology. The electricity requirements for the three technologies are compared below:

Table 5-6 : Preferred Technology Electricity Requirements

Aspect	WSPo	CW	IAPS
Flow Meters	<0.1kWh (Can run off 24V battery for four years)	<0.1kWh (Can run off 24V battery for four years)	<0.1kWh (Can run off 24V battery for four years)
Other	None	None	1kWh Paddlewheel

While a 1kWh paddlewheel could be powered by solar energy, it is the author's experience that solar panels are stolen in the study area and should the paddlewheel fail, the entire process halts. Thus a constant grid-supply is recommended.

Construction Materials

Considering the process descriptions provided in Section 5.3, Table 5-7 provides a summary of the prominent construction materials required and also indicates which can easily be provided by the local community.

Table 5-7 : Preferred Technology Construction Materials

STP Component	Material	WSPo	CW	IAPS
Inlet Works	Concrete	✓	✓	✓
	Steel Screen	✓	✓	✓
	Connecting pipes	✓	✓	✓
All Ponds	Earth Pond	✓ L	✓ L	✓ L
	HDPE Pond Lining	✓	✓	✓
	Overflow chambers	✓	✓	✓
	Connecting Pipes	✓	✓	✓
Artificial Wetland	Earth Pond	n/a	✓ L	n/a
	HDPE Pond Lining	n/a	✓	n/a
	Gravel Growth Medium	n/a	✓	n/a
	Connecting Pipes	n/a	✓	n/a
	Wetland Plants	n/a	✓	n/a
High Rate Algal Pond	Concrete Structure	n/a	n/a	✓
	Mechanical Paddle Wheel	n/a	n/a	✓
	Connecting Pipes	n/a	n/a	✓

Notes: *"✓" – Material required for technology*
"n/a" – Does not apply to technology
"L" – Material can be provided by local community

From Table 5-7, it can be seen that very little material can be provided by the local community. The author's experience of the study area is that in some instances there are local brick makers in the rural villages, from whom bricks can be purchased for the construction of the inlet works and overflow chambers. It is however recommended that the HRAP still be constructed using commercial bricks and concrete due to the specialised nature of the component and that it should be constructed as a watertight structure. Local labour can be utilised for all components.

It is not sure if the wetland plants can be sourced locally and this should be evaluated on a case-by-case scenario.

The use of local resources is thus maximised by the WSPo system, followed by the CW and then the IAPS.

STP Footprint (Land Area)

The footprint area of the three technologies were calculated based on Table 5-1 and Table 5-2 above, for the following three scenarios:

- Scenario 01: Compliance with NWA General Effluent Standards to discharge effluent to a water resource
- Scenario 02: Reduced Effluent Quality is acceptable, provided that the following Scenario 01 limits are still achieved:
  - Thermotolerant Coliforms
  - Chemical Oxygen Demand
  - Helminth Eggs
- Scenario 03: Compliance with NWA General Effluent Standards to irrigate up to 500kl/d

For all three scenarios, the land area was increased by 25% to allow for site access, pipework and ancillaries (Mara, 2003). Table 5-8, Table 5-9 and Table 5-10 below summarises the results of the calculations, with Annexure 17 providing detailed calculations. The matter of effluent quality is separately discussed in Section 5.7.

Table 5-8 : STP Land Requirements - Scenario 01

	WSPo	CW	IAPS
Components in Series[1]	6 (1An–1SF–4MP)	6 (1An–1CW–4MP)	9 (1PFF–2HRAP–2ASP-4MP)
Parallel flow streams	2	2	2
Total Retention Time (days)	340	280	118
Total Storage Volume (m3)	119 236	102 817	50 507.37
Required Land Area (ha)	15.2	13.5	8.2
Required Land Area per person (m2/person)	26.35	23.33	14.14
Relative land use (% of max)	100%	89%	54%
Land Use Ranking	3	2	1

(Table Notes: 1: An = Anaerobic Pond; SF = Secondary Facultative Pond; MP = Maturation Pond; CW = Constructed Wetland; HRAP = High Rate Algal Pond; ASP = Algal Settling Pond; PFF = Primary Facultative Pond with Fermenting Pit; Component Description Example: "1An = 1No Anaerobic Pond")

From the above three technologies, only the IAPS can provide a compliant effluent. The IAPS also requires about 54% of the land area required by the WSPo.

For all three options the required land to provide effluent to an acceptable quality is quite expansive and can make these options not viable. In order to make these options more viable, the required land area needs to reduce and this can only be done by relaxing the required effluent standards, or treating a weaker raw sewage (influent).

Table 5-9 : STP Land Requirements - Scenario 02

	WSPo	CW	IAPS
Components in Series[1]	5 (1An–1SF–3MP)	5 (1An–1CW–3MP)	5 (1PFF–1HRAP–1ASP-2MP)
Parallel flow streams	2	2	2
Total Retention Time (days)	36	22	35
Total Storage Volume (m3)	17 442	14 226	16 723
Required Land Area (ha)	3.1	3.2	3.1
Required Land Area per person (m2/person)	5.43	5.58	5.36
Relative land use (% of max)	97%	100%	96%
Land Use Ranking	2	3	1

(Table Notes: 1: *An = Anaerobic Pond* *SF = Secondary Facultative Pond*
MP = Maturation Pond *CW = Constructed Wetland*
HRAP = High Rate Algal Pond *ASP = Algal Settling Pond*
PFF = Primary Facultative Pond with Fermenting Pit

For Scenario 02, it can be seen that all three technologies require approximately the same area of land. The required land area has reduced significantly from Scenario 01 after Phosphorous and Ammonium compliance limits were omitted.

Table 5-10 : STP Land Requirements - Scenario 03

	WSPo	CW	IAPS
Components in Series	3 (1An–1SF–1MP)	3 (1An–1CW–1MP)	5 (1PFF–1HRAP–1ASP-2MP)
Parallel flow streams	2	2	2
Total Retention Time (days)	28	9	31
Total Storage Volume (m3)	13 444	4 474	14 723
Required Land Area (ha)	2.3	1.5	2.6
Required Land Area per person (m2/person)	3.89	2.66	4.46
Relative land use (% of max)	87%	60%	100%
Land Use Ranking	2	1	3

(Table Notes: 1: *An = Anaerobic Pond* *SF = Secondary Facultative Pond*
MP = Maturation Pond *CW = Constructed Wetland*
HRAP = High Rate Algal Pond *ASP = Algal Settling Pond*
PFF = Primary Facultative Pond with Fermenting Pit

By evaluating Scenario 03, there has been a significant reduction in the land requirements for CW, while only a marginal reduction in the areas required for WSPo and IAPS has been required. The IAPS is now also the technology with the largest land requirement which is exactly the opposite than what was seen in Scenario 01.

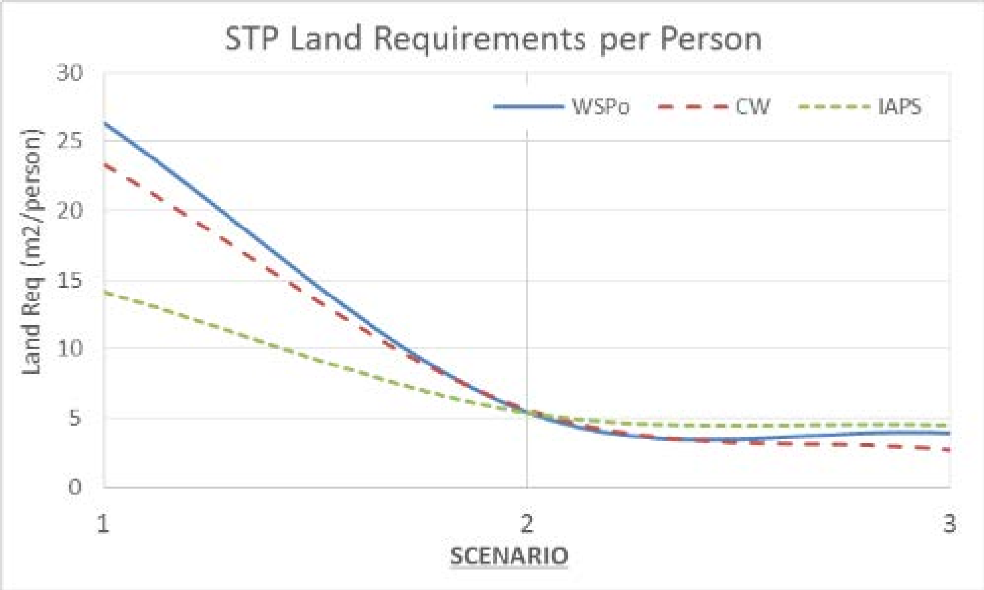


Figure 5-1 : STP Land Requirement Comparison

5.5 STAFFING REQUIREMENTS

Considering the STP Classification and Staffing requirements described in Section 4.3 and Annexure 8, each of the realistic STP Technologies can be classified as follows:

Table 5-11 : STP Classification and Senior Staff Levels

Technology	STP Class	Process Controller Class per Shift	Supervisor Class	Schooling Requirement
WSPo	E	Class I	Class V*	Grade 10**
CW	E	Class I	Class V*	Grade 10**
IAPS	D	Class II	Class V*	Grade 12**

**does not have to be at the works at all times but must be available at all times.*
***Additional schooling requirements are provided in Annexure 8*

Considering the organisational structure and preferred maintenance methods currently being employed in the Study Area (Section 4.4), the support structure is proposed for the implementation of STPs in the study area are illustrated in Figure 5-2

Each Supervisor will be responsible for a maximum of 7 STPs. Each STP will have a Senior Plant Process Controller and further local supporting staff. The size of the supporting staff is a function of the type of technology. Due to the remote locations of the STP and potential lack of electricity at the STPs, effluent samples will be taken to a central laboratory where the testing needs to be done. DWS requires effluent sampling to be performed once a month.

While general maintenance can be performed by the local team, more specialised maintenance (eg. mowing of lawn, M&E repairs), will be performed by a central maintenance team that rotates between the various STPs.

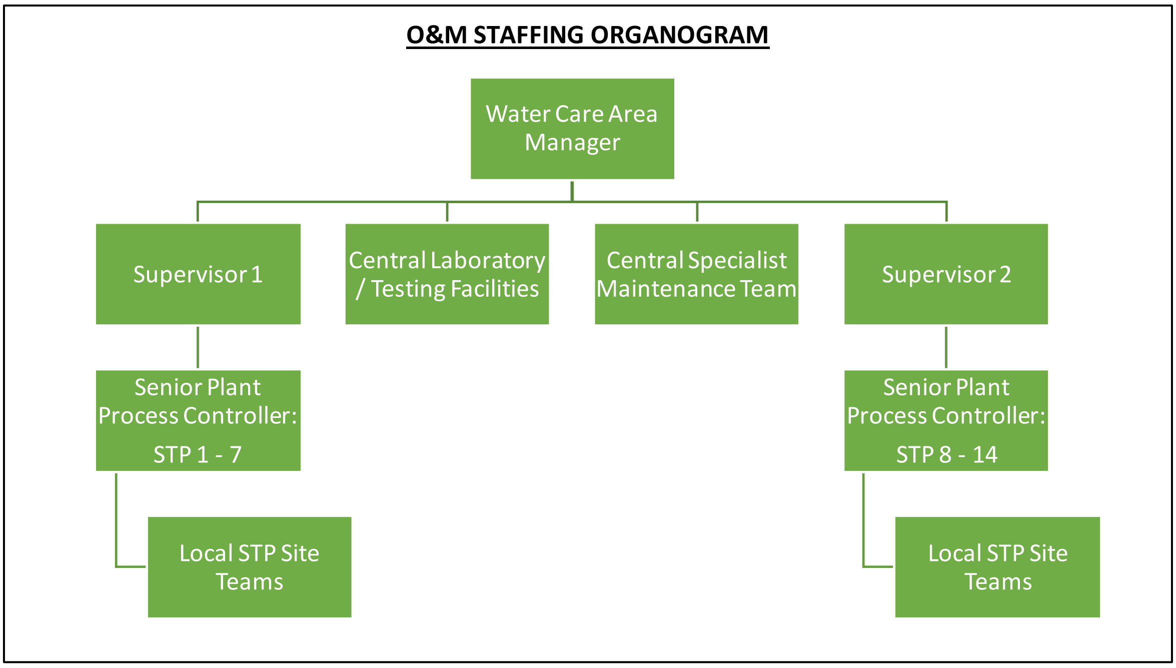


Figure 5-2 : Proposed O&M Staffing Organogram

Table 5-12 : Local Staffing Requirements

Staffing Description	WSPo	CW	IAPS
Day Shift?	Y	Y	Y
Night Shift?	N/A	N/A	Y
Shift Length (h)	12	12	12
Process Controller – Senior (PCs)	2 *(Rotating on / off duty)*	2 *(Rotating on / off duty)*	3 *(Rotating day / night and one off duty)*
Process Controller – Trainee (PCt)	0	0	2 (Rotating on / off duty)
General Maintenance Team (GM)	1	1	2
Security Staff (S)	N/A	N/A	3 *(Rotating day / night and one off duty)*
Staff per Day Shift	2 *(1 x PCs, 1 x GM)*	2 *(1 x PCs, 1 x GM)*	5 *(1 x PCs, 1 x PCt, 2 x GM, 1 x S)*
Staff per Night Shift	N/A	N/A	2 *(1 x PCs, 1 x S)*
Total Local Staff per STP	3	3	10

(*Table Source: Compiled by Author based on information provided in Mara(2003) and NWA(1985)*)

Staffing requirements per STP is summarised in Table 5-12 and in the following list:

- The IAPS requires a night shift and security due to the presence and continuous operation of the Mechanical and Electrical components.
- Trainee Operators and General Maintenance Teams only work during the day shift
- It is assumed that every central laboratory staff member will be able to process one new STP Effluent sample per day, for every day of the month.
- It is also assumed that a a 3-man Central Maintenance crew does two STPs per day, for every day of the month

With reference to the above staffing considerations, Annexure 18 provides a detailed calculation of all additional staff required in the study area. Figure 5-3 illustrates the total additional local and centralised staff required to implement each of the three STP technologies:

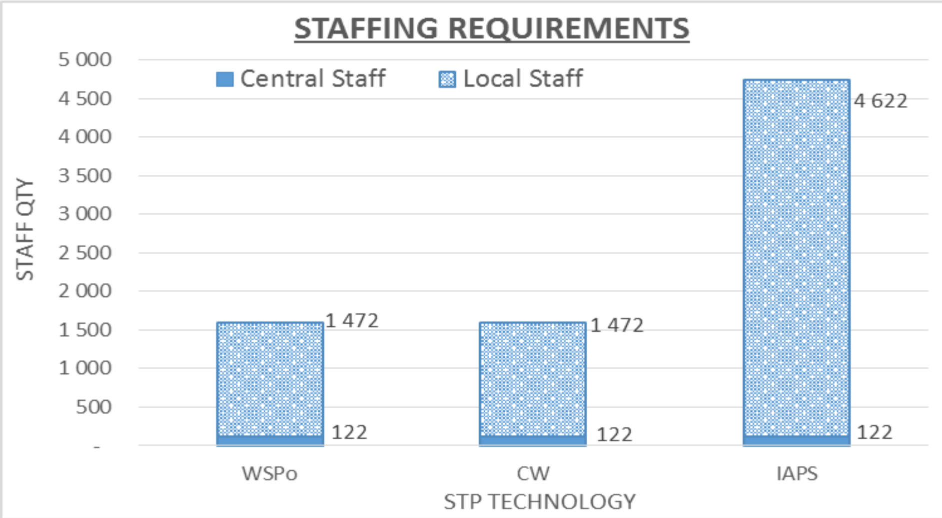


Figure 5-3 : Additional Staffing Requirements

For the purpose of this study it was assumed that irrespective of what the final effluent quality needs to be, the staffing requirements will not change for the different technology options. The author wishes to point out that should significant changes to land area occur, the workload on operators and maintenance teams can also increase / decrease and a change to the team size might have to be considered.

Based on Figure 5-3, it can be seen that while both the WSPo and CW has the same staff requirements, the IAPS requires approximately three times more local staff. While this could be seen as maximising local job creation, this will also increase the financial strain on the WSP by a factor of three compared to the other two STPs. One of the main reasons for the high staff requirement at the IAPS is because the technology requires a full-time presence, while for the other technologies a smaller team with no night shift is required. For all three technologies, the central staff requirements are the same.

5.6 OPERATION AND MAINTENANCE REQUIREMENTS

Operation and Maintenance (O&M) requirements are comprised of either activities unique to the technology (eg. algal removal/harvesting from IAPS) or those applicable to all technologies (eg. Effluent sampling as per legislative requirements). O&M activities are scheduled according to the following recurrence intervals/periods:

- Daily (D)
- Weekly (W)
- Monthly (M)
- Semi-Annually (S-An)
- Annually (An)
- Other (longer than annual, eg desludging of ponds every 3 – 5 years)

O&M Activities are also executed by different team members, depending on the content and technical diffulty of the activities. Team members responsible for the various O&M activities have been defined in Section 5.5 and are summarised below:

- Plant Process Controllers (PC): Either Senior or Trainee
- General Maintenance (GM): Locally based
- Specialist Maintenance (SM): Centrally based and rotates between STPs
- Supervisors (S): Centrally based and rotates between STPs

A detailed list of O&M Activities, assigned to different team members at different recurrence intervals are provided in Annexure 18. Figure 5-4 indicates the distribution of activities between the various team members:

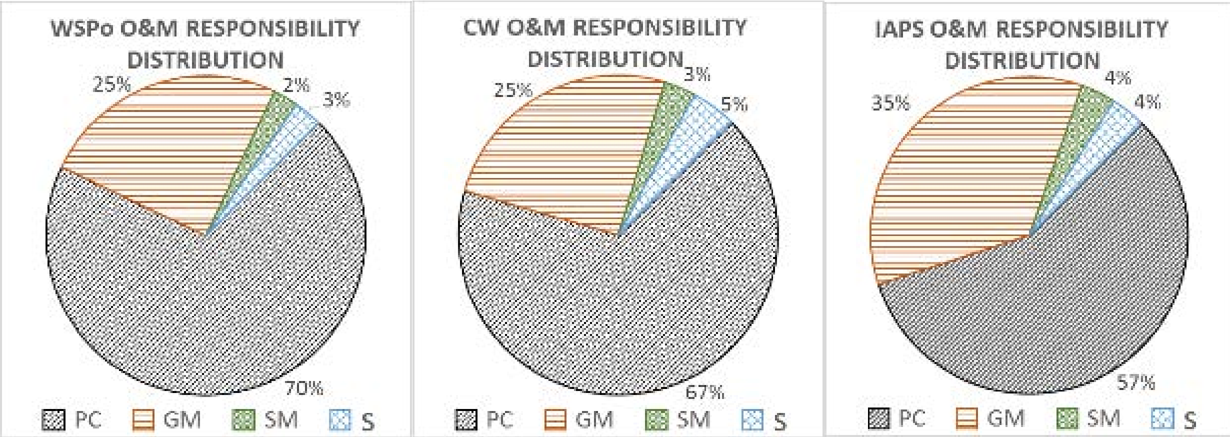


Figure 5-4 : O&M Responsibility Distribution

Figure 5-4 shows that for all three technologies, most of the activities will be performed by the local team, with WSPo having the highest local team involvement fraction at 95%. The O&M activities are further illustrated in Figure 5-5, which also shows the total number of activities which will occur over a 5-year period (ie. when at least one pond desludging has occurred).

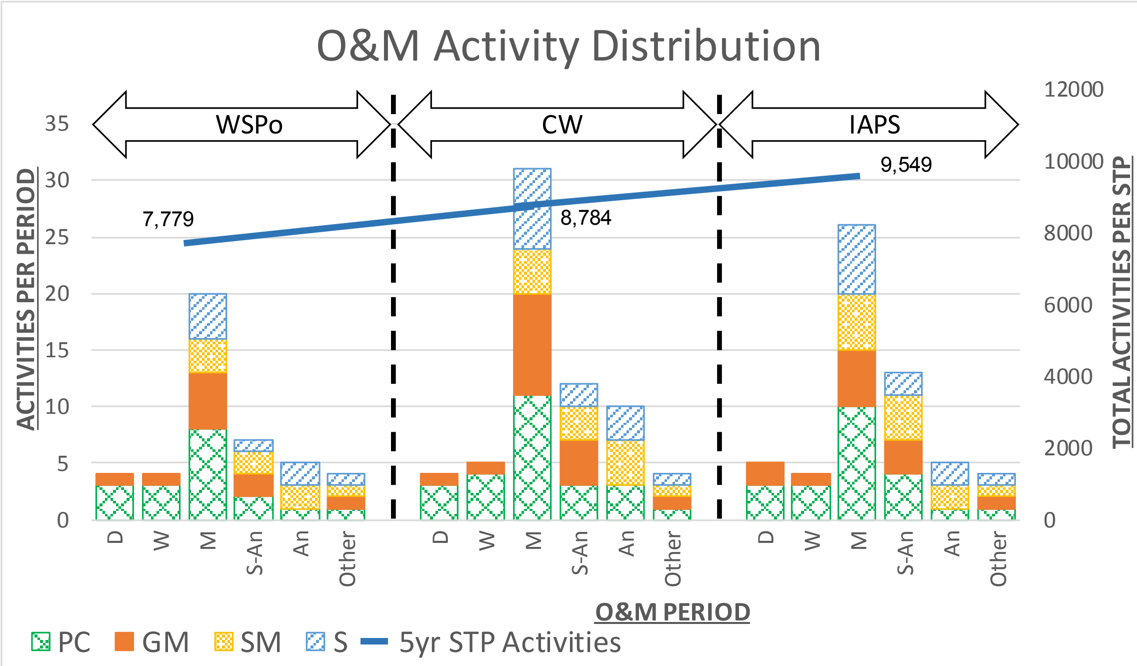


Figure 5-5 : O&M Activity Distribution

From Figure 5-5 it can be seen that the WSPo has the lowest over-all activities and also the lowest per recurrence interval. The IAPS has the most activities and is 22% more than for the WSPo. For all three technologies it can be seen that all activities occurring within a month can be performed by the local team, with the off-site team only required to visit the site once a month. It is interesting to note that the CW has the highest monthly activity requirements.

In order to accurately determine the workload on the staff, the intensity and time requirement for each of the technologies needs to be determined first. This is however not possible within the context of this study and should be considered for future research. In order to perform a first round evaluation of the intensity and efficiency of the staff to perform the O&M activities, the O&M activities that the local staff can perform, was compared with the size of the local team. This is summarised in Table 5-13.

Table 5-13 : O&M Activity intensity

Description	WSPo	CW	IAPS
Local Activities	1,850	2,006	2,257
Local Staff	3	3	7
Annual Activities / staff member	617	669	322
Daily Activities / staff member	1.7	1.8	0.9

From Table 5-13 it would appear that the staff utilisation intensity of both the WSPo and CW is the same, the intensity for the IAPS is approximately 50% of them. This would suggest that staff employed on an IAPS will not be used as cost efficiently than for the other technologies.

5.7 TREATMENT END-PRODUCT EVALUATION

All three STP technologies will provide treated effluent and sludge as end-products. Depending on the quality of these products, different applications for them exist. The IAPS system also provides algae as a by-product which can be used for cattle feed, bio-gas production and even bio-fuel. Campbell et al. (2003)

TREATED SEWAGE EFFLUENT (TSE)

For this study, it is assumed that the TSE must either comply with the NWA General Discharge Standards for discharging into a water resource, or for the related standards to irrigate with the TSE up to 500kl/d. During an interview with a Stakeholder, it was recommended to provide a livestock drinking trough outside of the STP facility. This will help prevent livestock from entering the STP site. It has been reported in the past that livestock entering the STP premises looking for water, either puncture the pond linings when walking into the ponds, or drown within the sewage.

Effluent quality will thus be evaluated against the National Water Act General Dsicharge Standards (NWA 2013), the "South African Water Quality Guidelines Volume 4 Agricultural Use: Irrigation" (DWAF 1996) and the "South African Water Quality Guidelines Volume 5 Agricultural Use: Livestock Watering" (DWAF 1996(2)). Based on the sewage characteristics provided in Table 5-2, only certain parameters will be reported on, as summarised in Table 5-14 below:

Table 5-14 : Effluent Standards

Sewage Characteristic	Unit	Discharge to Water Resource[1]	Irrigation up to 500 kl/d[1]	Water for Agricultural Irrigation[2]	Water for Livestock[3]
BOD (filtered)	mg/l	37.5	200	n.s	n.s
COD	mg/l	75	400	n.s	n.s
Organic Nitrogen*	mg/l	15	n.s	< 30	< 100
Ammonia (NH_4^+ – N)	mg/l	6	n.s	n.s	n.s
Phosphate (P)	mg/l	10	n.s	n.s	n.s
Thermotolerant Coliforms	FC /100ml	1.00E+03	1.00E+05	< 1	< 1000
Helminth Eggs[4]	Eggs/ litre	< 0.1	< 0.1	n.s	n.s

(Table Notes: 1: NWA (2013) 2: DWAF (1996)
3: DWAF (1996(2)) 4: Assumed, based on Smith(2011)
"n.s" = Not Specified

Table 5-15 compare the effluent quality from the three STP technologies in operation globally with the effluent standards provided in Table 5-14. Where information was available, the required STP area per PE was also included for comparative purposes.

The author wishes to point out that this comparison is just indicative of what effluent qualities are achieved globally using these technologies. No guarantee can be provided that the same results can be replicated in South Africa, since the effluent quality is a function of:

- Local Climatology
- Raw Sewage Composition
- STP Design
- Land Availability
- STP Operations

From Table 5-16, Table 5-17 and Table 5-18, the following conclusions can be drawn:

- It is difficult to draw comprehensive conclusions since there are very few overlapping parameters tested to draw a comparison with
- Land area requirements vary widely, but in general more land is required to provide a better quality effluent
- Land area requirement is also a function of the quality of the influent and what pre-treatment has already been performed
- Almost all of the STPs are non-compliant when effluent quality is compared against the NWA General Discharge Standards for Water Resources (“River”, NWA 2013)
- Almost all of the STPs are compliant when effluent quality is compared against the NWA General Irrigation Standards up to 500kl/d (“Irrig.”, NWA 2013)
- In almost all cases, the STP Raw Sewage (Influent) was much weaker than what is designed for in this study and in some cases very close to the required effluent discharge standards already.
- Based on available information no STP complied with the Agricultural Irrigation guidelines (“Agrig.”, DWAF 1996) due to the stringent Thermotolerant Coliform parameter.

In order to compare the three STP technologies on a comparative basis, each STP was designed based on the same parameters, as provided in Section 5.2. The design was performed for each of the three scenarios described in Section 5.4. The results are summarised in Table 5-18, with the detailed calculations provided in Annexure 17.

Table 5-15 : WSPo Effluent Quality from Global STPs

Sewage Characteristic	Unit	Design Raw Sewage	Effluent Standards				Mburu et al. (2009)		Bouza-Deano et al. (2012)		Ensink et al. (2007)		Mara (2006)	
			River[1]	Irrig.[2]	Agrig.[3]	Cattle[4]	Infl.[5]	Effl.[6]	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
BOD (filtered)	mg/l	580	37.5	200	n.s	n.s	232	20	471	94	394	110	NI[7]	10
COD	mg/l	1159	75	400	n.s	n.s	424	100	904	226	NI	NI	NI	NI
Nitrogen	mg/l	87	15	n.s	< 30	< 100	NI	NI	NI	NI	NI	NI	NI	NI
Ammonia (NH4+ – N)	mg/l	174	6	n.s	n.s	n.s	39	17	86	43	NI	NI	NI	5
Phosphate (P)	mg/l	46	10	n.s	n.s	n.s	4	3	40	22	6	4	NI	NI
Thermotolerant Coliforms	FC/ 100ml	4.00 E+07	1.00 E+03	1.00 E+05	< 1	< 1.00 E+03	NI	NI	NI	NI	2.00 E+07	1.00 E+04	NI	NI
Required Area	m^2/PE	n/a	n/a	n/a	n/a	n/a		8.3		1.0		2.0		4.85

Table Notes: 1: NWA General Discharge Standard to Water Resources (NWA 2013) 2: NWA General Irrigation Standard up to 500 kl/d (NWA 2013)
3: Water Quality Policy for Agricultural Irrigation (DWAF 1996) 4: Water Quality Policy for Agricultural Irrigation (DWAF 1996(2))
5: "Infl." = Influent Constituents 6: "Effl." = TSE Constituents
7: "NI" = No Information

Table 5-16 : CW Effluent Quality from Global STPs

Sewage Characteristic	Unit	Design Raw Sewage	Effluent Standards				Mburu et al. (2009)		Mara (2006)		Rousseau et al. (2005)	
			River	Irrig.	Agrig.	Cattle	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
BOD (filtered)	mg/l	580	37.5	200	n.s	n.s	232	29	NI	10	73.7	1.8
COD	mg/l	1159	75	400	n.s	n.s	424	58	NI	NI	NI	NI
Organic Nitrogen	mg/l	87	15	n.s	< 30	< 100	NI	NI	NI	NI	0.9	1.1
Ammonia (NH4+ – N)	mg/l	174	6	n.s	n.s	n.s	39	36	NI	5	21.7	5.7
Phosphate (P)	mg/l	46	10	n.s	n.s	n.s	4	3	NI	NI	6.70	2.7
Thermotolerant Coliforms	FC/ 100ml	4.00 E+07	1.00 E+03	1.00 E+05	< 1	< 1.00 E+03	NI	NI	NI	NI	NI	NI
Required Area	m^2/PE	n/a	n/a	n/a	n/a	n/a		3.4		28		7.5

Table 5-17 : IAPS Effluent Quality from Global STPs

Sewage Characteristic	Unit	Design Raw Sewage	Effluent Standards				El Hamouri (2012)				Wells et al. (nd)		Campbell et al. (2003)	
							No MP[1]		With MP					
			River	Irrig.	Agrig.	Cattle	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
BOD (filtered)	mg/l	580	37.5	200	n.s	n.s	45	35.0	45	25.0	NI	NI	116	61.5
COD	mg/l	1159	75	400	n.s	n.s	110	250.0	110	170.0	1162	151	NI	NI
Organic Nitrogen	mg/l	87	15	n.s	< 30	< 100	NI	NI	NI	NI	8	9.4	NI	NI
Ammonia (NH4+ – N)	mg/l	174	6	n.s	n.s	n.s	NI	NI	NI	NI	19	1.8	24	8.6
Phosphate (P)	mg/l	46	10	n.s	n.s	n.s	7.5	2.7	7.5	2.4	16.6	5.3	1.9	1.5
Thermotolerant Coliforms	FC/ 100ml	4.00 E+07	1.00 E+03	1.00 E+05	< 1	< 1.00 E+03	4.6 E+05	2.7 E+04	4.6 E+05	2.4 E+03	2.0 E+06	8.0 E+02	1.6 E+06	1.2 E+04
Required Area	m^2/PE	n/a	n/a	n/a	n/a	n/a		2.5		NI		18		4.5

Table Notes: 1: El Hamouri (2012) evaluated the performance of an IAPS with and without the inclusion of a Maturation Pond (MP)

Table 5-18 : STP Effluent Comparison

Sewage Characteristic	Unit	Design Raw Sewage	Effluent Standards				Scenario 01[1]			Scenario 02[1]			Scenario 03		
			River	Irrig.	Agrig.	Cattle	WSPo	CW	IAPS	WSPo	CW	IAPS	WSPo	CW	IAPS
BOD (filtered)	mg/l	580	37.5	200	n.s	n.s	0.01	0.03	0.15	3.4	13.5	2.4	4.8	71.0	2.9
COD[1]	mg/l	1159	75	400	n.s	n.s	0.2	0.06	3.1	67.2	27	47.2	116.2	142.0	58.2
Nitrogen (N)	mg/l	87	15	n.s	< 30	< 100	0.9	0.9	6.2	12.2	12.1	**29.3**	19.3	42.0	46.8
Ammonia (NH4+ – N)	mg/l	174	6	n.s	n.s	n.s	5.5	5.8	5.7	**109.4**	**83.7**	**54.1**	117.2	130	58.8
Phosphate (P)	mg/l	46	10	n.s	n.s	n.s	**23.2**	**23.2**	7.5	**23.3**	**23.7**	**17.3**	23.4	25.7	17.3
Thermotolerant Coliforms	FC/ 100ml	4.00 E+07	1.00 E+03	1.00 E+05	< 1	< 1.00 E+03	2.95 E-22	4.01 E-18	4.47 E-08	5.10 E+02	9.96 E+01	7.82 E+02	3.89 E+04	8.15 E+04	6.13 E+03
Helminth Eggs	Eggs/ litre	1 000	< 0.1	< 0.1	< 1	n.s	0	0	7.33 E-16	1.19 E-05	9.99 E-06	3.04 E-05	2.43 E-03	4.7 E-03	1.00 E-03
Required Area	m^2/PE	n/a	n/a	n/a	n/a	n/a	26.4	23.3	14.1	5.4	5.6	5.4	3.9	2.7	4.5

Table Notes: 1: **Bold** items failed to comply with NWA General Discharge Standards to Water Resources ("River"). Only applicable to Scenario 01 & 02.

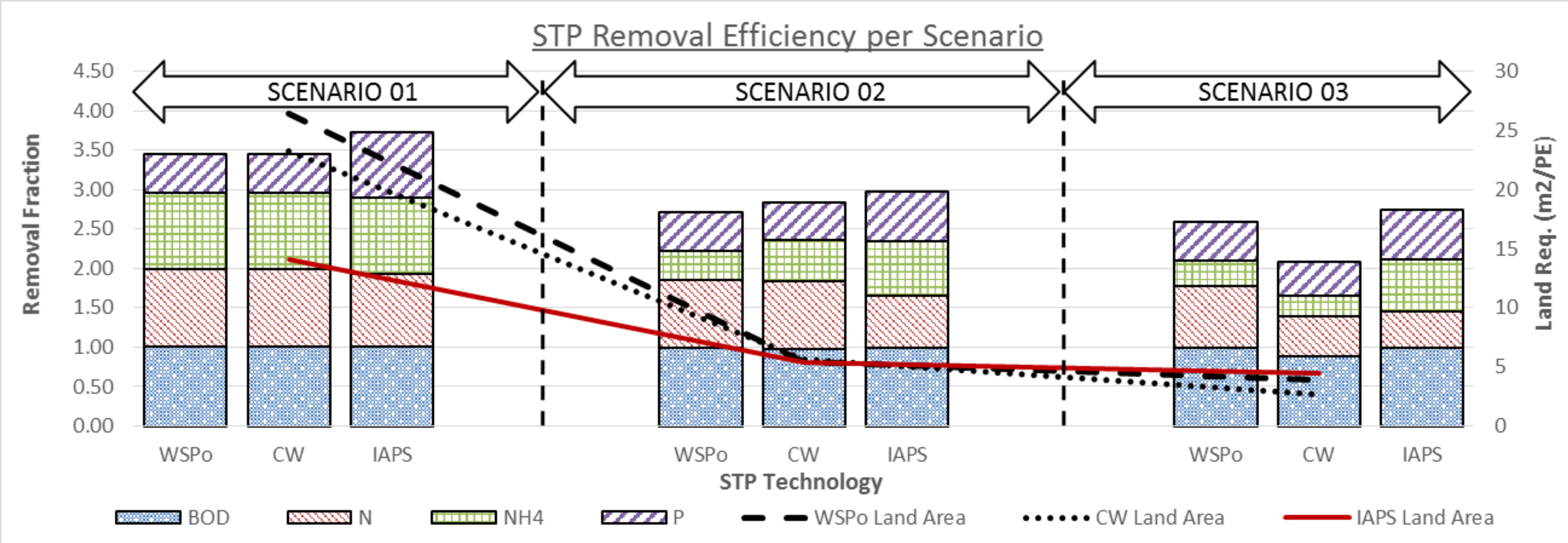


Figure 5-6 : STP Removal Efficiency per Scenario

Considering Table 5-18 and Figure 5-6 : STP Removal Efficiency per Scenario, the following conclusions can be drawn:

Scenario 01:

- Only the IAPS can provide the comply with NWA General Discharge Standard to a Water Resource, since both the WSPo and CW fail to achieve the Phosphate Removal
- The IAPS also requires almost 50% less land than the other technologies.
- A significant amount of land is still required to achieve the required effluent quality for all three technologies
- Al three technologies comply with the other effluent quality criteria ("Irrig", "Agric" and "Cattle").

Scenario 02:

- The land area requirements for all three technologies are very similar
- All three technologies fail the Ammonia and Phosphate quality criteria ("River").

- The IAPS also fails the Nitrogen quality criteria.
- Al three technologies comply with the “Irrig” and “Cattle” effluent quality criteria but all fail the “Agric” quality criteria due to the stringent Coliform criteria (< 1 FC/100ml)

Scenario 03:

- The IAPS requires the most land to comply with the NWA General Standards for irrigation up to 500kl/d.
- The CW requires the least amount of land.
- All three technologies fail the Water Quality Criteria for Livestock drinking ("Cattle") due to the Coliform requirements. This can however be easily addressed
- All three technologies fail the Water Quality Criteria for Agricultural Irrigation ("Agric") due to the Coliform requirementsand the Nitrogen Requirements (Only CW and IAPS).

General

- It is difficult to draw a comparison between the required land areas for existing STPs in operation globally and for this study
- Different pond dimensions for each STP were selected based on practicality to construct. This does also impact on the overall hydraulic retention time and system performance.
- For all three technologies, less land is required if the required effluent standard is relaxed
- The IAPS is the most efficient in removing Ammonium and Phosphate.
- The WSPo is most effective in removing Nitrogen
- The CW shows the largest drop in overall removal efficiency from Scenario 02 to Scenario 03
- BOD removal has been relatively consistent for both the WSPo and IAPS across all three scenarios, with only the CW showing a remarkable drop in efficiency from Scenario 02 to Scenario 03.

Should a TSE disposal option be selected other than discharging into a Water Resource ("River" effluent standard), the unique ability of the IAPS system becomes less important. Most of the effluent improvement through the IAPS technology option is obtained through the pond-related components of the treatment process.

It is interesting to note that for Scenario 03 the CW requires less land than the WSPo. Mara(2003 & 2006) suggested that the CW would require more land when compared with a WSPo system that utilises secondary facultative ponds Mburu et al. (2013) also suggested that CW and WSPo land area requirements are very similar. Even though the CW requires less land, from Figure 5-6 it can also be seen that the overall removal efficiency of the CW is also less. Thus by drawing a linear comparison between removal efficiency and land area, to increase the removal efficiency to match that of a WSPo, will require a very similar land area than for WSPo.

The author has also evaluated the calculations provided by Mara(2003) in support of his statement and can confirm his agreement with this statement. However this is a function of the selection of removal constants and also the BOD loading. The author found that less land per PE is required to treat a high BOD loading through a CW than through a secondary facultative pond. The secondary facultative ponds need to increase in size in order to limit the pond's BOD effluent to 60-80mg/l in order to prevent the pond from turning Anaerobic (Smith(2011)). As the BOD loading into the secondary facultative reduces, the land area requirement starts leaning to WSPo in favour over the CW.

For Scenario 03, should the technologies be adjusted to comply with a Thermotolerant Coliform limit of $3E10^3$ FC/100ml, this will mean that they comply with the Water Quality Criteria for Livestock Drinking ("Cattle") as well. If the Thermotolerant Coliform limit for Agricultural Irrigation ("Agric") can also be amended to correspond with that for Livestock

Drinking, then the WSPo will likely be the only Scenario 03 technology to comply with the Water Quality Criteria for Agricultural Irrigation as well.

The Water Quality Criteria for Agricultural Irrigation (DWAF 1996) specified the limit of 1FC/100ml in order to permit unrestricted irrigation, with little likelihood of human pathogens being transmitted. The guideline does however permit a concentration of maximum 1000 FC/100ml to be considered for pasture and irrigation of vegetables which will typically be eaten raw, provided that there is less than 1 Helminth egg / litre of water.

The guideline further recommends less than 10 000 FC/100ml in order to prevent the clogging of drip irrigation by pathogen culture growths within the pipes.

A limit of 1000 FC/100ml does correspond well with the NWA general discharge standards (NWA 2013) into a water resource (1000 FC/100ml), for irrigation up to 2Ml/d (1000 FC / 100ml) and the Water Quality Criteria for Livestock Drinking (1000 FC / 100ml). By adjusting the Agricultural Irrigation Criteria to allow for 1000 FC/100ml, all three technologies in Scenario 2 comply with this criteria and the WSPo also complies with this in Scenario 03. With minor adjustment all three technologies can comply with this criteria in Scenario 03 as well.

SLUDGE QUALITY

Freese and Nozaic (2009) refer to the "Guidelines for the Utilisation and Disposal of Wastewater Sludge" (Hereafter called "Sludge Guidelines", Herselman and Snyman (2006)) when discussing the issue of sewage sludge and what to do with it. This document is also used by DWS and DEDEAT when considering Waste License Applications and Environmental Authorisations.

Considering the study area, disposal to a hazardous waste site will be costly and difficult due to the travel distances. It is also not the purpose of this study to perform an evaluation of sludge benefits, management techniques and disposal options. This can be separate research which can also be performed using the study area.

All three technologies currently being evaluated produces a sludge through anaerobic processes. Some comments on the suitability of the sludge for local handling and beneficiation is provided in this section.

According to the Sludge Guidelines a sludge is classified using three categories, namely:

- Microbial Class: A, B or C
- Stability Class: 1, 2 or 3
- Pollution Class: a, b or c

The Microbial Class is determined by the pathogens in the sludge and focusses on disease transmission. Stability Class evaluates the sludge's potential to generate odours and attract vectors (eg. flies and rodents). The pollution class looks at the chemical composition of the sludge and its potential to adversely affect local soil conditions and groundwater. Detailed parameters which comprise each of these categories are provided in Table 5-19.

In the study area the main form of agriculture is maize for personal use. According to the Sludge Guideline, sludge may only be used in maize cultivation if it complies with the following classification:

Table 5-19 : Sludge Classification

CLASS	PERMITTED USE		
Microbial Class	A (**Ag**, **GL**)	B (**Ag**, **GL**)	C (**Ag**, **GL**)
Stability Class	**1** (**Ag**, **GL**)	**2** (**Ag**, **GL**)	**3** (**GL**)
Pollution Class	**a** (**Ag**, **GL**)	**b** (**Ag**, **GL**)	**c -**

*(Table Notes: **Ag** = Agricultural Use; **GL** = General Land disposal*

Any sludge classified between "A1a" and "C2b" may be used for maize cultivation and fodder irrigation. If agricultural use is not considered, general land disposal may be permitted, provided it complies with either Pollution Class "a" or "b". Strict monitoring programmes will then also be required.

No literature could be found indicating how the composition of sludge can be calculated based on the raw sewage design load. For the purpose of this study it was rather decided to evaluate sludge from existing STPs and determine what type of classification can be expected.

Table 5-20 provides the test results of sludge samples taken at three STPs in the Eastern Cape. These do not fall in the study area but consist of Waste Activated Sludge Plants and Pond Systems. Samples were taken from the Sludge Drying Beds and Anaerobic Ponds, as applicable. The sources of the information have requested to remain anonymous. Sudge results frok a STP in Seville, Spain are also reported on (Bouza-Deano et al. (2012))

Bouza-Deano et al. (2012) indicated that the sludge sample was taken from the Anaerobic Pond and it is reported that the pond has not been desludged for 15 years. The sludge samples from the Eastern Cape ponds are of a similar age

The WSPo evaluated by Bouza-Deano et al. (2012) did not focus on testing for Microbial, thus a class C sludge was assumed as this was the same class obtained by two other STPs. While Pond System 2 has a Microbial Class of A, it seems questionable that no Faecal Coliforms were detected. Overall, it would appear that the sludge in Pond System 2 has a very low concentration of all sludge constituents.

The majority of the WAS System results for the Pollution Class is much lower than for Pond System 1 and Bouza-Deano et al. (2012). This is expected since this sludge is a lot younger than for Anaerobic Ponds. Research performed by Bouza-Deano et al. (2012) further found that over long periods without desludging, the sludge volume decreases due to continued organic decomposition and compaction in the lower layers of sludge. The cumulative effect is a reduced rate of sludge generation. Consequently, Bouza-Deano et al. (2012) hypothesizes that desludging intervals can be extended beyond the 5-year horizon.

Delayed desludging could lead to metal build up and a reduction in the Pollution Class of the sludge. However, by evaluating the above results it can be seen that for pond systems, even after 15 years without desludging, the Pollution Class is still "a".

While the Sample Size of test results are too small to make a definitive conclusion, the initial hypothesis is that delayed desludging can be considered for ponds in the study area without risking the Sludge quality to become unsuitable for either agricultural use or local land disposal.

Table 5-20 : Sludge Quality at Existing STPs

Class	Parameter	Unit	Classification Limits			Source			
			A/a/1	B/b/2	C/c/3	Bouza-Deano et al. (2012)	Pond System 1[1]	Pond System 2[1]	WAS System[1]
A/B/C	Faecal Coliform	CFU/g d.w.	< 1 x 10^4	1 x 10^4 - 1 x 10^7	> 1 x 10^7	NI	4.40E+08	0	2400
A/B/C	Helminth ova	eggs/g d.w	< 1	1 - 4	> 4	NI	> 4	0	15
a/b/c	Arsenic (As)	mg /kg d.w	< 40	40 - 75	> 75	9.8	< 0.001	NI	0.15
a/b/c	Cadmium (Cd)	mg /kg d.w	< 40	40 - 85	> 85	2	0.67	0.18	0.07
a/b/c	Chromium (Cr)	mg /kg d.w	< 1 200	1 200 - 3 000	> 3 000	54.9	20.2	1	13.91
a/b/c	Copper (Cu)	mg /kg d.w	< 1 500	1 500 - 4 300	> 4 300	378.3	706	1.8	10.73
a/b/c	Lead (Pb)	mg /kg d.w	< 300	300 - 840	> 840	113.1	89.1	< 0.01	1.59
a/b/c	Mercury (Hg)	mg /kg d.w	< 15	15 - 55	> 55	5.7	< 0.001	NI	0.08
a/b/c	Nickel (Ni)	mg /kg d.w	< 420	420	> 420	28	51.4	1.6	5.37
a/b/c	Zinc (Zn)	mg /kg d.w	< 2 800	2 800 - 7 500	> 7 500	997.3	852	30.6	42
1/2/3	Stability Comment	n/a	Compliance on a 90 percentile basis.	Compliance on a 75 percentile basis.	Compliance below 75 percentile	assume 1	1 (lab test)	1 (lab test)	1 (lab test)
Sludge Classification						Assume worst case: C1a	C1a	A1a	C1a
Current Sludge Application:						No sludge application	No sludge application	No sludge application	No sludge application

(Table Notes: 1: Results provided from STPs in Study Area. The source requested to remain anonymous)

During an interview with a Stakeholder the concern was raised that the local villagers might not want to use the dried sludge for agricultural use due to it originating from human faeces. Community engagement and education might be required to validate agricultural use, but if this is unsuccessful, the land disposal is the only option.

In response to this, another Stakeholder mentioned during their interview that an alternative use for the sludge is erosion protection and land restoration. DWS has initiatives such as "Working for Water" (http://www.dwaf.gov.za/wfw/) running in the Eastern Cape whereby invasive plant species are removed and soil erosion is remediated. These organisations are always looking for nutrient rich soil for their projects. By having a depot of sludge at each of the WSPs throughout the Study Area could assist these organisations with their projects.

ALGAE HARVESTING

Algae harvesting only applies to the IAPS system. Algae can be used for either cattle feed, methane gas production, fertiliser, health products and even biofuel. (Campbell et al 2003). While these by-products can be considered very advantageous for job creation, the author is of the opinion that very limited benefits can be received from the Algae Harvesting given the rural context of the study area.

Algae harvesting will be more beneficial in urban areas where the demand is higher and the product distribution is easier to establish.

Campbell et al (2003) estimated that approximately 30t/ha/year of Algal can be harvested from an IAPS. The estimated area required for an IAPS in the study area is 9 319.83 m2, or 0.9ha. This will result in approximately 27t of algal per year, or 74kg of algal per day. (About the size of two bags of cement if dried).

Considering the relatively small volume of Algal product, algal harvesting would need to be used on a much larger scale to become a beneficial by-product. For this study, harvesting algal on such a small scale would be more of a burden to manage.

5.8 ECONOMIC PERFORMANCE

The study area is wholly located within the rural areas of the Eastern Cape. Few urban settlements are present and the majority of residents are indigents. From interviews with Stakeholders (and the author's own experience) it was confirmed that capital projects are mostly funded through the Municipal Infrastructure Grant (MIG). The source of MIG funding is National Treasury, which allocates some of the Tax collected to MIG. Thus it is in effect the citizens of South Africa which pays for the MIG projects.

The O&M and Capital Replacement of the new infrastructure are the responsibility of the WSP to fund. The funding is usually provided through revenue collection in urban areas and through the Indigent Grant in rural areas. The Indigent Grant is also provided by National Treasury from Tax Collections. The economic evaluation of the technologies therefore needs to focus on two aspects:

- Life Cycle Costing (LCC)
- Operational Costing

The LCC looks at the effective use of tax payers funding and also includes Operational Costs as recommended by Muga et al. (2007). It is however recommended to look at the

Operational Costing separately to determine the potential local cost recovery by the WSP from local beneficiaries.

The LCC was performed by calculating the Net Present Value (NPV) of all different costs over the entire operational life of the STP. The different parameters and assumptions which had to be made to perform the costing is summarised in Table 5-21.

From interviews with Stakeholders, it was confirmed that the land in rural areas are typically Municipal Commonage and belongs to the Local Municipality. The WSA and the Local Municipality thus enters into an agreement to establish the infrastructure on municipal land, without any land having to be purchased or annual property taxes to apply.

This is of great benefit since the value of land contributes significantly to the overall lifecycle costing. Costs associated with the STP Property is thus excluded in the final NPV Calculations. The detailed calculations are provided in Annexure 19 and summarised in Table 5-22.

Table 5-21 : Life Cycle Costing Parameters

LCC Cost Component	WSPo	CW	IAPS
Capital Costs			
Initial Capital	Calculated as Per Annexure?, based on latest Eastern Cape Construction Rates[1]		
Capital Replacement Costs (Only applies to M&E)	Replaced every 5 yrs[2]	Replaced every 5 yrs[2]	Flow meters: 5yrs.[2] Rest every 10yrs.[3]
Land Value	R5/m^2		
Maintenance Costs			
Annual Civil & Structural Repair Costs	0.2% of Civil Capital Cost[4]	0.3% of Civil Capital Cost[4]	0.4% of Civil Capital Cost[5]
Annual M&E Repair Costs	3% of M&E Capital Cost[4]	3% of M&E Capital Cost[4]	4% of M&E Capital Cost[5]
Labour and Material Costs	Incl. Above. This includes central support.		
Operational Costs			
Chemicals	Not required[6]		
Electricity	Electricity price increase: 8.5% per annum[7] Eskom Averaged charge: R1.65/kWh[7] Paddle Wheel Power Requirement: 1kWh per wheel		
Rates and Taxes	Services: R8 400 per site[8] Property Tax: 2.2c/R of Property Value[8]		
Staffing	As per Table 5-12 Hourly rates indicative, based on input from Stakeholders		
Other			
Inflation Rate	6.4%[9]		
Annual Salary Increases	2% above inflation		
Interest Rate 1	7.0%		
Interest Rate 2	9.0%		
Interest Rate 3	12%		
STP Operational Life	40yrs (Based on Civil Infrastructure)		

Table Notes:
1: Rates provided by Stakeholders — *2: Flowmeter batteries*
3: Paddlewheel and security related — *4: Adapted from Sato et al.*
5: Stakeholders recommend 0.5% (Civil) and 5% (M&E) WAS STPs
6: No chlorine required. — *7: Based on current local trends*
8: Indicative municipal tariffs — *9: Averaged future rate*

Figure 5-7 compares the annual O&M costs of each STP technology. The initial capital costs per STP is also illustrated. Figure 5-8 shows the composition of the O&M Costs for all the STPs in Scenario 03. For all three technologies the Staffing costs contributes the most to O&M Costs.

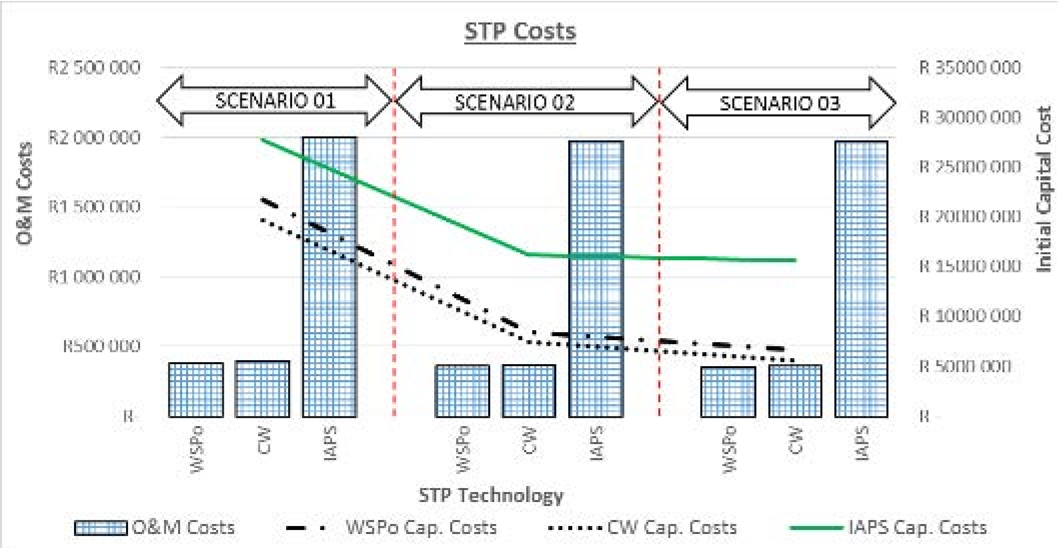


Figure 5-7 : STP Costs

From Figure 5-7 it can be seen that the O&M Costs of the IAPS is much higher than compared with the WSPo and CW. The IAPS capital costs is also the highest in all scenarios, with the CW Capital Costs consistently the lowest. The Capital Replacement Costs are not included in Figure 5-7, but is addressed as part of the NPV Calculations.

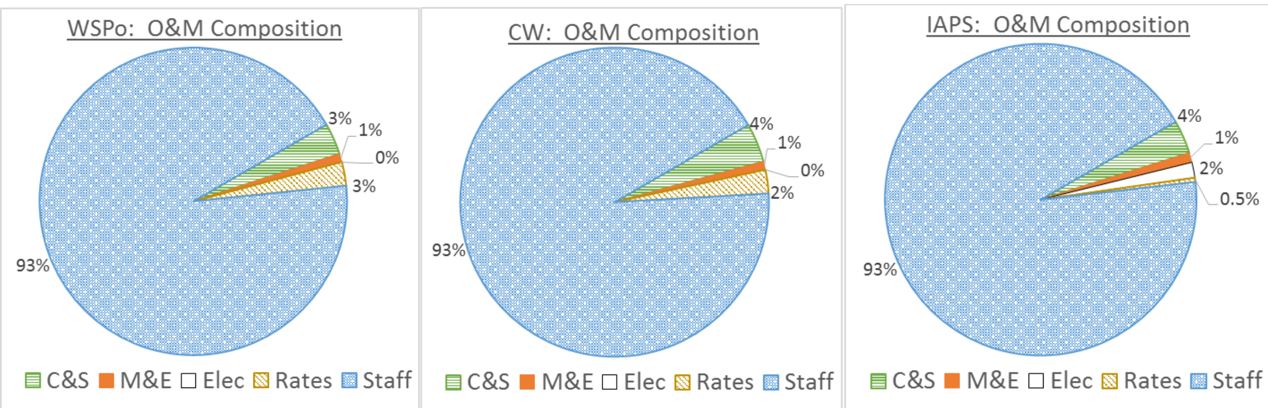


Figure 5-8 : O&M Composition per STP

Muga et al. (2007) emphasized the importance of estimating the operational costs of STPs over their entire life cycle, to accurately reflect the electricity requiremetns. With reference to Figure 5-8, it can be seen that for low-technology options, the highest contributor to annual O&M Costs are labour-related.

Table 5-22 : STP Cost Summary

	COST ASPECTS	SCENARIO 01			SCENARIO 02			SCENARIO 02		
		WSPo	CW	IAPS	WSPo	CW	IAPS	WSPo	CW	IAPS
	STP Land Area Req (ha):	15.2	13.5	8.18	3.1	3.2	3.1	2.2	1.5	2.6
	Population Served:	5 780	5 780	5 780	5 780	5 780	5 780	5 780	5 780	5 780
Initial Capital Costs	Civil & Structural Capital	R 21 569 311	R 19 552 018	R 27 140 087	R 8 328 057	R 7 341 740	R 15 688 025	R 6 553 175	R 5 418 872	R 15 176 030
	Mech. & Elec. Capital	R 114 507	R 114 507	R 618 340	R 114 507	R 114 507	R 465 664	R 114 507	R 114 507	R 435 128
	Total Capital Cost:	**R 21 683 818**	**R 19 666 525**	**R 27 758 428**	**R 8 442 565**	**R 7 456 247**	**R 16 153 689**	**R 6 667 683**	**R 5 533 379**	**R 15 611 158**
	Cost/m^2	R 142	R 146	R 339	R 269	R 231	R 521	R 296	R 361	R 607
	Cost/PE	R 3 752	R 3 403	R 4 802	R 1 461	R 1 290	R 2 795	R 1 154	R 957	R 2 701
	Costs/HH	R 18 758	R 17 013	R 24 012	R 7 303	R 6 450	R 13 974	R 5 768	R 4 787	R 13 504
O&M Costs Combined (Year 1)	Maintenance: Civil & Structural	R 39 063	R 53 115	R 98 305	R 15 083	R 19 945	R 71 030	R 11 868	R 14 721	R 68 712
	Maintenance: Mech. & Elec.	R 3 111	R 3 111	R 22 397	R 3 111	R 3 111	R 21 084	R 3 111	R 3 111	R 19 701
	Operational: Electricity	R -	R -	R 31 365	R -	R -	R 31 365	R -	R -	R 31 365
	Operational: Rates and Taxes	R 8 938	R 8 938	R 8 938	R 8 938	R 8 938	R 8 938	R 8 938	R 8 938	R 8 938
	Operational: Staffing	R 332 571	R 332 571	R 1 842 106	R 332 571	R 332 571	R 1 842 106	R 332 571	R 332 571	R 1 842 106
	Total O&M Costs	**R 383 683**	**R 397 734**	**R 2 003 111**	**R 359 702**	**R 364 564**	**R 1 974 523**	**R 356 488**	**R 359 340**	**R 1 970 822**
	Total O&M Cost/m^2	R 3	R 3	R 24	R 11	R 11	R 64	R 16	R 23	R 77
	Total O&M Cost/PE	R 66	R 69	R 347	R 62	R 63	R 342	R 62	R 62	R 341
	Total O&M Costs/HH	R 332	R 344	R 1 733	R 311	R 315	R 1 708	R 308	R 311	R 1 705
Net Present Value (7% Interest Rate)	Initial Capital Costs	R 20 265 251	R 18 379 930	R 25 942 456	R 7 890 247	R 6 968 455	R 15 096 905	R 6 231 479	R 5 171 383	R 14 589 868
	Capital Replacement Costs (CRC)	R 570 628	R 570 628	R 1 646 104	R 570 628	R 570 628	R 1 320 202	R 570 628	R 570 628	R 1 255 022
	O&M Costs	R 16 744 227	R 17 185 095	R 89 387 167	R 15 991 828	R 16 144 371	R 88 490 208	R 15 890 976	R 15 980 478	R 88 374 099
	TOTAL NPV	**R 37 580 106**	**R 36 135 654**	**R 116 975 726**	**R 24 452 704**	**R 23 683 455**	**R 104 907 316**	**R 22 693 083**	**R 21 722 489**	**R 104 218 989**
	Total NPV Cost/m^2	R 247	R 268	R 1 430	R 779	R 734	R 3 382	R 1 009	R 1 417	R 4 051
	Total NPV Cost/PE	R 6 502	R 6 252	R 20 238	R 4 231	R 4 097	R 18 150	R 3 926	R 3 758	R 18 031
	Total NPV Costs/HH	R 32 509	R 31 259	R 101 190	R 21 153	R 20 487	R 90 750	R 19 631	R 18 791	R 90 155
Equivalent Annual Costs (EAC)	**Total EAC (TEAC) - For Total NPV**	**R 2 818 851**	**R 2 710 504**	**R 8 774 248**	**R 1 834 176**	**R 1 776 476**	**R 7 869 007**	**R 1 702 189**	**R 1 629 385**	**R 7 817 377**
	TEAC Cost/m^2	R 19	R 20	R 107	R 58	R 55	R 254	R 76	R 106	R 304
	TEAC Cost/PE	R 488	R 469	R 1 518	R 317	R 307	R 1 361	R 294	R 282	R 1 352
	TEAC Costs/HH	R 2 438	R 2 345	R 7 590	R 1 587	R 1 537	R 6 807	R 1 472	R 1 410	R 6 762
	0&M and CRC EAC (OCEAC)	**R 1 298 772**	**R 1 331 842**	**R 6 828 327**	**R 1 242 336**	**R 1 253 778**	**R 6 736 602**	**R 1 234 771**	**R 1 241 484**	**R 6 723 003**
	OCEAC Cost/m^2	R 9	R 10	R 83	R 40	R 39	R 217	R 55	R 81	R 261
	OCEAC Cost/PE	R 225	R 230	R 1 181	R 215	R 217	R 1 166	R 214	R 215	R 1 163
	OCEAC Costs/HH	R 1 124	R 1 152	R 5 907	R 1 075	R 1 085	R 5 828	R 1 068	R 1 074	R 5 816

The WSPo costs are very similar than for the CW in all scenarios. This is because for O&M the same staffing structure is required, while for capital costs both STPs comprise mostly of ponds with similar costs. The lower capital costs for the CW is attributed to the smaller area requirement for the wetland. With reference to Section 5.7, should a raw sewage influent with lower strength require treatment, it could reverse the pricing order of the WSPo and CW.

Figure 5-9 compares the Net Present Value of the different STP with each other, for each of the Scenarios.

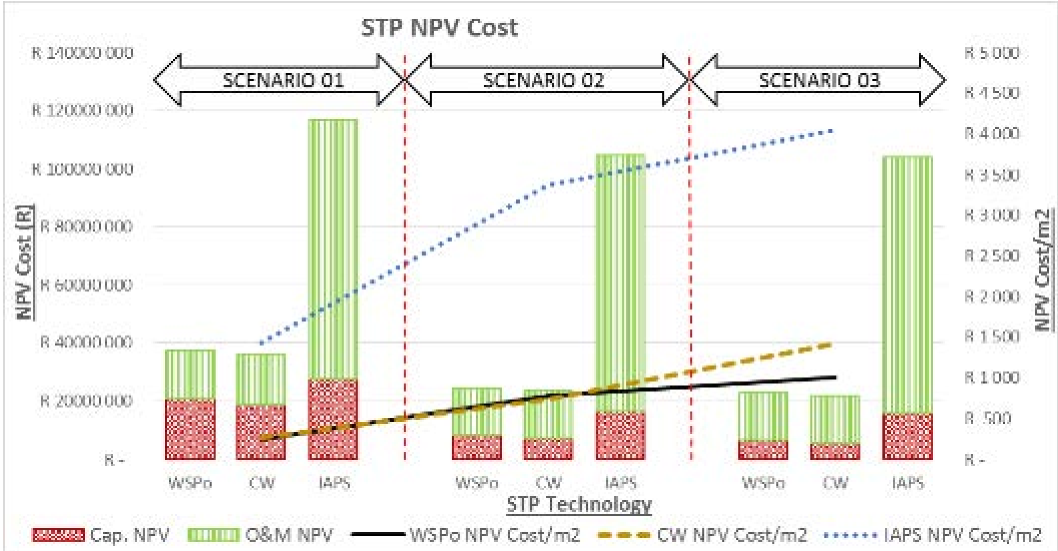


Figure 5-9 : NPV Calculations

Similar as with Figure 5-7, the WSPo and CW NPVs are substantially less than for the IAPS. What is interesting to note is that with reducing land requirement (due to relaxed effluent quality requirements), the NPV cost per m2 increases.

This is because those components of the NPV with costs not directly affected by land area, starts contributing more when costs associated with required land area starts reducing. The former type of costs typically include Staff, Service Provision Rates and Infrastructure components such as Inlet Works and Paddle Wheels.

What is of further interest is that the WSPo has the lowest NPV/m2 for Scenario 03. The reason why the CW's NPV/m2 does not follow the same trend as with the WSPo and IAPS, is because the required CW land area has reduced by a larger fraction than what the construction value has reduced. The reason for this limited reduction in construction costs is, as described in the previous paragraph, attributed to the non-land related costs.

The Equivalent Annual Cost (EAC), as recommended by Muga et al. (2007) was calculated. The EAC is subdivided in two components. The Capital EAC (CAPEAC) is required to calculate how much funding must annually be set aside for the initial capital investment to build the STP. This amount needs to be adjusted annually based on the applicable interest rate and can be used to calculate a loaN repayment.

The second component is the O&M and Capital Replacement EAC (OCEAC). This is used to calculate what the annual budget should be to cover O&M as well as future capital replacement works. The OCEAC also needs to be adjusted annually based on inflation and is very important in this study since the MIG expects the WSP to fund their own O&M and Refurbishment/Replacement projects.

Figure 5-10 illustrates the relation between the CAPEAC, OCEAC and the Total EAC (TEAC = CAPEAC + OCEAC). The figure also indicates the OCEAC/Household (HH). Costs per household are typically used in cost recovery models.

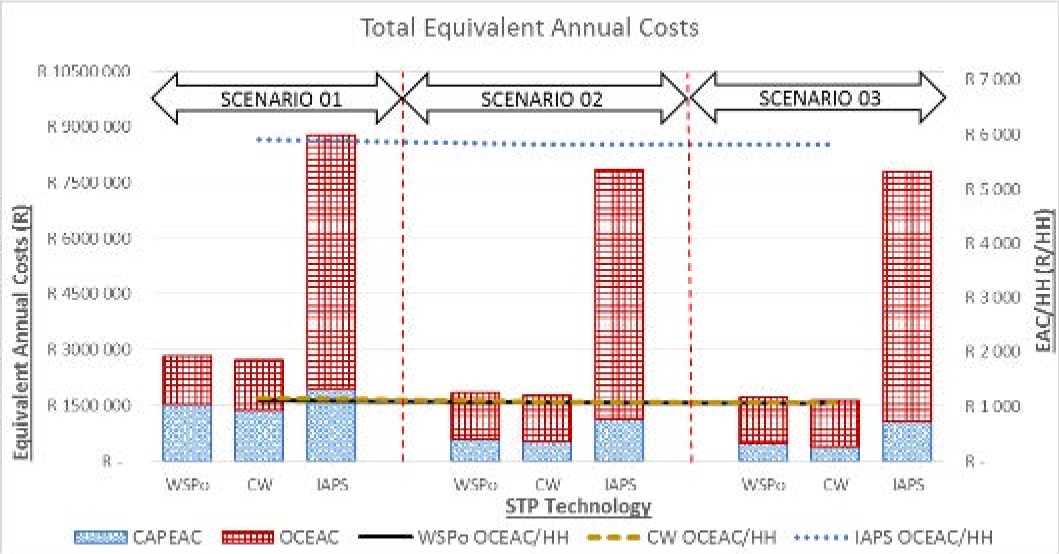


Figure 5-10 : Total Equivalent Annual Costs

Figure 5-10 indicates that the OCEAC forms the bulk of the TEAC, with its contribution increasing when effluent quality standards become more relaxed. The OCEAC/HH for all three STPs are relatively consistent across all three Scenarios. The WSPo and CW are very similar at an annual OCEAC/HH of R1100/HH. The OCEAC/HH for IAPS is 430% higher at R5850/HH.

It is difficult to compare the STP Options on a financial basis with similar Global applications since the costing is influenced by local economics, exchange rate fluctuations, political dynamics, raw sewage and required effluent constituents to name but a few. Table 5-23 indicates the fluctuations in the price between technologies across the world. When evaluating the O&M Costs as a percentage of the Capital Costs, it can be seen that for both WSPo and CWs, the O&M % varies from very high to very low. Very limited information was obtainable on the finances of an IAPS.

To evaluate these costs on a comparative basis can be very difficult and time consuming, which can be a research topic on its own. It is rather recommended to compare the recommended STP technologies against the local industry norms.

Table 5-23 : Global STP Financial Comparison

STP Cost Component		Mburu et al. (2013)		Mara		Mara		Sato et Al		Sato et Al	
WSPo	Capital Cost	440 250	Euro	120	ecu/PE	700	DEM/PE	167	US$/m3/d	35.6	US$/PE
	O&M Costs	282.8	Euro	4.5	ecu/PE	1.2	DEM/PE	1.67	US$/m3/d	0.53	US$/PE
	O&M % of Capital Costs	0.06%		3.75%		0.17%		1.00%		1.49%	
CW	Capital Cost	1183.5	Euro	190	ecu/PE	1500	DEM/PE				
	O&M Costs	100	Euro	5.5	ecu/PE	1.3	DEM/PE				
	O&M % of Capital Costs	8.45%		2.89%		0.09%					

Table 5-24 compares the costs recommended by the MIG, with that obtained from Local Design Engineers. These are also compared with Costs for all three STP options being considered for this study. The STP Costs provided by the local designers and reported on in the MIG, is a conventional Waste Activated Sludge STP. This means the effluent is at least compliant with the NWA General Discharge Standards (NWA 2013). The MIG will typically not award funding to a project which exceeds their guidelines.

Scenario 01 and Scenario 03 costs are thus used for comparative purposes. Scenario 01 complies with the General Discharge Standards to a Water Resource, while Scenario 03 complies with the General Standards for Irrigation.

Table 5-24 : Local Industry STP Cost Comparison

STP Cost Components	Scenario 01			Scenario 03			Engineering Estimate	Municipal Infrastructure Grant	
	WSPo	CW	IAPS	WSPo	CW	IAPS		Rate 1	Rate 2
Capital Cost/HH	R 18 757.63	R 17 012.57	R 24 012.48	R 5 767.89	R 4 786.66	R 13 504.46	R 16 434.31	R 23 088.22	R 17 408.16
O&M Cost/HH	R 331.91	R 344.06	R 1 732.79	R 308.38	R 310.85	R 1 704.86	R 1 013.24	R 617.15	
O&M % of Capital Costs	1.8%	2.0%	7.2%	5.3%	6.5%	12.6%	6.2%	2.7%	3.5%

The Engineering Estimate Costs compare well with those costs provided by MIG, especially Rate 2. It is expected that a low-technology option would have a lower Capital and O&M cost than when compared with a WAS STP. Scenario 01's Capital Costs are very much in line with those for the WAS. The high capital and O&M Costs for the IAPS also makes it very unlikely for MIG to award funding for this technology.

For Scenario 03 the WSPo and CW costs are about a third of the WAS costs and The O&M costs about two to three times less. This would suggest that these costs are in the correct order and funding will quite likely be awarded by MIG. While the IAPS costs have also reduced significantly, their O&M costs are still higher than for a WAS system.

Even though MIG does not award funding for O&M activities, these costs are looked at when evaluating the final technology to implement. This is because MIG needs to consider the overall sustainability of the technology, over its entire lifecycle. Furthermore, should the O&M be funded through the Equitable Share (DOR (2017)), then the funding for Capital and O&M costs have the same source: National Treasury.

Through the economic evaluation above it can be concluded that due to the high NPV Cost and NPV Cost/m^2, the IAPS is not an economic option. Its high staff requirement also makes it OCEAC very high. This will quite likely mean insufficient funding will be available to operate and maintain this STP.

The WSPo and CW have very similar economic performances, with the CW being slightly less expensive than the WSPo. The OCEAC of the WSPo is however a bit less and with a more economic use of land Figure 5-9 than the CW.

5.9 SECTION SUMMARY

In this section, the performance of the three realistic STP options was evaluated. This evaluation focussed on Technical, Institutional and Economic aspects. A standard set of criteria was used for comparative purposes. The most import criteria was the strength of the raw sewage and also the required effluent discharge quality.

It was concluded that all three technologies depend in some way or another on ponds during the treatment process train. All three technologies use minimal electricity, with only the WSPo and CW being able to continue operating without a continuous electrical supply. The WSPo will also be able to provide most of construction materials locally. For all options significant land area (14 – 26m^2/PE) is required to comply with the legislated standards for discharging to a water resource. Land requirements however decreases with more relaxed effluent discharge standards (or weaker raw sewage influent).

WSPo and CW have similar staffing requirements, but due to the M&E components of the IAPS, the staffing requirement for the IAPS is about three times more than the other STP technologies. The IAPS also require a higher level of education to comply with the NWA staff qualification requirements.

All three technologies' monthly O&M work can be done by local staff, with external staff only having to visit the STP once a monthl. The WSPo has the lowest activities overall as well as per period. The IAPS has the highest overall activities, but due to large staff compliment, the average number of activities per individual is less than for the other technologies. This could possibly mean the IAPS staff are not used economically.

Only the IAPS is able to provide effluent quality compliant with NWA for discharge to a water resource. All technologies can easily comply with the effluent standards for agricultural use. In the latter case treatment through pond components are more important than any of the other processes. Sludge from ponds will easily comply with agricultural or land disposal without any special treatment.

Capital costs for IAPS is the highest in all situations, with CW the lowest. The NPV for the CW is also the lowest, but due to the WSPo using land more effectively to treat sewage, the WSPo has the lowest NPV/m^2. O&M Costs for the WSPo and CW are also very similar, with the IAPS higher by a factor of five.

This section assisted in answering research questions 1, 4, 6 and 10. The table below summarises which sections have assisted in answering which research questions:

Table 5-25 : Section 5 and Research Question Correlation

RESEARCH QUESTIONS	SECTION REFERENCE						
	Section 5.2	Section 5.3	Section 5.4	Section 5.5	Section 5.6	Section 5.7	Section 5.8
1. What low-technology wastewater treatment options are available?		X					
3. How applicable are these options to be used on a large scale?	X	X	X		X	X	X
4. Are there any success stories for these treatment options? (Local and/or International)						X	X
8. What risks exist to the South African policies if high volume low technology options are used?	X			X		X	
9. What are the financial implications for implementing such high volume low technology options?			X				X
10. How will the community benefit from the selected technology? (e.g. involvement in O&M and agricultural re-use of effluent)			X	X	X	X	X

6. STAGE 3 ANALYSIS: CHALLENGES AND SOLUTIONS

6.1 SECTION INTRODUCTION

In this section, challenges which have been identified through the previous Analysis Stages (Sections 4 & 5) are listed. Stakeholder engagement through questionnaires and interviews are also used to further elaborate on potential challenges which can be experienced in the study area.

The impact different policies and legislation has on selecting technologies are first discussed. This is followed by looking at possible funding and cost recovery models which can be considered to finance the implementation and continued use of the STP in the study area.

Local challenges, focussed mostly on stakeholder engagement and practical tips, are then described. These were determined predominantly through stakeholder engagement. In Section 6.5, all challenges identified in the preceding sub-sections are then taken together and possible solutions to them summarised in Table 6-1.

As a last step in the Stage 3 Analysis, a multi-criteria decision making process is used to evaluate the different realistic technologies. This considers all that has been learnt across all three Analysis Stages and intends to select the preferred technology by comparing the technologies against each other, based on a standard but project specific, set of criteria.

6.2 IMPACT OF POLICIES AND LEGISLATION ON TECHNOLOGIES

In the preceding analysis stages, areas in which policies and legislation influence technology selection the most, were identified. These are listed below and discussed thereafter:

- Effluent and Sludge Quality
- Storage Volume
- Staffing Requirements
- Pond Linings
- Application of legislation

Effluent Quality

TSE Quality needs to comply with the requirements provided in the National Water Act (NWA). The NWA also prescribes different TSE discharge options. In Section 5.4, 5.7 & 5.8 it was shown that depending on the discharge option, the realistic technologies could no longer become financially viable.

The legislated quality standards therefore influences the technology selection and can even impose a more unsustainable technology on the WSP.

Storage Volume

The NWA also prescribes a maximum storage volume of 50 000m3 of domestic sewage in a wastewater pond system. As can be seen from **Error! Reference source not found.** and Table 5-8, the storage volume for all three technologies in Scenario 01 are above this upper limit. This means that pond systems cannot be used to treat effluent to an acceptable level for disposal to a water resource due to large storage requirements.

If discharging to a water resource is a requirement, legislation therefore requires a more advanced and possible less sustainable technology to be considered.

Staffing Requirements

The NWA also recommends a certain staffing level, as discussed in Section 5.5, for different levels of STP complexity. The more advanced the STP Technology, the more experienced and qualified the staff must be. This can be problematic in the study area where the local education level is low.

From engagements with Stakeholders a problem that is being experiences is that the staff are obtaining the necessary qualifications but they do not have the actual experience to perform the task. This has become a paper exercise and the actual compliance of the STP Operation is still not addressed.

Pond Linings

In Section 5.8, HDPE linings of all ponds upstream of the Maturation Ponds were allowed for. This has been on recommendation from Stakeholders which have had to implement pond systems in the past. While the lining of ponds is not a NWA requirement, it is a requirement to comply with environmental legislation.

Based on Stakeholder feedback it would appear this a contentious issue as the requirement of a lining is dependent on the government official's interpretation of the environmental legislation. The issue revolves around protecting groundwater from contamination against sewage. If the requirement for expensive linings can be reduced or omitted, then the costs for pond-systems can reduce even more.

Interpretation of legislation

During the interviews with Stakeholders it became apparent that the initial perception that DWS is not willing to change policies, or that they are resistant to low-technology options, was incorrect. While most stakeholders agreed that policies should be revisited, it became apparent that high-level political intervention will be required to change them.

Another issue raised is that government officials responsible for interpreting the NWA or the Environmental Legislation rather interprets the letter of the law and not the intent. This contributes to the issue identified above, whereby decisions are guided towards advanced technologies due to the inability of low-technology options being able to comply with the legislation.

6.3 FUNDING STRATEGIES AND COST RECOVERY

The various IDP documents indicate that the study area is mostly inhabited by an indigent population that does not earn any income. This means that cost recovery within the study area for service delivery is not very likely. The WSA and WSP are thus dependent on grant funding to implement projects and sustain their operation and maintenance. This was also suggested during an interview with a Stakeholder.

Grant funding is provided by the National Treasury, with the calculated annual allocations published in the Division of Revenue Bill (Hereafter called "the Bill"). According to the Bill, grants are subdivided in two main categories, namely Unconditional and Conditional Grants (DOR(2017)). The Unconditional Grants can be used at the discretion of the receiving authority. The Conditional Grants are only awarded after a business plan has been prepared and approved. The latter grants are then only permitted to be used for the intended purposes. The prominent Unconditional Grant applicable to this research is the Equitable Share (ES). This is calculated on national level and focusses on distributing a portion of national revenue to provincial funds. A higher ES is awarded to municipalities with larger indigent populations since these municipalities cannot recover costs from their communities. (DOR(2017))

The ES makes allowance for indigent subsidies to pay for service delivery and public servant salaries. The ES is currently used to pay for O&M within the study area. The prominent Conditional Grants applicable to this research are:

- Municipal Water Infrastructure grant
- Municipal Infrastructure grant (MIG)
- Rural Households Infrastructure grant
- Bucket Eradication Programme grant
- Regional Bulk Infrastructure grant

These are used to implement projects focussed on reducing service delivery backlogs but can also be used to upgrade and refurbish existing assets.

Table 5-24 indicated that the IAPS's Capital and O&M costs are too high when compared with the benchmark costs provided by MIG. This would suggest that a funding business plan recommending an IAPS would likely be rejected. For all three effluent disposal scenarios, both the WSPo and CW are below the benchmark MIG costs and will be favourably received by a MIG funding application.

Institutional and Social Stakeholders were asked to rank potential cost recovery options as part of the issued questionnaires. Both focus groups allocated the highest ranking to "The municipality to pay all costs directly". The final ranking is illustrated in Table 6-1. During a follow-up interview one stakeholder indicated that there were previous attempts at cost recovery from the local communities but that these have failed.

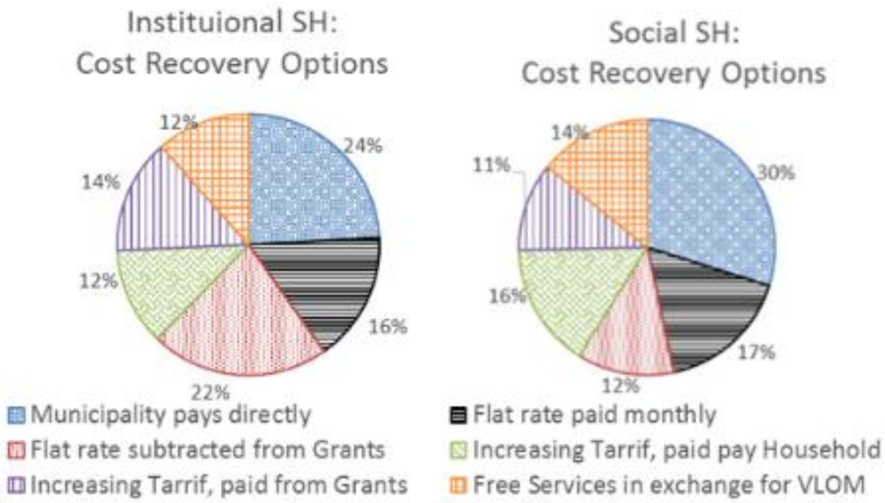


Figure 6-1 : Cost Recovery Options

The evaluation of current funding structures and stakeholder interactions would suggest that grant funding will remain the likely source of funding for the foreseeable future. Direct cost recovery from the community is not likely and should rather be considered through the ES.

The method for calculating the ES to ensure sufficient funding is allocated for sanitation services should however be revisited..

6.4 LOCAL CHALLENGES WITH TECHNOLOGIES

Questionnaires, Field Investigations and Stakeholder interviews contributed to identifying local challenges. The main challenges are listed below and discussed thereafter:

- Community Participation
- Site Security
- Agricultural re-use of effluent and sludge
- Provision of chemicals and spare parts

Community Participation

From returned questionnaires it became apparent that extensive community engagement does not occur during the technology selection process. However, through stakeholder engagement it also became apparent that local villagers have an expectation that "government" is to provide the services to them and they are entitled to these services. There is thus limited interest from the communities to participate in technology selection and eventual management of the technologies.

Considering urbanisation and loss of scarce skills already experienced within the DM, it is only reasonable to assume that the WSPrs will have difficulty procuring permanent site staff from outside of the local communities. Employing operators from outside of the local community will also not be received well by the local villagers due to potential loss of local jobs.

Site Security

Field investigations indicated that security is a problem at STPs. Electrical cables are stolen from M&E components. Children enter the STP site to swim in the treated effluent and are at risk of drowning. Cattle also enter the site to graze on the green grass around the ponds and also drink the effluent. It has been reported that cattle hooves can puncture the pond linings and can also drown in the effluent.

Agricultural re-use of Effluent and Sludge

Stakeholders have indicated that local villagers are sceptical of using sludge from STPs for agricultural purposes. They are aware this originates from human faeces and are thus cautious of it. They do not have any objection to using cattle faeces for agricultural use.

No such reservation has however been documented regarding the treated effluent. If effluent is to be used for irrigation use, then some form of management of the effluent distribution will be required in order to ensure it is sustainably and consistently used.

Provision of Chemicals and Spare Parts

Field investigations suggest that in urban areas it takes about 30 days for spare parts to be provided from the central depots. This timeframe applies to urban areas and it is thus hypothesized that for rural area the delay could be even more.

6.5 RECOMMENDED LOCAL ADAPTATION OF TECHNOLOGIES

Solutions to the challenges described earlier in this section is provided in Table 6-1 for local adaptation to the study area.

Table 6-1 : Recommended Local Adaptation of Technologies

No	Problem and Solutions
01	**Effluent Quality and Storage Volume Requirements** It is foreseen that legislation will not likely be amended to be more inclusive of the rural areas of South Africa. It is rather recommended that the selected technology needs to consider local re-use of effluent which will still comply with legislation, while reducing the stringent requirements of the NWA. For this study this can be realised through re-using the effluent locally for irrigation.
02	**Interpretation of Legislation** It is foreseen that the interpretation of legislation will remain a contentious issue. Continuous engagement with and education of government officials is however important to build industry-wide relationships and trust. Technical issues such as pond linings, effluent quality and storage volumes should be debated and the financial impacts and execution of the NSAPSD emphasized.
03	**Funding and Cost Recover** It is foreseen that grant funding will remain the main source of finance for capital projects. The large indigent populace means the Equitable Share will have to be used to finance local O&M activities. The ES will however have to be revisited to make sure sufficient funding is available to cover the additional O&M costs. For long term sustainability, local cost recovery needs to be investigated.
04	**Community Participation** Community participation does occur to a lesser degree as part of the Environmental Impact Assessment process. More intense engagement is however required to sensitise the community to re-use the effluent and to provide local staff to operate and maintain the STP. Local pride in the use of the STP can assist in ensuring its sustainable use.
05	**Site Security** Access can be regulated by providing a security fence with access control. The STP should be designed not to depend on electricity with security staff only provided where electricity supply cannot be avoided. Specialised equipment should rather be kept centrally and not on-site. Cattle can be kept out of the STP by providing livestock drinking troughs and irrigated grazing outside the site.
06	**Agricultural re-use of Effluent and Sludge** The STP can be designed such that the effluent is safe for agricultural use. If the community remains resistant to sludge use, then the WSPr can stockpile it on-site for future use or dispose of it themselves to local land. The infrequent desludging requirements will not pose an undue strain on the local maintenance teams. The allowance of a sludge storage pond in the design is recommended.
07	**Provision of Chemicals and Spare Parts** The dependence on chlorine for disinfection can be designed out by allowing for waste stabilisation ponds to reduce the E.Coli to acceptable standards. By using effluent solely for local agriculture, the risk of polluting local water resources have been sufficiently reduced. By designing the STP to be as low-technology orientated as possible, the need for M&E spare parts can also be reduced.

6.6 MULTI-CRITERIA SCORING OF REALISTIC OPTIONS

As mentioned in Section 3.7, a multi-criteria decision making (MCDM) process was used on the realistic technology options. This is based on the Analytical Hierarchy Process developed by Saaty (1977). This method is used by some design engineers in the industry to compare different treatment technologies with each other.

The three technologies were evaluated based on a standard set of criteria. The core of the criteria was selected by a WSPr as the aspects most important to them when choosing a technology. These aspects corresponded well with the criteria used by the Design Engineers for their own evaluations.

In order to ensure the scoring process addressed all aspects of Sustainability in an integrated manner, at least one of each of the SHTEFIE parameters had to be included. The MCDM process can use a maximum of 9 criteria to compare options against. Since SHTEFIE only consists of 7 aspects, two more were selected.

As part of the issued questionnaires, it became evident that all Stakeholders place a higher importance on Health and Economic aspects than on the rest of the SHTEFIE aspects. (Refer to Annexure 20 for detailed rankings). Thus an additional Health and Economic-related aspect was selected. The final evaluation criteria are provided in Table 6-2. The detailed calculations are provided in Annexure 21, with the final results illustrated in Figure 6-2.

Table 6-2 : MCDM Performance Criteria Description

PERFORMANCE CRITERIA DESCRIPTION:	
Social	Can easily be operated with limited resources (staff and equipment)
Health	Sufficient Retention Time to accommodate shock loading/component failure
Health	Effective Pathogen Removal without Chlorination / Similar
Technical	Technology has been tried and tested in the wider industry
Economy	NPV/m2 of STP Land
Economy	OCEAC Costs / Household
Financial	Capital Cost
Institutional	Simplified O&M Activities
Environmental	Consistently achieve a reasonable level of effluent quality

Most of these criteria compare very well with those selected in the Sustainable Ranking executed in the Stage 1 Analysis. In Stage 1, the sustainable ranking was approached from a wider application to provide different options for further evaluation. The MCDM then looks at the detailed evaluation of the realistic options, for local application.

The NPV/m2 of STP land area was selected as one of the Economic Criteria as it combines the lifecycle costing of the STP with the value of land on which the STP is to be established. The OCEAC Costs per Household has been selected as the other Economic Criteria as it measures the STP's potential cost recovery by the WSPr. The Capital Cost has been selected as the Financial Criteria since initial capital funding is usually funded separately.

From Figure 6-2 it can be seen that the WSPo has the highest ranking at 57 points, which is 124% higher than the second highest, the IAPS. It is interesting to note that the while the

WSPo has remained consistently the highest ranked technology, the rankings for the CW and IAPS have reversed.

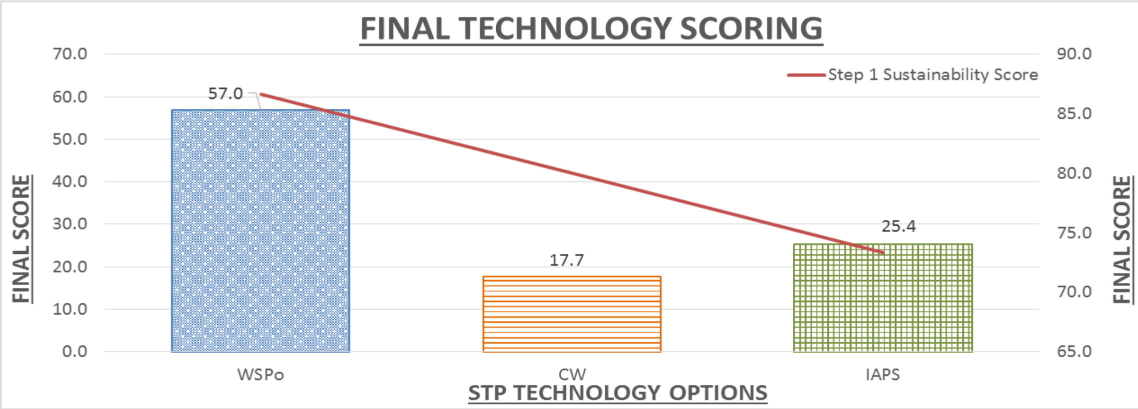


Figure 6-2 : Technology Scoring

6.7 SECTION SUMMARY

This section concludes a 3 stage analysis process by evaluating anticipated challenges which can be experienced in the study area and proposes solutions to them.

In Section 6.2 it was indicated that in some cases legislation is applied according to the letter and not to the intent. This leads to technologies having to be selected for compliance purposes without considering the impact it has on sustainability. The challenges with funding and cost recovery was highlighted in Section 6.3. The indigent nature of the study area makes the beneficiaries as well as WSA very dependent on grant funding for implementation of projects and for sustaining them thereafter.

Section 6.4 focussed on identifying local implementation challenges. The challenges mostly revolves around community support for the project. The major community requirements focusses on providing local staff to operate the STP, staying out of the site and committing to using the effluent. The remote nature of the study area also complicates the provision of chemicals and spare parts on time.

In Section 6.5 solutions to the challenges identified are provided. It is concluded that the local legislative environment will not change soon, thus technologies should rather adapt to using legislation to maximum benefit. Solutions should rather focus on re-using effluent locally with buy-in from all stakeholders.

Section 6.6 rounds off this Analysis Stage by performing a sustainability scoring of the realistic technologies. The outcome of the scoring would suggest that the WSPo is the most suitable technology for the study area.

Section 6 have assisted in answering the following research questions:

Question 3: *How applicable are these options to be used on a large scale?*
Question 5: *Why is the DWS so resistant to permitting high-volume low technologies?*
Question 6: *What community challenges are likely to be experienced in operating wastewater treatment works?*
Question 8: *What risks exist to the South African policies if high volume low technology options are used?*

Question 9: *What are the financial implications for implementing such high volume low technology options?*

Question 10: *How will the community benefit from the selected technology? (e.g. involvement in O&M and agricultural re-use of effluent)*

7. DISCUSSION OF RESULTS

7.1 SECTION INTRODUCTION

This sections provides a summary of the results obtained through this research. While the research provided insight to many peripheral aspects, only those relevant to answering the research questions are provided in this section.

The approach followed to collect information on the research topic is first summarised. The success obtained and any lessons learnt are also provided. Thereafter the main compliancy issues are identified and the ability for the realistic STP options to comply, evaluated.

The ability for the STP options to overcome certain local practical challenges are summarised. These challenges were identified during the field investigations and Stakeholder Engagement. Following this, the cost implications of the options are summarised and compared with each other.

The most important advantages and disadvantages of the realistic technologies, which were identified during all three analysis stages are then reported on. This Section concludes with reflecting on the definition of "Appropriate Technology" and how the STP Options satisfy this definition.

7.2 INFORMATION COLLECTION

Information for this research was collected through three avenues, namely:

- Literature reviews
- Stakeholder engagement
- Field investigations.

In Section 2, an initial literature review was performed to determine the current body of knowledge and identify any research shortfalls. Research methodologies from previous literature were also evaluated for local adaptation. The main sources of information were from institutional websites and research publications.

It was found that while a plethora of literature was available on sewage treatment, it posed quite difficult to obtain peer reviewed literature specific to appropriate technology selection in a rural environment. Peer reviewed research papers of South African origin were even more scarce.

The research topic and literature reviews were used to structure questions as part of the Stakeholder Engagement process. Stakeholder Engagement was performed by initial questionnaires in the Stage 1 Analysis Stage, followed up by interviews in the Stage 3 Analysis Stage.

The response rate for the questionnaires were very low. The confidence level in this feedback as being representative of the entire study area is therefore seen as medium-to-low. The reasons cited for the low response rate was time limitations and unable to answer the questions.

Due to time restriction on the part of the author, field investigations were limited to three STP visits and stakeholder interviews to five interviews. Findings from the field investigation were also used to develop questions for the interviewers. Through these interviews, stakeholders provided the author with additional literature to review for inclusion in the study.

The time limitations caused the stakeholder engagement to be very one-dimensional. It was attempted to improve the accuracy of the information through having overlapping questions for various stakeholders. This tested the response of one stakeholder against another's and triangulated the feedback received.

7.3 COMPLIANCY WITH POLICIES AND LEGISLATION

In order for any STP to be built, an Environmental Authorisation is required. The details of this process is discussed in Section 4.3. Prior to the operation of the STP, a Water Use License will also be required. These processes are interlinked and both need to comply with the National Water Act. Government Officials evaluate these applications and are responsible for the interpretation and final application of the various portions of legislation.

The NWA also allows a General Authorisation (GA) for certain water-related activities. In terms of sewage treatment, the GA provides guidelines on the following:

- Limits to sewage discharges to treatment ponds
- Sewage storage volume limitations
- Effluent quality criteria for irrigation
- Effluent quality criteria for discharge to a water resource (Either General or Special Standards)

Figure 2-5 indicates that the entire study area falls within the GA. The General Effluent Discharge Limits to a Water Resource applies to almost the entire study area, with only a portion in the inland requiring Special Discharge Standards.

In addition to the Irrigation standards provided in the NWA, DWS has also provided Water Quality Guidelines for the application of water in different manners. The compliance of the three STP Options with the GA and DWS Water Quality Policies were evaluated for the following three Effluent Disposal Scenarios:

- Scenario 01: Compliance with GA for Effluent Discharge to a Water Resource
- Scenario 02: As per Scenario 01, but with relaxed nutrient removal criteria
- Scenario 03: Compliance with NWA General Effluent Standards for irrigation

Table 7-1 summarises the results for these Scenarios:

Table 7-1 : STP Compliance evaluation

COMPLIANCE ASPECT	SCENARIO 01			SCENARIO 02			SCENARIO 03		
	WSPo	CW	IAPS	WSPo	CW	IAPS	WSPo	CW	IAPS
Water Resource Discharge	x	x	✓	n/a	n/a	n/a	n/a	n/a	n/a
Pond Storage Volumes	x	x	x	✓	✓	✓	✓	✓	✓
NWA Irrigation Quality	✓	✓	✓	✓	✓	✓	✓	✓	✓
DWS Irrigation Quality	✓	✓	✓	✓	✓	✓	(✓)[1]	x	x
DWS Livestock Drinking Quality	✓	✓	✓	✓	✓	✓	(✓)[2]	(✓)[2]	(✓)[2]

Table Notes: 1: Will comply if DWS quality guideline uses for relaxed E.Coli limit. (Section 5.7)
2: Will comply if STP is designed for sufficient E.Coli removal.
"x": Does not comply with requirements "✓": Complies with requirements

From Table 7-1 it can be seen that the storage volume limitation prevents any STP Option from being used for effluent disposal to a Water Resource. For Scenario 01 only the IAPS can provide the required effluent quality. All technologies comply with the Scenario 02 requirements and 03 requirements. However, in Scenario 03 it is only the WSPo which can easily also comply with the DWS guidelines for TSE re-use for agricultural purposes.

In Section 5.7, the sludge quality which the STPs are believed to provide were determined to be compliant with local agricultural and land disposal requirements.

The staffing levels recommended by the NWA were evaluated in Section 5.5. It was determined that process controllers require either a Grade 10 diploma (WSPo and CW) or Grade 12 certificate (IAPS) to be eligible to become a process controller at one of the STPs. Based on the local populace's level of education, it is believed that Process Controllers can be sourced from the local community.

7.4 PRACTICALITY OF OPTIONS FOR LOCAL IMPLEMENTATION

In Section 4.4, it was determined that pond systems are the prominent technology being applied in the study area. With all three STP Options being pond-related, local stakeholders will be reasonably well acquainted with these technologies. The WSPo is the technology stakeholders are most familiar with.

Through the field investigations performed in Section 4.4, sludge removal from ponds was identified as a challenge. Local supervisors recommended that sludge holding ponds should be allowed for, into which the sludge from Anaerobic ponds can be drained.

Construction materials required for each of the STP Options was evaluated in Section 5.4. It was concluded that the WSPo uses the most local resources of all three options. Figure 5-3 in Section 5.6 indicates that both the WSPo and CW requires the smallest O&M team. All activities occurring within a month can be performed by the local team, which can be sourced from the local community. However, the CW requires more O&M activities to be performed by this local team, which could become too onerous for them to maintain.

Interviewed Stakeholders have indicated that HDPE Pond linings are not in their opinion required. However, government officials might request their inclusion in order to protect local groundwater sources. These linings have a major cost implications. The costs provided in Section 5.8, allowed for HDPE linings for all ponds upstream of the Maturation Ponds.

Interviews with Stakeholders have indicated that they believe the local communities are willing to use the TSE for irrigation. They are however of the opinion that any more direct use of effluent, such as for fish farming, will not be supported by the local communities. Community buy-in is required to consistently use the effluent for agricultural purposes. A simplified and ease-of-access system to supply and distribute the irrigation water is thus required.

7.5 COST IMPLICATIONS OF TECHNOLOGY

The economic performance of the different STP Options were evaluated in Section 5.8. Funding options and cost recovery were also briefly discussed and further elaborated on in Section 6.3. Due to the lack of an income-generating populace in the study area, the WSA and WSP are dependent on grant funding from national treasury. These funds are used to implement new infrastructure projects and for the O&M of their existing infrastructure.

Capital costs are funded through the MIG, provided that the costs for the STP are not unreasonable. The equivalent annual costs for O&M and Capital Replacement Costs (OCEAC) are typically either funding through the municipal equitable share or the indigent grant. It was concluded that the most important cost-related metrics for evaluation purposes are:

- Capital Cost/HH
- O&M/HH
- NPV/m^2

The MIG provides guidelines on the above according to which the financial viability of projects are evaluated. Table 7-2 compares the different STP Options against each other, using the above cost metrics:

Table 7-2 : Cost Comparison of STP Options

COST METRIC	SCENARIO 01			SCENARIO 03		
	WSPo	CW	IAPS	WSPo	CW	IAPS
Capital Cost/HH	R 18 758	R 17 013	R 24 012	R 5 768	R 4 787	R 13 504
O&M/ HH	R 332	R 344	R 1 733	R 308	R 311	R 1 705
NPV/ m^2	R 247	R 268	R1 430	R 1 009	R 1 417	R 4 051
Capital Cost/HH	MIG: R 18k – R 23k per HH					
O&M/ HH	MIG: R 617 per HH					

For Scenario 01, all three STP technologies have too high Capital Cost / HH to justify funding be awarded for its implementation. Therefore the only financially viable option is to implement a STP technology with effluent disposal according to Scenario 03: Utilising TSE for local irrigation.

For both Scenarios 01 and 03 the IAPS has too high O&M costs / HH when compared with the MIG Guidelines. The WSPo has the lowest O&M Cost / HH and NPV/m^2 of all STP Options for all Scenarios.

It can thus be concluded that considering only the three STP options listed above, the most financially viable for sewage treatment in the study area is the WSPo.

7.6 ADVANTAGES AND DISADVANTAGES OF TECHNOLOGIES

Table 7-3 summarises some advantages and disadvantages for each of the realistic STP options. These were identified through the course of this study, with Section references also provided.

Table 7-3 : STP Advantages and Disadvantages

STP	ADVANTAGES	DISADVANTAGES
WSPo	➢ Pond systems have high buffer potential in case of component failure / system overload. Section 4.6 ➢ Low costs to build a STP that must comply with irrigation standards. Section 5.8 ➢ Has the lowest O&M Costs of all STPs. Section 5.8 ➢ Is the prominent technology currently used in the study area. Section 5.8	➢ Pond systems have difficulty to achieve all effluent quality parameters for discharge to a water resource according to the NWA GA. Section 4.6 & 6.2 ➢ Sludge removal can be complicated if not designed for from start. Section 4.4 ➢ Requires the largest land area to comply with GA Discharge Standards to a Water Resource. Section 5.4 ➢ Very high costs to build a STP that must comply with effluent discharge to a water resource. Section 5.8
CW	➢ Community can use their agricultural skills to maintain the CW. Section 4.6 ➢ System functions under gravity, thus does not require electricity. Section 4.6 ➢ Use the smallest area of land to treat sewage for compliance with GA Discharge Standards for irrigation. Section 5.7 ➢ Most O&M Activities can be performed by staff procured from the local community. Section 5.6	➢ Pond systems have difficulty to achieve all effluent quality parameters for discharge to a water resource according to the NWA GA. Section 4.6 & 6.2 ➢ If reeds are not maintained then the system can fail. Section 4.6 ➢ Requires the second largest land area to comply with GA Discharge Standards to a Water Resource. Section 5.4 ➢ Has the most activities to be performed within a month. Section 5.6
IAPS	➢ Community can be involved with most of the O&M activities. Section 4.6 ➢ Land in rural areas have low value due to large areas being available. Section 4.6 ➢ Use the smallest area of land to treat sewage for compliance with GA Discharge Standards to a Water Resource. Section 5.7 ➢ Only technology apply to comply with NWA GA standards for discharging to a water resource. Section 5.7	➢ Community can be involved with some of the O&M activities, but might struggle with some of the Concrete and M&E related activities. Section 4.6 ➢ Limited M&E components, but will still require electricity. Section 4.6 ➢ Requires the largest land area to comply with GA Discharge Standards for irrigation purposes. Section 5.4 ➢ HRAP system not required for sewage treatment to comply with irrigation standards. Section 5.7

Annexure 22 provides a more comprehensive list of advantages and disadvantages. By evaluating the information provided in the annexure, it can be seen that:

- WSPo has more advantages than disadvantages (72% vs 28% split)
- CW has about the same amount of advantages than disadvantages (48:52% spit)
- The IAPS has less advantages than disadvantages (30:70% split)

From the information above it would appear the WSPo is more beneficial for the study area.

7.7 APPROPRIATENESS OF TECHNOLOGY

As mentioned in Section 3.2, an appropriate technology demonstrates a balance between the three spheres of overall sustainability. These are: Economic, Environmental and Societal sustainability. A trade-off between these options are however required due to the BATNEEC principle. According to BATNEEC the selected technology must not entail excessive costs.

The most sustainable technology options were selected through the Sustainable Ranking process in Section 4.8. Figure 7-1 illustrates the sustainability of these options based on a pre-determined set of criteria, as descried in Section 6.6 and Annexure 21.

The second step in evaluating the realistic STP options' sustainability utilised a pairwise comparison process to evaluate the different technologies against each other. Evaluation was performed using a standard set of criteria which was developed in consultation with a local WSPr. These criteria also included the factors recommended by Mburu et al. (2013) in Section 2.13, which needed to be considered when selecting an appropriate technology.

Figure 6-2 and Figure 7-1 illustrates both rounds of sustainability evaluation. It can be seen that the WSPo is consistently higher, and sustainably more balanced between the three spheres of sustainability, than the other options.

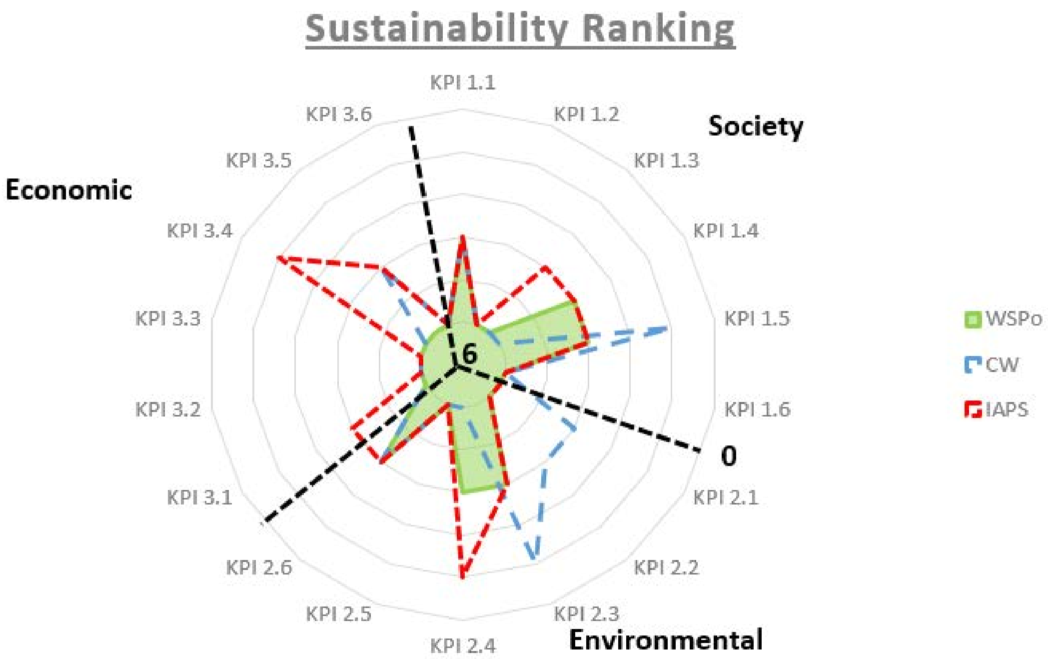


Figure 7-1 : Sustainability Ranking of Realistic Technologies

In order to confirm that the realistic options comply with BATNEEC, their costs were also evaluated. The costing has been discussed in Section 7.5 and it has been concluded that the method of effluent disposal has significant influence on the technology costs. In order to comply with BATNEEC (and BPEO) the effluent needs to be re-used locally. Should legislation, authorities or other stakeholder require the effluent to be discharged to the local water resourced. It is quite likely that in order to comply with BATNEEC, there will be a trade-off between the three spheres of sustainability, resulting also in a less desired BPEO.

Assuming that effluent re-use will be possible, the WSPo STP technology has consistently proven to be the preferred technology for local application.

7.8 SECTION SUMMARY

As mentioned in the Section Introduction, this section summarises the major findings of the research.

Section 7.2 discussed the method of information collection and what the major challenges were. Collected information mostly originated from literature reviews and stakeholder engagement. The accuracy of the collated information was influenced by the low response rate to questionnaires and time limitations. Time limitations prevented extensive stakeholder interaction, which was originally intended.

Section 7.3 summarised the most important legislative and policy requirements, for technology selection. It was identified that the effluent quality for different disposal options and the storage volume limitations, have the most influence on the selection process. The effluent quality required in the Effluent Disposal Scenario 01 is too high for any of the technologies to comply with, while not exceeding the storage limitations. All technologies will comply with Scenario 02 and Scenario 03. The WSPo is also the easiest to adjust for compliance with the additional agricultural re-use quality guidelines provided by DWS.

Section 7.4 looked at the practically of the options. Pond systems are familiar to the local stakeholders, thus no major problems are foreseen. Issues with sludge management and the requirement for pond linings were identified, and could be resolved during the design stage. The WSPo will mostly use local materials and the O&M activities can easily be done by local communities. The O&M activities for the CW and IAPS are more intensive than for the WSPo.

Section 7.5 summarised the cost implications of the various options. It was concluded that the Effluent Disposal Scenario 01 causes none of the technologies to be financially viable. For Scenario 03 only the WSPo and CW are financially viable when compared with the industry benchmark.

In Section 7.6 the advantages and disadvantages of the various STP options are compared. It was shown that the WSPo has more advantages than disadvantages. The IAPS has the poorest comparison, with less advantages than disadvantages.

Lastly, in Section 7.7 the different STP Options where compared against the original definition of “Appropriate Technology”. It was indicated that the effluent disposal options (Scenarios 01, 02 and 03) influences the appropriateness of the technology. In order for the technologies to be appropriate, Scenario 03 needs to be selected.

The IAPS has proven the least appropriate across all three Scenarios. The CW is almost as appropriate as the WSPo, but a lower sustainability score was calculated for the CW. The WSPo has consistently proven to be the most appropriate when all factors of appropriateness are considered.

Considering the local application of the STP Options, the WSPo has been identified as the technology that complies the most with the BATNEEC and BPEO principles.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 SECTION INTRODUCTION

This section completes the research by reflecting on what has been achieved and confirming what has been concluded.

The original aims, objectives and methodology are first evaluated and aspects which have posed problematic to address, highlighted.

The preferred technology for implementation in the study area is then confirmed. Motivations for the selection is provided and further substantiated by referring to the various Sections within this report which have contributed to selecting this technology.

Through the course of this research, certain research gaps have been identified. Those gaps which the industry can benefit from by resolving, are identified and summarised in this section. Possible considerations for research into these gaps and how to resolve them are also provided.

8.2 EVALUATION OF AIMS, OBJECTIVES AND METHODOLOGY

8.2.1 EVALUATION OF STUDY AIMS

As mentioned in Section 1.5, the aim of this research was to:

"Select the most appropriate technology for sewage treatment in the rural areas of the Eastern Cape (Study Area)"

This aim forms the main theme in the title of this research:

"Appropriate Technology Selection for Sewage Treatment in the Rural Eastern Cape".

The Study Area was defined in Section 1.3, as part of those portions of the Eastern Cape which formed part of the historic Transkei "Homelands". The study boundaries were selected as the Local Municipal Boundaries falling within the old Transkei.

The definition of "appropriate" was selected through the Literature review in Section 2.13. The definition was firmed up in Section 3.2, as part of the Research Methodology.

As mentioned in Section 1.4, this research focusses on the hypothetical scenario of providing the whole of the study area with waterborne sanitation. Thus the sewage treatment technologies focussed only on off-site options.

The selection procedure followed a three stage analysis process and is discussed in Section 3. A consolidated list of South African and International Technologies went through a first round sustainability analysis to select the top three technologies for the local context. These were then evaluated based on their technical, institutional and economic performance. As the last step of the analysis their ability to be adapted for local challenges were discussed and through a Multi-Criteria Decision Making process in Section 6.6, they were provided with an overall ranking for preference.

As can be seen from the summary above, a systematic process was followed to understand the current context and select an off-site sewage treatment technology which is most appropriate for the study area.

8.2.2 EVALUATION OF STUDY OBJECTIVES

To achieve the study objectives, responses to local challenges had to be obtained. Furthermore, specific research questions also had to be answered. These challenges and questions are listed in Section 1.5.

Responses to the local challenges were found mostly through Stakeholder engagement. Engagement was done either through Questionnaires or Interviews. These challenges are addressed in Sections 5 and 6.

Research Questions were answered by a combination of the Literature Review in Section 2, the stakeholder engagement mentioned in the preceding paragraph and the Analysis Stages (Section 4 - 6).

In general, these challenges and questions were adequately addressed as part of this research. The following questions and challenges had some limited success and will be shortly discussed below:

Research Challenge 01: How willing is DWS to change its policies?

Time limitations have prevented this issue to be addressed in depth. It is foreseen that the legislative environment will not change and that any solution needs to comply within this legislative environment. Stakeholders have indicated that the effluent standards favour advanced technologies which would typically be used in a developed country. South Africa is both a developed and a developing country, thus the legislation does pose some problems.

In reflection, this research challenge has not become as important as originally thought. This is because the local application can easily comply within the local legislation.

Research Challenge 02: Do local communities have the ability to learn new skills?

This challenge was only addressed through Social Questionnaires and due to the low response rate could possibly not be a fair reflection of the entire study area. The O&M requirements did consider using local resources as much as possible and considering the nature of work, this could easily be achieved.

Research Challenge 03: How willing are local authorities/service providers to transfer responsibilities for operating and maintaining treatment works to the local communities?

This challenge was only addressed through Questionnaires and Interviews. Due to the low response rate this could possibly not be a fair reflection of the entire study area. Through stakeholder interviews it became apparent that for governing reasons the responsibility will not be handed over to the local community. The complexity of service delivery and the role of the local community is a research topic on its own. In order to not detract from the aim of this research, this issue was not further considered.

Research Question 03: How applicable are these options to be used on a large scale?

This question focussed on the premise that high volume, low technology options could possibly be used in the study area, but due to legislative limitations they were not permitted.

However, as the research progressed it became apparent that the volume of sewage that will be treated will be much less than originally anticipated. Thus the issue with local legislation is no longer applicable.

Research Question 04: Are there any success stories for these treatment options? (Local and/or International)

Local and international success stories were referenced to in Section 2. They were also used to evaluate local performance against in Section 5. However, since this question was a follow-up on research question 03 above, its relevance became less important. The types of realistic technologies selected were also not very controversial for the size of application.

Research Question 05: Why is the DWS so resistant to permitting high-volume low technologies to be used?

Through the review of legislation it was confirmed that neither DWS nor the South African legislation has preference for a specific technology. The only requirement is that it needs to comply with prescribed effluent standards. The National Water Act's General Authorisation also prevents the use of pond systems larger than 1Ml/d. For this study the pond volume will be 0.5Ml/d, thus does not pose a problem.

Initially there was a wrong perspective of DWS's position on this matter, which led to the inclusion of this research question. In Section 6 the challenges that local stakeholders have with DWS's interpretation of legislation was alluded to. Considering the size of STPs proposed for implementation in the study area, it was rather decided to not address this issue in further detail as part of this study.

Research Question 06: What community challenges are likely to be experienced in operating wastewater treatment works?

With reference to Research Challenge 01 above, this research challenge became less relevant and was not further evaluated in this research. It is briefly discussed in Section 6.4.

Table 8-1 below evaluates to what degree this research has been able to achieve the various objectives and if there are any outstanding issues that should still be addressed.

Table 8-1 : Evaluation of Research Objectives

Objective No	Research Objective	Achieved through Sections
01	Objective: To understand the motivations behind current South African Policies. Degree of Achievement: **Medium-High**. The literature review and implementation of local legislation contributed much to understanding the motivations. This was further informed by the Stakeholder engagement. Due to time limitations the origin of the standards prescribed in the legislation and potential adjustments to them could not be firmly addressed	Section 2.4 – 2.6 Section 4.3 Section 4.5 Section 6.2
02	Objective: To identify low-technology wastewater treatment options which can be used on a large scale. Degree of Achievement: **High.** Different technologies were identified and the typical application scale also determined	Section 2.7 Section 2.11 Section 2.14 Section 4.4 Section 4.6
03	Objective: To understand the O&M requirements and associated costs for the various treatment technology options available. Degree of Achievement: **High.** Each of the three realistic technologies were evaluated based on their O&M requirements and associated costs.	Sections 5.5 Section 5.6 Section 5.8
04	Objective: To address the applicability of such technologies to South Africa, with specific focus on the rural areas of the Eastern Cape. Degree of Achievement: **High.** WSPos are currently being applied in the Study Area. Both the CW and the IAPS also has STPs in South Africa. O&M and staffing requirements also considered the local context. Any issues with adapting the technology for local conditions were also directly addressed	Section 2.7 Section 4.4 Section 4.5 Sections 5.5 Section 5.6 Section 6.4 Section 6.5
05	Objective: To identify the social and competency challenges faced by the local community or water service providers in operating and maintaining sewage treatment works. Degree of Achievement: **Medium.** Input from the Communities and WSPs mostly occurred through Literature Reviews, Stakeholder Engagement and Field investigations. A poor response rate to the questionnaires were received. Due to limited time, limited site visits and stakeholder engagement occurred. This was also mostly through convenience sampling, which means the sample size could not be a fair representation of the whole study area.	Section 2.3 Section 4.2 Section 4.5 Section 6.4 Section 6.5

8.2.3 EVALUATION OF RESEARCH METHODOLOGY

The research methodology followed the process depicted by Figure 1-4, as replicated below in Figure 8-1.

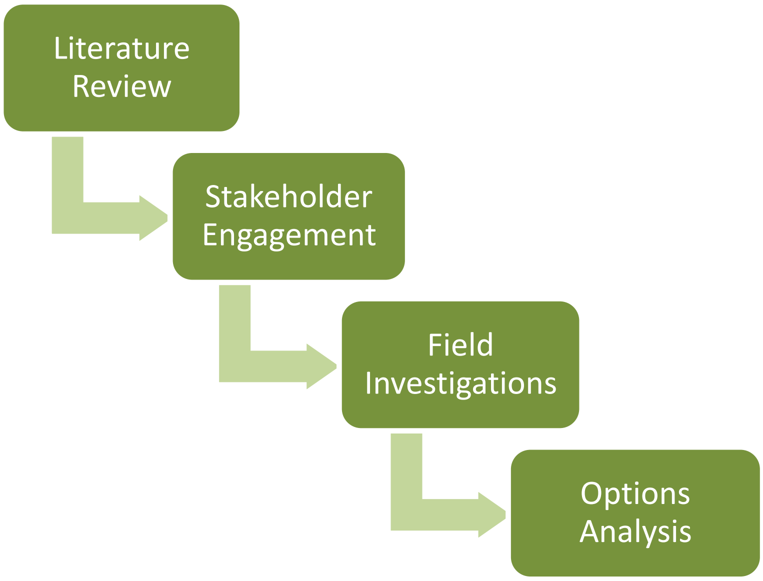


Figure 8-1: Research Approach Structure

The research methodology followed a very systematic process which assisted in converging to a preferred solution. This convergence already started to indicate a preferred option by Stage 2 of the Analysis (Section 5).

Some reflections on the research methodology's efficiency is provided below:

Literature Sourcing

The original literature review was based on the Detailed Research Plan and perception of the local challenges. As the research progressed and stakeholders were engaged with, it became apparent that perceptions of the problem was not in all cases true. Furthermore, additional literature and alternative technology were recommended by stakeholders as the research continued. While an attempt was made to incorporate their comments, the author is of the opinion that some improvements to this research could have been made, had the supplementary information been used from the start.

Accuracy of Results

The accuracy of the research has been severely influenced by limited time, as discussed in Sections 3.8 and 3.9. Very small sampling sizes and poor response rates to questionnaires can also influence the relevance of these findings when applied to the whole study area.

Alternative technology options

The difficulty with this research is that the Study Area is quite large. Different social, political or environmental dynamics could be at play in different areas of the study area. These differences could mean that a technology in one area is possibly not the preferred technology in another.

As the study progressed it also became apparent that the method of effluent discharge influences the type of technology to be used. It was realised that there is not one specific technology suitable for all applications. While it is disappointing that the research did not identify this issue from the start, the systematic research approach has shown resilience by being able to identify this issue.

The need for a Pilot Plant

The initial thoughts were that a Pilot Plant would be necessary to confirm the use of the selected technology in the study area. Following the selection of the three most appropriate technologies it however became apparent these are technology currently being applied in South Africa and no Pilot Plant is required.

8.3 PREFERRED TECHNOLOGY OPTION

The preferred technology option is the one which is most appropriate for the study area. The definition of "appropriate" has been provided in Section 3.2 and is very much dependant on sustainability and the adequate integration of the SHTEFIE aspects in the final application.

During the Stage 1 Analysis performed in Section 4, the following three realistic technologies were selected, using a first round sustainability evaluation:

- Waste Stabilisation Ponds (WSPo)
- Constructed Wetlands (CW)
- Integrated Algal Pond System (IAPS)

These technologies were subsequently evaluated in the Stage 2 and Stage 3 Analysis in order to select the Preferred Technology for local application. During the evaluation it was determined that the strength of the raw sewage and required effluent disposal method plays a vital role in selecting the most appropriate technology.

Assuming a strong raw sewage with a local agricultural re-use of treated sewage effluent (without disposing to a water resource), it was determined that the Waste Stabilisation Pond system is the most appropriate for local application.

The treatment process is discussed in detail in Sections 4 and 5.

The motivations for selecting the WSPo is provided in Table 8-2, with the reasons being categorised using SHTEFIE. References to the applicable research sections are also provided.

Table 8-2 : Motivations for Preferred Technology

Sustainability Aspect	Motivation for Selection	Section Reference
S Social	Staff can be locally procured to operate and maintain the STP. Effluent re-use for agricultural use is beneficial. CW & IAPS have same benefits	Section 5.5 – 5.7 Section 6.4
H Health	Can be designed to have a low health risk (E.Coli). Security fencing also allowed for to keep local villagers, especially children, out of STP Site. CW & IAPS have same benefits	Section 5.7 Section 6.5
T Technical	Treated Effluent complies with requirements for agricultural use. No electricity required to Operate the STP and no special spare parts required. CW has same benefits but the IAPS requires an electrical supply and the whole STP fails if the paddle wheel fails.	Section 5.4 Section 5.6
E Economic	Has the lowest operational costs meaning the WSA can procure funding for this option more easily compared with the other options. Uses land area more economically than other options with a NPV/m^2 of R1,007/m2. IAPS has highest overall costs.	Section 5.8 Section 6.3
F Financial	Has the second lowest capital costs and which is about a third of a WAS system. Funding from MIG is thus very likely.	Section 5.8 Section 6.3
I Institutional	Has the lowest Daily and Weekly O&M Activities, which can all be performed locally without the involvement of the WSPr's central team. Technology is well known by local WSPr. CW has the highest O&M activities for the same period.	Section 4.4 Section 5.6
E Environmental	WSPo effluent quality complies with legislated parameters. Since it is used locally and not discharged into the local water resources the chance of pollution is less likely. Both CW and IAPS have same benefits, but have less of a retention time and thus less safety buffer in case process failure at the STP occurs.	Section 5.4 Section 5.7 Section 6.2 Section 6.5

It needs to be emphasized that there is not one technology that will always be the best suited for all situations. Should the parameters change within which this technology has been selected, another technology might be better suited and the evaluation process needs to be revisited.

8.4 RECOMMENDATIONS FOR FUTURE RESEARCH

Through the course of this research, certain opportunities for future research has been identified. These are briefly described below, with additional information provided in Annexure 23.

Evaluation of the current sewage effluent standards to promote sustainability and encourage development considering the current disparities within the South African developmental status

As part of this research, stakeholder engagement indicated that the effluent discharge standards are too strict to be achieved with low-technology options. South Africa has major inequality with a country that has characteristics from both a developed and a developing country. It is proposed that the unilateral application of the current effluent discharge standards be revisited in favour of a matrix decision making process to select different effluent standards depending on the developmental status of the local authorities..

Establishment of a uniform approach to STP treatment efficiency scoring.

A universal coefficient is proposed that will assist in better interpreting the Costs/m^2 or m^2/PE commonly reported on in literature from different countries.

The problem with evaluating technologies using Costs/m^2 or m^2/PE, is that they are possibly not being evaluated on a comparative basis. It is difficult to compare the economic performance of the same technology between two countries since the socio-economic differences could be too big to reconcile. It is proposed to rather look at a more universal approach that transcends political boundaries. An option is to rather look at the biological processes to determine a removal efficiency coefficient.

Standardised Criteria for Sustainability Calculations for the South African Industry

Having a standard method of interpreting and implementing sustainability will be beneficial to the local industry. Policymakers will understand what their policies are to promote. Design Engineers will understand what their designs needs to comply with, while Clients in turn will now what to look for when Engineer's propose a specific technology for implementation.

Evaluation of the origin and motivation for the 1Ml/d limit to Pond-Systems.

Through engagement with Stakeholders it has become apparent that the origin of the 1Ml/d legislated limit on pond systems is uncertain. It is recommended that the origin of this limit be researched and challenged. If a pond limit is still required, it is recommended that research be performed into what a more realistic pond limitation should be. Any other control and monitoring requirements associated with the higher pond limitations should also be looked at.

8.5 SECTION SUMMARY

In conclusion, the Research Aims have been adequately and systematically addressed in the research. It was also concluded that some research challenges and questions were not as relevant as originally thought due to the nature of the study area. All research objectives were achieved to a medium-to-high degree of certainty.

The preferred technology for local application is the Waste Stabilisation Pond system. This selection is on condition that the effluent is used for local application and not to be discharged to the local water resources. The main reasons for this selection is the low capital and O&M costs and also the beneficial re-use of the effluent by the local community. The Constructed Wetland has not been selected due to the higher O&M intensity and lower safety buffer in case treatment failure occurs.

Some future research aspects have been provided which will assist in promoting development and sustainable technology selection in South Africa. The removal efficiency coefficient can also be used as a global benchmark for comparison purposes.

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OR
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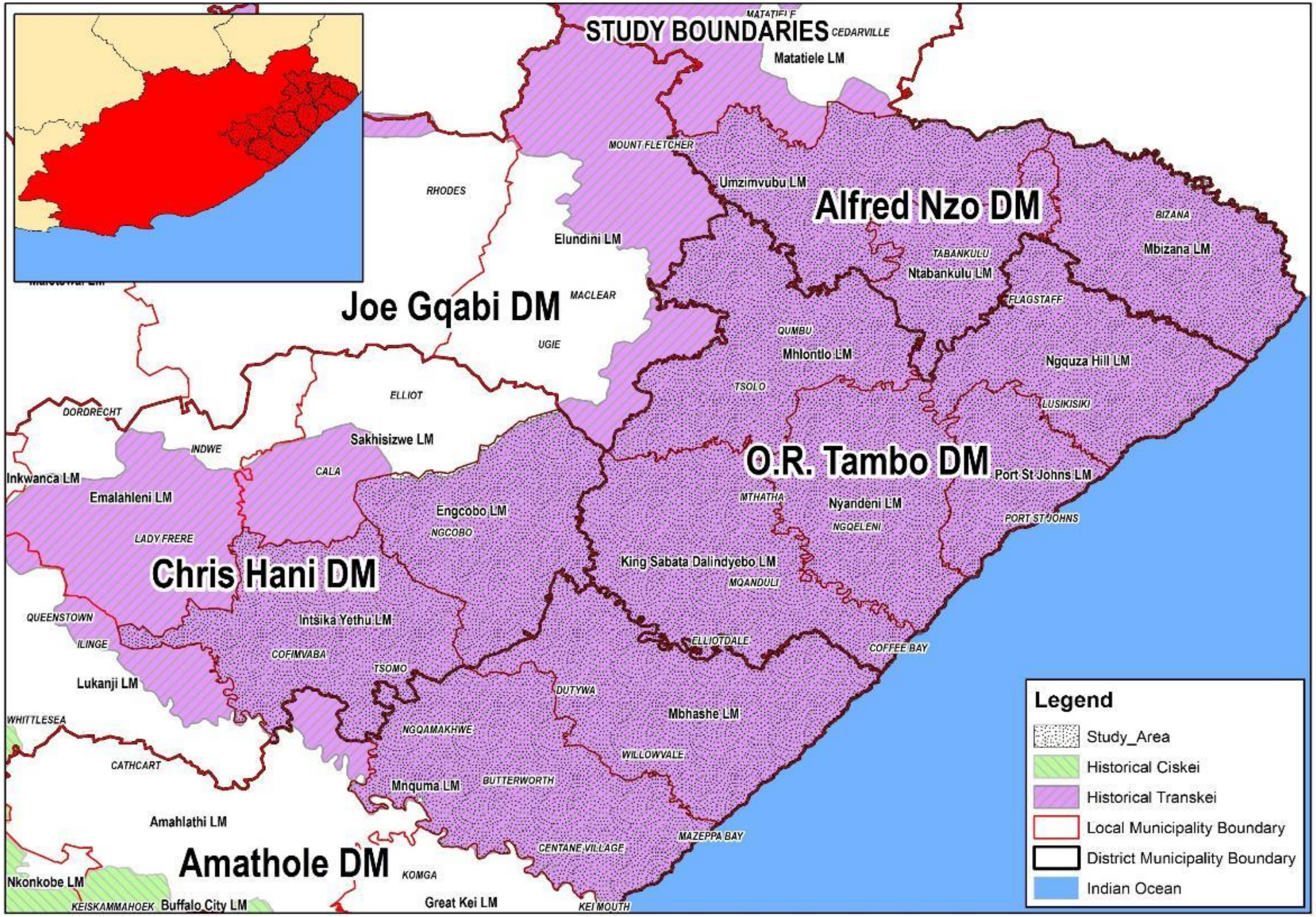
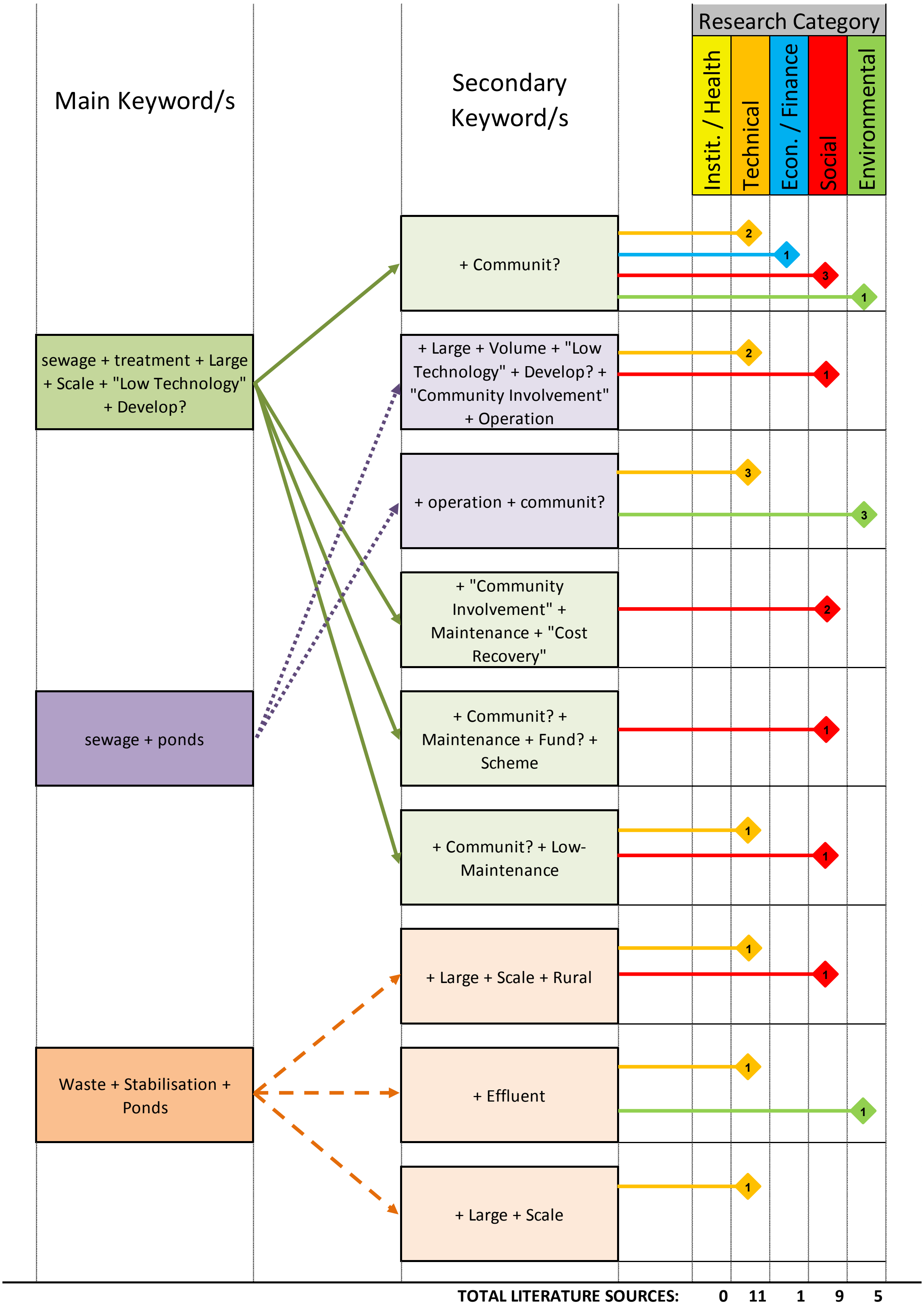
ANNEXURES

Annexure 1: Study Area Boundaries



Annexure 2: Keyword Search Methodology

Figure below depicts the typical search methodology applied in this research.



Through trial and error a combination of Main and Secondary Keywords was able to provide information which is suitably related to this study's research topic. Each literature piece was then recorded in a Literature Matrix and using the scoring described in Section 2.2, the literature was ranked in order of relevance to this research topic. The highest ranking literatures are illustrated below.

RESOURCES							
Doc ID	Search Method/ Source	Keyword used	Paper Name	Website	Link to paper	Research Category	Keywords listed in source
1	Science Direct via Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit?	Decentralised approaches to wastewater treatment and management: Applicability in developing countries	http://www.sciencedirect.com	Sources\1-s2.0-S00	Technical	Wastewater; Decentralised management; Applicability; Developing countries
2	Google Scholar	sewage + ponds + Large + Volume + "Low Technology" + Develop? + "Community Involvement" + Operation	Wastewater treatment technology adapted to small and medium communities in the Mediterranean region	http://[illegible]	Sources\[illegible]	Technical	n/a
3	Science Direct	sewage + ponds + operation + communit?	Economic evaluation of sewage treatment processes in India	http://www.sciencedirect.com	Sources\1-s2.0-S00	Environmental	n/a
4	Science Direct via Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit?	Sustainability of wastewater treatment technologies	http://www.sciencedirect	Sources\1-s2.0-S0	Social/ Economic/ Environmental	Wastewater treatment; Activated sludge; Lagoon; Land treatment; Sustainable development; Indicators; Design
5	Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + "Community Involvement" + Maintenance + "Cost Recovery"	[illegible] DETERMINING AFFORDABLE AND SUSTAINABLE SANITATION DEMAND IN [illegible]	http://www.wrc.org.za/	Sources\1666-1-08	Social	n/a
6	Science Direct	sewage + ponds + operation + communit?	The effect of sewage effluent on the physico-chemical and biological characteristics of the Sand River, Limpopo, South Africa	http://www.sciencedirect	Sources\1-s2.0-S1	Environmental	Macroinvertebrates; Self-purification; Suitability; Sewage effluent; Pollution
7	Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit? + Maintenance + Fund? + Scheme	Development of a Community Based Low Cost Domestic Wastewater System for Kandahar City, Afghanistan	http://www.faculty.[illegible]	Sources\[illegible].pdf	Social	n/a
8	Google Scholar	sewage + ponds + Large + Volume + "Low Technology" + Develop? + "Community Involvement" + Operation	CHOOSING THE APPROPRIATE TECHNOLOGY FOR SEWAGE TREATMENT IN SMALL NOVA SCOTIA COMMUNITIES	http://www.collectionscan	Sources\mq24327.p	Technical / Social	n/a
9	Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit? + Low Maintenance	Application of science and technology in rural areas (ASTRA): An Ethiopian context	http://www.academicjourna	Sources\article[illegible]	Technical / Social	Application of science and technology in rural areas (ASTRA); economic development; Ethiopia
10	Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + "Community Involvement" + Maintenance + "Cost Recovery"	MAKING THE CASE FOR SANITATION	http://www2.ids.ac.uk/	Sources\[illegible]	Social	n/a
11	Taylor & Francis	Waste + Stabilisation + Ponds + Large + Scale + Rural	Community-based approaches for addressing the urban sanitation challenges	http://www.tandfonline.c	Sources\09603123	Social	urban basic services; infrastructure planning; environmental sanitation; household; centralised approach; community/individual sanitation
12	Science Direct	sewage + ponds + operation + communit?	Distribution and spatial variability of sludges in [illegible] stabilisation pond systems [illegible] over long period of time	http://www.sciencedirect	Sources\1-s2.0-S00	Technical	Stabilisation ponds; Sludge accumulation rate; Desludging; Sludge characteristics; Multivariate analysis
13	Science Direct	sewage + ponds + operation + communit?	Maturation ponds. Experiences in their operation in the United Kingdom as a tertiary treatment process for a high quality sewage effluent	http://www.sciencedirect	Sources\1-s2.0-00	Technical / Enviro	n/a
14	Science Direct via Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit?	Urban wastewater treatment technologies and the implementation of discharge standards in developing countries	http://www.sciencedirect	Sources\1-s2.0-S14	Technical / Social	Developing countries; Discharge standards; Institutional development; Wastewater treatment; Water quality legislation
15	Science Direct	sewage + ponds + operation + communit?	A review of the sustainable value of effluents and sludges from wastewater stabilization ponds	http://www.sciencedirect	Sources\1-s2.0-S0	Technical	Sustainability; Stabilization; [illegible]; Ponds; Effluent; [illegible]; Aquaculture; [illegible]; Algal protein
16	Taylor & Francis	Waste + Stabilisation + Ponds + Effluent	Rethinking natural, extensive systems for tertiary treatment purposes: the high-rate algae pond as an example	http://www.tandfonline	Sources\[illegible]	Technical / Enviro	Two-stage subflow [illegible] (VTSUAWs); High-rate algae pond; Nutrients; Faecal coliforms; Ammonia stripping; Phosphate precipitation
17	Science Direct via LCP	Waste + Stabilisation + Ponds + Large + Scale	Performance [illegible] and economics analysis of waste stabilisation ponds and horizontal subsurface flow constructed wetlands treating domestic wastewater: A case study of the [illegible] wastewater treatment works	http://www.sciencedirect.com	Sources\1-s2.0-S00	Technical	Waste stabilisation ponds; Horizontal subsurface flow constructed wetlands; Performance; Economics; [illegible]
18	Taylor & Francis	Waste + Stabilisation + Ponds + Large + Scale + Rural	Domestic wastewater management in South and Southeast Asia: the potential benefits of a decentralised approach	http://www.tandfonline	Sources\15-75 [illegible].pdf	Technical	centralised and decentralised wastewater management; [illegible] wastewater; sanitation conditions; South Asia and Southeast Asia
19	Google Scholar	sewage + treatment + Large + Scale + "Low Technology" + Develop? + Communit?	Community-based Technologies for Domestic Wastewater Treatment and Reuse: Options for Urban Agriculture	https://118.96.[illegible]	Sources\domestic[illegible]	Social	n/a

	SOURCE SCORING						RESEACRH ASPECTS										
Doc ID	Quality of Citation (10)	Peer Reviewed (15)	Relevance to Topic (40)	Recency (15)	Objective Approach (20)	Total (100)	Ponds/ WTS	Large Scale	Inst. Aspects?	RSA Policies	Effluent Quality	Rural Areas	Developing Countries?	O&M Aspects	Cost considerations	Community Involvement	Correlation Index
1	7	13	21	12	15	68	y		y		y	y	y	y	y	y	8
2	3	9	24	10	12	58	y		y		y	y	y	y	y	y	8
3	8	12	32	12	16	80	y	y			y	y	y	y	y		7
4	7	13	31	12	15	78	y	y	y		y			y	y	y	7
5	6	12	30	13	15	76			y	y			y	y	y	y	6
6	8	12	28	14	14	76	Y		y	y	y		y	y			6
7	7	13	26	12	15	73	y		y		y		y	y	y		6
8	6	13	30	8	16	73			y		y	y		y	y	y	6
9	7	11	23	15	12	68			y			y	y	y	y	y	6
10	6	12	22	13	15	68			y			y	y	y	y	y	6
11	8	13	26	12	15	74			y			y	y		y	y	5
12	8	12	24	13	15	72	y	x			y	y		y			5
13	8	12	27	6	15	68	y	x			y			y	y		5
14	7	12	28	9	16	72	Y		Y		Y		Y				4
15	8	12	30	8	13	71	y				y			y		y	4
16	7	12	23	12	15	69	y		y		y			y			4
17	8	12	31	14	16	81	y				y				y		3
18	7	12	28	11	15	73			y		y		y				3
19	6	5	22	8	10	51	y	y			y	y	y		y		6

Annexure 3: General Authorisation Discharge Standards

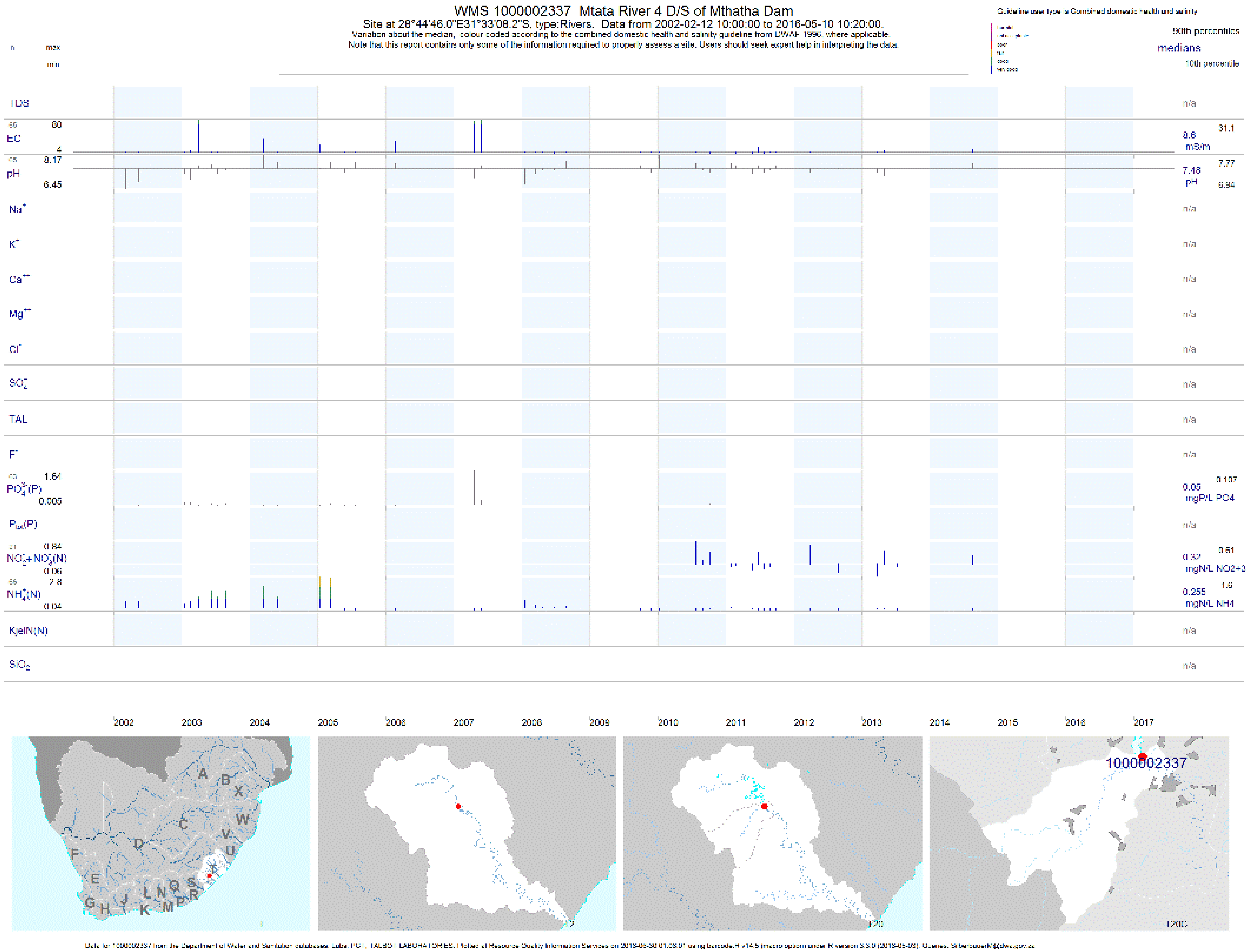
SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 ml)	1000	0
Chemical Oxygen Demand (mg/l)	75 (i)	30(i)
pH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)	6	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1,5
Chlorine as Free Chlorine (mg/l)	0,25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m
Ortho-Phosphate as phosphorous (mg/l)	10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)	1	1
Soap, oil or grease (mg/l)	2,5	0
Dissolved Arsenic (mg/l)	0,02	0,01
Dissolved Cadmium (mg/l)	0,005	0,001
Dissolved Chromium (VI) (mg/l)	0,05	0,02
Dissolved Copper (mg/l)	0,01	0,002
Dissolved Cyanide (mg/l)	0,02	0,01
Dissolved Iron (mg/l)	0,3	0,3
Dissolved Lead (mg/l)	0,01	0,006
Dissolved Manganese (mg/l)	0,1	0,1
Mercury and its compounds (mg/l)	0,005	0,001
Dissolved Selenium (mg/l)	0,02	0,02
Dissolved Zinc (mg/l)	0,1	0,04
Boron (mg/l)	1	0,5

Source: NWA 2013

VARIABLES	**LIMITS**		
	Irrigation up to 2Ml/d	Irrigation up to 0.5Ml/d	Irrigation up to 0.05Ml/d
pH	not less than 5,5 or more than 9,5 pH units	not less than 6 or more than 9 pH units	not less than 6 or more than 9 pH units
Electrical Conductivity	does not exceed 70 milliSiemens above intake to a maximum of 150 milliSiemens per metre (mS/m)	not exceed 200 milliSiemens per metre (mS/m);	not exceed 200 milliSiemens per metre (mS/m);
Suspended Solids	does not exceed 25 mg/l	N/A	N/A
Chloride as Free Chlorine	does not exceed 0,25 mg/l	N/A	N/A
Fluoride	does not exceed 1 mg/l	N/A	N/A
Soap, Oil and Grease	does not exceed 2,5 mg/l	N/A	N/A
Chemical Oxygen Demand	does not exceed 75 mg/l	does not exceed 400 mg/l after removal of algae;	does not exceed 5000 mg/l after removal of algae;
Faecal coliforms	do not exceed 1000 per 100 ml	do not exceed 100 000 per 100 ml	do not exceed 100 000 per 100 ml
Ammonia (ionised and un-ionised) as Nitrogen	does not exceed 3mg/l	N/A	N/A
Nitrate/Nitrite as Nitrogen	does not exceed 15 mg/l	N/A	N/A
Sodium Adsorption Ratio (SAR)	N/A	does not exceed 5 for biodegradable industrial wastewater	does not exceed 5 for biodegradable industrial wastewater

Source: NWA 2013

Annexure 4: Example of RQIS information



data_description_macro.txt

Suggested citation:
DWS 2016. National Water Management System data extracted on 2016-06-30. Department of Water and Sanitation, Pretoria.

Laboratory analysis for site 1000002337 () by:
Monitor Laboratories; Talbot and Talbot. (PCT; TALBOT LABORATORIES)

Analytical methods may have changed through the years:
For example, see Analytical Methods Manuals TR136 and TR151 at https://www.dwa.gov.za/iwqs/reports/tr.aspx

Be particularly careful when using pH data from 1978 to 1989

These summary files do not include method detection limits, and instead insert the detection limit in place of any result less than the detection limit:
For results that include method detection limits, please request full data files from the Contact email below

Database site description:
Mtata River 4 D/S of Mthatha Dam

Data extraction:
2016-06-30 01:05:45 using script barcode.R v 14.5 with the macro option, under R version 3.3.0 (2016-05-03)

Abbreviations:

mon_variable_abbr	measure_unit_abbr	mon_variable_name	measure_unit_name	mon_variable_id
Ca-Diss-Water	mg/L	Calcium	Milligram per Litre	52
Cl-Diss-Water	mg/L	Chloride	Milligram per Litre	46
DMS-Tot-Water	mg/L	Dissolved Major Salts	Milligram per Litre	63
EC-Phys-Water	mS/m	Electrical Conductivity	Millisiemens per Metre	56
F-Diss-Water	mg/L	Fluoride	Milligram per Litre	24
K-Diss-Water	mg/L	Potassium	Milligram per Litre	50
KJEL N-Tot-Water	mg/L	Kjeldahl Nitrogen	Milligram per Litre	9
Mg-Diss-Water	mg/L	Magnesium	Milligram per Litre	32
Na-Diss-Water	mg/L	Sodium	Milligram per Litre	30
NH4-N-Diss-Water	mg/L	Ammonium Nitrogen	Milligram per Litre	13
NO3+NO2-N-Diss-Water	mg/L	Nitrate + Nitrite Nitrogen	Milligram per Litre	11
P-Tot-Water	mg/L	Total Phosphorus	Milligram per Litre	37
pH-Diss-Water	pH units	pH	Units of pH	3
PO4-P-Diss-Water	mg/L	Ortho Phosphate as Phosphorus	Milligram per Litre	39
Si-Diss-Water	mg/L	Silicon	Milligram per Litre	34
SO4-Diss-Water	mg/L	Sulphate	Milligram per Litre	42
TAL-Diss-Water	mg/L	Total Alkalinity as Calcium Carbonate	Milligram per Litre	27

Some laboratories measure NO2 and NO3 separately: in such cases WMS adds them together as NO3+NO2-N-Calc-Water.

Disclaimer:

While staff have taken due care in preparing these results, the Department of Water and Sanitation cannot be held responsible for the accuracy of data provided nor for interpretations made.

Scientific complications in the attached interpretation or accompanying graphs are beyond the scope of this report.

Page 1

data_description_macro.txt

Please inform us of any results or site descriptions that appear to be incorrect.

Contact:

For data directly from the WMS database, please contact Marica Erasmus, Resource Quality Information Services, Department of Water and Sanitation.
E-mail: MaricaE@dwa.gov.za
Landline: +27 12 808 9610 (currently out of order)
Cell: +27 82 908 2895, or see https://www.dwa.gov.za/iwqs/egotour/staflist/callus.aspx
Fax: +27 12 808 0338

For official correspondence, please write to:
The Director,
Resource Quality Information Services,
Department of Water and Sanitation,
Private Bag X313
Pretoria
South Africa
0001

Page 2

Annexure 5: Monitoring requirements for domestic wastewater discharges

DISCHARGE VOLUME ON ANY GIVEN DAY	MINIMUM MONITORING REQUIREMENTS
10 to 100 cubic metres	pH Electrical Conductivity (mS/m) Faecal Coliforms (per 100 ml)
100 to 1 000 cubic metres	pH Electrical Conductivity (mS/m) Faecal Coliforms (per 100 ml) Chemical Oxygen demand (mg/l) Ammonia as Nitrogen (mg/l) Suspended Solids (mg/l) Phosphate (mg/l)
1 000 to 2 000 cubic metres	pH Electrical Conductivity (mS/m) Faecal Coliforms (per 100 ml) Chemical Oxygen demand (mg/l) Ammonia as Nitrogen (mg/l) Nitrate/Nitrite as Nitrogen (mg/l) Free Chlorine (mg/l) Suspended Solids (mg/l) Ortho-Phosphate as Phosphorous (mg/l)

Source: NWA 2013

Annexure 6: Selection of Key Performance Indicators for Step 1 of the Sustainability Evaluation

KPA	KPI	LITERATURE CONSULTED						Relevance Score	KPI Type 1	KPI Type 2	KPI Type 3	FINAL KPI	FINAL KPI DESCRIPTION
		vd Merwe 2012	Muga et al. 2007	NSAPSD	Breslin n.d	Green Drop Report	Questionnaires						
Social	Sludge processing constraints	X						3	Technical	Environmental	Health		
Social	Availability of reasonably priced land	X	X					3	Economic			KPI 1.1	Sufficient land available for STP
Social	Projected population growth	X						1	Technical				
Social	Opportunities for re-use of treated effluent or value added returns and by-products from the system	X						3	Technical	Economic	Environmental		
Social	Proximity of community to the infrastructure	X						2	Health	Technical			
Social	Availability of fresh water for domestic use	X						1	Technical	Institutional			
Social	Acceptance by the community	X						2	Institutional				
Social	Workforce Education Level		X					2	Institutional				
Social	Employment Opportunities		X					3	Institutional				
Social	Community size served		X					1	Institutional	Technical			
Social	Plant Aesthetics		X					2	Technical				
Social	Public Participation in Technology Selection		X					2	Institutional	Technical	Economic		
Social	Creating sustainable human settlements			X				2	Institutional	Technical			
Social	Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)			X				2	Institutional	Economic	Environmental	KPI 1.2	STP will help promote community development
Social	healthy ecosystems and natural resources are preconditions to human wellbeing and that there are limits on the goods and services that they can provide.			X				3	Environmental	Technical	Institutional		
Social	achievement of appropriate and justifiable social and economic goals			X				2	Economic	Institutional	Technical		
Social	Community buy-in on selected technology						X	2	Institutional	Technical	Health		
Social	communities to participate in the technology selection and eventual operation of the scheme				x			2	Technical	Institutional			
Social	ownership which the local communities took in operating and maintaining				x			3	Technical	Institutional			
Technical	Applicable Flow Rate (Ponds possibly not suitable for large and highly populated areas)	X						3	Society	Environmental			
Technical	Influent Sewage Characteristics impact on type of process to be used	X						3	Environmental	Health			
Technical	Potential inhibiting constituents to the treatment process	X						3	Environmental	Institutional			
Technical	Sludge processing constraints	X						3	Environmental	Health	Institutional		
Technical	Sensitivity of the receiving water body or land	X						3	Environmental	Society	Institutional	KPI 2.3	Technology's ability to comply with water quality requirements
Technical	Energy requirements and efficiency	X						3	Economy				
Technical	Projected population growth	X						1	Institutional	Society	Institutional		
Technical	Opportunities for re-use of treated effluent or value added returns and by-products from the system	X						3	Society	Economic			
Technical	Availability of fresh water for domestic use	X						1	Institutional				
Technical	Water Quality Compliance	X						3	Institutional	Environmental			
Technical	EOD Removal		X					2	Environmental				
Technical	TSS Removal		X					3	Environmental				
Technical	NH3 Removal		X					3	Environmental				
Technical	Phosphorous Removal		X					3	Environmental				
Technical	Pathogen Removal		X					3	Environmental	Health			
Technical	Energy Use		X					3	Economy				
Technical	Plant Aesthetics		X					2	Society				
Technical	Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)			X				2	Society	Economic	Environmental		
Technical	achievement of appropriate and justifiable social and economic goals			X				2	Economy	Society	Health		
Technical	consume much more energy during their operational life than other technologies			x				3	Economy				
Technical	Sludge Treatment					x		3	Environmental	Health			
Technical	e.Coli / Faecal Coliform					X		3	Environmental	Health			
Technical	Ammonia as Nitrogen					X		3	Environmental				
Technical	COD					X		3	Environmental				
Technical	Nitrate/Nitrite as Nitrogen					X		3	Environmental				
Technical	Ortho-Phosphate as Phosphorous					X		3	Environmental				
Technical	pH					X		3	Environmental				
Technical	Electrical Conductivity					X		3	Environmental				
Technical	Suspended Solids					X		3	Environmental				
Technical	O&M was not focussed sufficiently enough on during the design stage				x			3	Institutional	Society			

Economic	Energy requirements and efficiency	X						3	Technical	Environmental		KPI 3.3	Efficient use of electricity over operational life of technology
Economic	Availability of funding to construct the facility	X						3	Institutional	Technical			
Economic	Running cost recovery and consumer's ability to pay for the on-going operation and maintenance of the system	X						3	Society	Technical		KPI 1.3	O&M activities suitable for local application
Economic	Availability of reasonably priced land	X	X					3	Environmental	Society		KPI 3.6	STP size is economic for local land value
Economic	Projected population growth	X						1	Society	Institutional			
Economic	Opportunities for re-use of treated effluent or value added returns and by-products from the system	X						3	Society	Environmental	Institutional		
Economic	Cost to users		x					3	Society	Technical	Institutional	KPI 1.4	Ability of consumer to pay for O&M of STP
Economic	Operation and Management Costs		x					3	Institutional	Technical			
Economic	Capital Costs		x					3	Technical				
Economic	Economic development			X				2	Society	Technical		KPI 3.1	Sustainable job creation opportunities
Economic	Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)			X				2	Society	Environmental		KPI 3.4	STP construction value considerate of client's financing capacity
Economic	achievement of appropriate and justifiable social and economic goals			X				2	Society	Institutional	Technical	KPI 3.2	STP will help promote local economic development
Institutional	Legal requirements ito water use licensing	X						2	Technical	Environmental			
Institutional	Capacity of the local authority to operate and maintain the system	X						3	Society	Technical			
Institutional	Capacity to provide scientific analysis and support to the operational staff	X						3	Technical	Society		KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff
Institutional	Availability of reasonably priced land	X	X					3	Society				
Institutional	Employment Opportunities		X					3	Society	Technical		KPI 3.5	Opportunities for value adding by-products from the STP
Institutional	Public Participation in Technology Selection		X					3	Society	Environmental	Technical	KPI 2.5	Degree of Public Participation in Technology Selection
Institutional	Opportunities for re-use of treated effluent or value added returns and by-products from the system	X						3	Environmental	Technical	Health		
Institutional	Acceptance by the community	X						2	Society	Technical	Environmental		
Institutional	Enhancing systems for integrated planning and implementation			X				2	Technical	Environmental	Society		
Institutional	Investing in sustainable infrastructure			X				2	Technical	Economic	Environmental		
Institutional	Creating sustainable human settlements			X				2	Society	Technical			
Institutional	Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)			X				2	Society	Economic	Environmental		
Institutional	healthy ecosystems and natural resources are preconditions to human wellbeing and that there are limits on the goods and services that they can provide.			X				2	Environmental	Technical			
Institutional	achievement of appropriate and justifiable social and economic goals			X				2	Society	Economic			
Institutional	Ability to locally operate the plant					X		2	Society	Technical			
Institutional	ownership which the local communities took in operating and maintaining				x			3	Society	Technical			
Environmental	Impact of physical climate on treatment process	X						3	Technical				
Environmental	Sludge processing constraints	X						3	Technical	Institutional	Health	KPI 2.2	Safe processing and disposal of sludge
Environmental	Sensitivity of the receiving water body or land	X						3	Technical	Institutional	Health		
Environmental	Energy requirements and efficiency	X						3	Economy	Technical			
Environmental	Availability of reasonably priced land	X	X					3	Society	Economic			
Environmental	Opportunities for re-use of treated effluent or value added returns and by-products from the system	X						3	Technical	Economic	Society	KPI 2.6	Re-use of treated sewage effluent or sludge
Environmental	Proximity of community to the infrastructure	X						2	Society	Technical	Health	KPI 1.6	Safe distance between community and STP
Environmental	Availability of fresh water for domestic use	X						1	Institutional	Technical			
Environmental	Ability to exploit Green Opportunities	X						2	Technical	Institutional	Society		
Environmental	Urban Heat Islands		X					1	Technical				
Environmental	Sustaining our ecosystems			X				3	Institutional	Technical			
Environmental	Using natural resources efficiently			X				3	Technical				
Environmental	Responding appropriately to emerging human development, economic and environmental challenges (including climate change, rising oil prices, globalisation and trade)			X				2	Society	Economic		KPI 2.4	Consideration of local resources in design and construction of STP
Environmental	healthy ecosystems and natural resources are preconditions to human wellbeing and that there are limits on the goods and services that they can provide.			X				2	Technical	Society		KPI 2.1	Safety measures in place to protect health of local ecosystems.

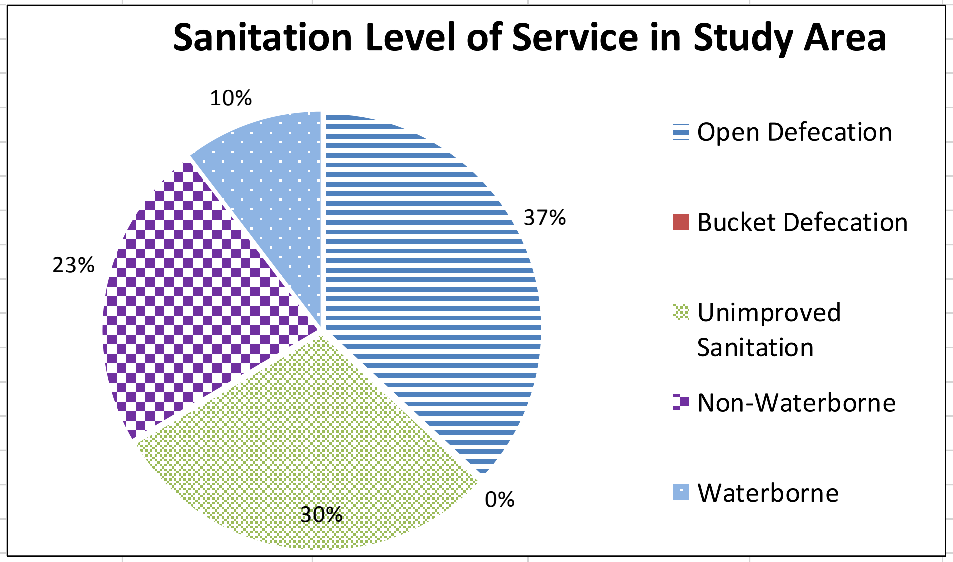
KPA	KPI	KPI No	Overlapping KPA	Final Description
Society	Economic	KPI 1.1	Economic	Sufficient land available for STP
	Health	KPI 1.2	Economic/Environmental	STP will help promote community development
	Technical	KPI 1.3	Economic	O&M activities suitable for local application
	Financial	KPI 1.4	Economic	Ability of consumer to pay for O&M of STP
	Institutional	KPI 1.5	Economic/Environmental	Community's ability to provide scientific analysis and support to the operational staff
	Environmental	KPI 1.6	Environmental	Safe distance between community and STP
Environmental	Society	KPI 2.1	Society	Safety measures in place to protect health of local ecosystems.
	Health	KPI 2.2	Society	Safe processing and disposal of sludge
	Technical	KPI 2.3	Economic	Technology's ability to comply with water quality requirements
	Financial	KPI 2.4	Economic	Consideration of local resources in design and construction of STP
	Institutional	KPI 2.5	Society / Economic	Degree of Public Participation in Technology Selection
	Economic	KPI 2.6	Economic	Re-use of treated sewage effluent or sludge
Economic	Society	KPI 3.1	Society	Sustainable job creation opportunities
	Health	KPI 3.2	Society	STP will help promote local economic development
	Technical	KPI 3.3	Society / Environmental	Efficient use of electricity over operational life of technology
	Financial	KPI 3.4	Society / Environmental	STP construction value considerate of client's financing capacity
	Institutional	KPI 3.5	Society / Environmental	Opportunities for value adding by-products from the STP
	Environmental	KPI 3.6	Environmental	STP size is economic for local land value

Annexure 7: Water Service Delivery and Demographic Details

Parameter	Unit	Amathole DM		Chris Hani DM		OR Tambo DM					Alfred Nzo DM		
		Mnquma LM	Mbhashe LM	Intsika Yethu LM	Engcobo LM	King Sabata Dalindyebo	Nyandeni LM	Mhlontlo LM	Port St Johns LM	Inguza Hill LM	Mbizana LM	Ntabankulu LM	Umzimvubu LM
Base date of information	year	2015	2015	2012	2012	2013	2013	2013	2013	2013	2013	2013	2013
Total Population	pax	252 390	254 909	145 725	156 309	451 009	290 191	188 070	156 063	278 185	281 905	123 976	191 620
Indigent Population	pax			6300hh							3 584		
No of Urban Settlements	No			32HH & 263800 - Whole CHDM		23 059	2 528	2 086	2 329	1 639		2.97%	
Urban Population	pax												
No of Villages	No	565	653	364	440	482	336	327	221	331	389	154	238
Rural Households	No	69 732	60 124			62 338	60 483	47 675	36 580	51 860	48 447	24 396	46 890
No of Households	No	69 732	60 124			105 240	61 647	43 414	31 715	56 213	48 447	24 396	46 890
No of people/village	pax/Village	446.71	390.37	400.34	355.25	935.70	863.66	575.14	706.17	840.44	724.69	805.04	805.13
Household Size	pax/HH	3.62	4.24			4.29	4.71	4.33	4.92	4.95	5.82	5.08	4.09
Population Growth	%	np	0.061%	-0.50%	-0.46%	0.82%	0.57%	-0.76%	0.60%	0.90%	1.37%		
No access to Water	%	39.1%	71.0%	18 843.00	23 605.00	59.7%	75.4%	70.8%	80.4%	84.9%	91.9%	75.0%	23.0%
Communal tap greater than 1km	%	2.8%	0.0%										
Communal tap between 0.5km and 1km	%	4.7%	0.0%	6 516.00	4 517.00								
Communal tap between 0.2km and 0.5km	%	9.8%	0.0%										
Communal tap within 200m	%	25.9%	25.0%	11 959.00	7 765.00								
Yard Tap	%	5.4%	4.0%	1 862.00	1 023.00								
House Connection	%	12.3%	0.0%	678.00	704.00	40.3%	24.6%	29.2%	19.6%	15.1%	8.1%	25.0%	77.0%
Villages without water	No	229	211	18 843.00	23 605.00								
Villages without sanitation	No	279	125	17 755.00	17 170.00						14.0%	70.0%	48.7%
SLOS: Open Defecation	No	54.0%	45.0%	17 755.00	17 170.00	17.20%	34.3%	25.9%	33.0%	20.3%	14.0%		
SLOS: Unimproved	No	27.0%	33.0%	10 157.00	7 749.00	25.3%	23.9%	39.6%	30.0%	42.4%	46.0%		
SLOS: Shared	No		0.0%			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
SLOS: Improved On-Site	No	7.0%	18.0%	10548.00	10795.00	23.7%	35.6%	25.5%	24.2%	24.3%	37.8%	27.8%	
SLOS: Improved Off-Site (Sewerage)	No	12.0%	4.0%	1397.00	1899.00	33.8%	6.2%	9.0%	12.8%	13.0%	2.2%	2.2%	51.3%
LM IDP Ref:		MqLM, 2015	MbLM, 2015	IYLM, 2015	ELM, 2015	KSDLM, 2015	NyLM, 2015	MhLM, 2015	PSJLM, 2015	IHLM, 2015	MzLM, 2015	NtLM, 2015	None Avail.
DM IDP Ref:		ADM, 2015		CHDM, 2015		ORTDM, 2015					ANDM, 2015		
DM WSDP Ref:		DWS, 2015 (3)		DWS, 2015 (4)		DWS, 2015 (5)					DWS, 2015 (2)		
LM IDP Pages:			23-34	10, 68-97, 169-217	20, 95-134						40-52, 100	57	
DMs WSDP Pages:		64	60-64	14		4		33	60		iv - vi, 4-5,		
DMs IDP Pages:				18-46, 86-89	18 - 34	21-49, 84-87, 192					19-28, 33-34		

WSA	LM	Rural Village Information			On-Site Sanitation				Off-Site Sanitation	% Improved Sanitation	% Off-Site Sanitation	Potential Water Demand Increase (Ml/d)
		Population	Tot no of Villages	Villages with Sanitation	Open Defecation	Bucket Defecation	Unimproved	Non-Waterborne	Waterborne			
ADM	Mnquma LM	252 390	565	286	54%	0%	27%	7%	12%	19%	12%	16.66
ADM	Mbhashe LM	254 909	653	528	45%	0%	33%	18%	4%	22%	4%	18
CHDM	Intsika Yethu LM	145 725	364	202	45%	0%	25%	26%	4%	30%	4%	11
CHDM	Engcobo LM	156 309	440	239	46%	0%	21%	29%	5%	34%	5%	11
ORTDM	King Sabata Dalindyebo	267 151	482	399	17%	0%	25%	24%	34%	58%	34%	13
ORTDM	Nyandeni LM	284 712	336	221	34%	0%	24%	36%	6%	42%	6%	20
ORTDM	Mhlontlo LM	206 529	327	242	26%	0%	40%	26%	9%	35%	9%	14
ORTDM	Port St Johns LM	180 003	221	148	33%	0%	30%	24%	13%	37%	13%	12
ORTDM	Inguza Hill LM	256 643	331	264	20%	0%	42%	24%	13%	37%	13%	17
ANDM	Mbizana LM	281 905	389	335	14%	0%	46%	38%	2%	40%	2%	21
ANDM	Ntabankulu LM	123 976	154	46	70%	0%	14%	14%	2%	16%	2%	9
ANDM	Umzimvubu LM	191 620	238	122	49%	0%	17%	17%	17%	34%	17%	12
												174

Sanitation LOS	No of Villages		% of total
Open Defecation	1 663		37%
Bucket Defecation	-		0%
Unimproved Sanitation	1 331		30%
Non-Waterborne	1 040		23%
Waterborne	466		10%
	4 500		
		Total Improved	33%
		Unimproved	67%



WSA	LM	Rural Village Information			No of HH	HH Size	Village Size (No of People)	Vilage Size (No of HH)	Average Village Distribution
		LM Area (sq.km)	Population	Tot no of Villages					
ADM	Mnquma LM	3 270	252 390	565	69 732	3.62	447	123	6
ADM	Mbhashe LM	3 169	254 909	653	60 124	4.24	390	92	5
CHDM	Intsika Yethu LM	2 711	145 725	364	39 857	3.66	400	109	7
CHDM	Engcobo LM	2 484	156 309	440	37 613	4.16	355	85	6
ORTDM	King Sabata Dalindyebo	3 027	267 151.26	482	62 338	4.29	554	129	6
ORTDM	Nyandeni LM	2 474	284 711.70	336	60 483	4.71	847	180	7
ORTDM	Mhlontlo LM	2 826	206 528.71	327	47 675	4.33	632	146	9
ORTDM	Port St Johns LM	1 291	180 002.67	221	36 580	4.92	814	166	6
ORTDM	Inguza Hill LM	2 477	256 643.02	331	51 860	4.95	775	157	7
ANDM	Mbizana LM	2 417	281 905	389	48 447	5.82	725	125	6
ANDM	Ntabankulu LM	1 385	123 976	154	24 396	5.08	805	158	9
ANDM	Umzimvubu LM	2 506	191 620	238	46 890	4.09	805	197	11
	TOTAL:	**30 037**	**2 601 871**	**4 500**	**585 995**	**4.44**	**578**	**130**	**7**

Annexure 8: STP and Operator Classification

STAATSKOERANT, 23 OKTOBER 2013 No. 36958 11

SCHEDULE 2

CLASSIFICATION OF A WATER SERVICES WORKS USED FOR THE TREATMENT OF WASTEWATER AND THE DISPOSAL OR RE-USE OF THE TREATED WASTE

Rating

Class of works Range of points	E <30	D 30 – 39	C 40 - 59	B 60 - 70	A >70

Points to be awarded at the discretion of the Director – General in accordance with the following criteria:

Technology	Unit Process	Control Elements	Maximum
Infrastructure	**Design Capacity in kilolitres per day (kℓ/d)**	0 to 500	1
		500 to 5 000	2
		5 001 to 20 000	4
		20 001 to 50 000	6
		50 001 to 250 000	8
		>250 001	10
		Actual volume: __________Kℓ/d	
	Installed power (kilowatts of installed power to operate)	0 – 5 kW	1
		5 – 100 kW	3
		101 –1000	5
		>1000 kW	10
Quality of intake water		Domestic	0
		Conservancy/Night soil	1 – 5**
		Industrial effluent	1 – 5**
		Internal recycle eg filtrate/centrate, supernatant etc.	2
		Leachate	1 – 3**

Process parameters	**Primary Treatment**	Manually raked	1
		screens..	2
		Automatic screens..	1
		Hand/mechanical grit removal..................................	2
		Automatic grit removal..	2
		Flow balancing..	2
		Primary sedimentation...	4
		Sludge fermentation..	
	Secondary Treatment		2
		Oxidation ponds	3
		Biodiscs..	4
		Biofilters (Biof)...	6
		Activated sludge: full nitrification............................	8
		Activated sludge: partial denitrification......................	10
		Activated sludge: Biological Excess phosphate removal.......	4
		Chemical Addition..	
	Tertiary Treatment		1
		Maturation ponds	1
		Reedbeds..	2
		Sand filters	
		Disinfection (eg. Chlorination, ammonium bromide, ozone	1 – 3*
		and UV 1-2)*...	2
		Chemical De-chlorination......................................	4
		Desalination/Membrane filters.................................	
		Treated water containing waste re-use for industrial	2
		purposes..	
		Treated water containing waste re-use for potable purposes	
		(this section of the plant must then be registered in terms of	Nil
		Schedule I)...	
	Sludge Treatment		4
		Anaerobic Digestion - <30 days retention......................	2
		- >30 days retention......................	
		Mechanical or physical/chemical sludge treatment including	7
		thickening, stabilisation and/or dewatering.....................	2
		Aerobic digestion..	1
		Sludge drying beds/lagoons.....................................	6
		Thermal sludge treatment.......................................	3
		Sludge heating...	
	Additional Factors		1-3*
		Gas engines, incineration, boilers.............................	3
		On-site steam generation.......................................	1-5*
		Partial to full plant automation................................	1-3*
		Odour control..	1-3*
		Standby power..	3
		24 hour telemetry monitoring...................................	
Control Processes	**Maintenance**	None by process controllers.....................................	0
		Basic maintenance by process controller.......................	1
		Specialised maintenance by process controller................	4
	Lab services	Reading with instrumentation by process controller...........	2
		Full lab service on site but not done by process controller,	
		although still a management function...........................	3
		Chemical analyses done by process controller..................	4
	Administration	Record Readings..	1
		Calculate daily flows and stock taking.........................	2
		Calculate dosing and generate reports.........................	4
		Work on computer (not just check screen)......................	5
	Trade Effluent by-laws	Trade effluent by-laws exist and are implemented.............	0
		No trade effluent by-laws.......................................	5
Sensitivity of water resource into which treated water containing waste is discharged		Low – e.g. oxidation pond with irrigation, evaporation pond, marine discharge..	2
		Medium – e.g. all discharges to any river or stream except in specially identified areas.....................................	4
		High – e.g. Special standard or where a receiving water quality standard is prescribed and estuaries.....................	6
	Reclamation/Reuse Type (Term)	**Applications**	**Maximum**

Water Reclamation and reuse	**Agricultural Irrigation**	Crops irrigated..	6
	Landscape irrigation	parks..	3
		golf courses..	3
		freeways..	3
		office and industrial developments....................	3
		residential..	3
	Industrial Activities	Cooling and process needs..............................	6
		Power Generation..	6
		Gas Production..	6
	Groudwater Recharge	spreading basins..	10
		direct injection to groundwater aquifers...............	10
	Other non-potable uses Fire protection, air condition, toilet flushing, construction water and sanitary sewer	fire protection..	4
		air condition..	4
		toilet flushing..	4
		construction water..	4
		sanitary sewer..	4
			4
	Potable reuse	Direct sewer treatment for potable supply..............	10

*points scored according to complexity of process – needs to be motivated and 1 additional point is then added per motivation.
** Points scored according to % of night soil, industrial effluent or leachate being discharged to the water services works making the process more complex. This motivation must include the Chemical Oxygen Demand concentrations.

SCHEDULE 3

PROCESS CONTROLLER REGISTRATION

This Schedule must be read in conjunction with the Qualifications registered with the South African Qualifications Authority on the National Qualifications Framework. The qualifications include Water and Wastewater Process operations and control and industrial water treatment support and control operations.

EDUCATIONAL REQUIREMENTS	Years appropriate experience per Class of Process Controller							
	Grand-parented	In Training (L)	I	II	III	IV	V	VI
1. None	**10**							
1. St 6/ Grade 8		0	-	-	-	-	-	-
1. * Skills programme equivalent to a value of at least 30 Credits of Core and/or Elective Unit Standards taken from the appropriate NQF 2 Qualification **plus** St 1/Grade 3 **or** the ABET equivalent			2					
1. St 6/ Grade 8 **plus** **Maintenance Workers Certificate; **or** 2. St 6/ Grade 8 **plus** **Treatment Training Certificate; **or** 3. NQF 1 GETC: Water Services		0	4	-	-	-	-	-
1. St 7/ Grade 9 **plus** **Maintenance Workers Certificate; **or** 2. St 7/ Grade 9 **plus** **Treatment Training Certificate; **or** 3. NQF 1 GETC: Water Services **plus** the Core Unit Standards from the Appropriate NQF 2 Qualification		0	3	-	-	-	-	-
1. St 8/ Grade 10 (or NTC 1) **plus** **Maintenance Workers Certificate; **or** 2. St 8/ Grade 10 (or NTC 1) **plus** **Treatment Training Certificate; **or** 3. St 8/ Grade 10 (or NTC 1) **plus** Water and Wastewater Treatment practice N1; **or**		0	2	5	-	-	-	-

EDUCATIONAL REQUIREMENTS	Years appropriate experience per Class of Process Controller							
	Grand-parented	In Training (L)	I	II	III	IV	V	VI
4. St 8/ Grade 10 (or NTC 1) **plus** the Core Unit Standards from Appropriate NQF 2 Qualification; **or** 5. Appropriate NQF 2 Qualification								
1. NTC 1 in Water and Wastewater Treatment practice		0	1.5	4	-	-	-	-
1. Std. 8/ Grade 10 (or NTC I) **plus** Operators certificate **or** 2. St 8/ Grade 10 (or NTC 1) **plus** the Core Unit Standards from the Appropriate NQF 3 Qualification.		0	1	3	9	-	-	-
1. St 9/ Grade 11 (or NTC II) **plus** Operators certificate **or** 2. St 9/ Grade 11 (or NTC II) **plus** the Core Unit Standards from the Appropriate NQF 3 Qualification; **or** 3. NTC II in Water and Wastewater Treatment practice; **or** 4. Appropriate NQF 3 Qualification.		0	0.5	2	7	15	-	-
1. Matric/ Grade 12 (or NTC III) (Mathematics + Science)		0	4	-	-	-	-	-
1. Matric/ Grade 12 (or NTC III) **plus** **Maintenance Workers Training Certificate; **or** 2. Matric/ Grade 12 (or NTC III) **plus** **Treatment Training Certificate		0	1	-	-	-	-	-
1. Matric/ Grade 12 (or NTC III) **plus** Operators Certificate; **or** 2. Matric/ Grade 12 (or NTC III) **plus** Water Treatment practice N3; **or** 3. Matric/ Grade 12 (or NTC III) **plus** Wastewater Treatment practice N3; **or** 4. Matric/ Grade 12 (or NTC III) **plus** the Core Unit Standards from the Appropriate NQF 4 Qualification; **or** 5. NTC III in Water Treatment practice; **or** 6. NTC III in Wastewater Treatment practice; **or** 7. Appropriate NQF 4 Qualification			0	0.5	3	8	15	-

EDUCATIONAL REQUIREMENTS	Years appropriate experience per Class of Process Controller							
	Grand-parented	In Training (L)	I	II	III	IV	V	VI
1. National Diploma **or** National Technical Diploma **or** NTC VI **or** 3 year BSc (all in appropriate field); **or** 2. Appropriate NQF 5 Qualification					0	2	6	-
1. B Tech (Higher National Diploma) **or** 4 year BSc (both in appropriate field); **or** 2. Appropriate NQF 6 Qualification						0	4	15
1. Professional Engineer or Professional Engineering Technologist (Act 81 of 1968) in appropriate field; or a Natural Scientist (Act 55 of 1982) in appropriate field.						0	3	12

* *This will apply only to those who have been working at a registered water services works for longer than 10 years with no classification or a Class 0 classification under Government Notice No. R. 2834 of 27 December 1985 and who have not achieved the relevant unit standards by recognised prior learning assessment. The non-prescriptive criteria allow for the older process controller who could not be classified under the old regulation to select Unit Standards relevant to their experience/training on which they can be assessed. A motivation for being registered in this category must accompany the application.*

** *Maintenance Workers / Treatment Training Certificate: Training must be accredited and/or hold CPD credits and have duration of not less than 5 days.*

NOTES ON SCHEDULE III

1. APPROPRIATE NQF QUALIFICATIONS

NQF qualifications are revised every three years and updated if necessary. Certificates issued for the following qualifications and any previous or updated versions thereof will be recognized, as indicated in Schedule III above.

1.1 NQF LEVEL 1

GETC: Water Services

SCHEDULE 4

MINIMUM CLASS OF PROCESS CONTROLLER REQUIRED PER SHIFT, AND SUPERVISION, OPERATIONS AND MAINTENANCE SUPPORT SERVICES REQUIREMENTS AT A WATER SERVICES WORKS

WORKS CLASS	CLASS OF PROCESS CONTROLLER PER SHIFT	CLASS OF PROCESS CONTROLLER FOR SUPERVISION*	OPERATIONS AND MAINTENANCE SUPPORT SERVICES REQUIREMENTS*
E	Class I	Class V*	THESE PERSONNEL MUST BE AVAILABLE AT ALL TIMES BUT MAY BE IN-HOUSE OR OUTSOURCED - electrician - fitter - instrumentation technician
D	Class II	Class V*	
C	Class III	Class V*	
B	Class IV	Class V	
A	Class IV	Class V	

NB. Fluoridation – for any class works, minimum process controller classification should be class IV

NOTES FOR SCHEDULES IV

*does not have to be at the water services works at all times but must be available at all times. If the Water Services Institution or owner of a water services works has no person of this class employed on that water services works, a contractor / consultant with the required qualifications as prescribed in Schedule III in respect of that particular class of persons shall be appointed to visit the water services works weekly.

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Cape Town Branch: Tel: (021) 465-7531

Information quoted above was obtained from WSAc (2013) and WSAc (2013(2))

Annexure 9: Supportive notes on STP Development Process

Some important considerations related to each of the following pieces of legislation needs to be emphasized:

National Water Act

The NWA prescribes which water uses will require a General Authorisation and which will require a specific Water Use License. These aspects of the NWA does not have major influence on the type of technologies which can be used.

The application of RWQO does however influence the selection of technology since not all technologies can achieve the desired objectives. The applicable RWQO are identified in consultation with DWS, for the specific catchment in which the STP will be established.

As discussed in Section 2.9 and illustrated in **Figure** 2-5, the location of the STP and discharge point can qualify for a General Authorisation of the NWA, whereby the effluent must either comply with General or Special Discharge Limits.

National Environmental Management Act

With the establishment of the NEMA, and specifically the NEMWA, an Environmental Authorisation (or License to construct) is required for any listed water activity, irrespective if it has a General Authorisation or a specific Water Use License.

The Environmental Authorisation does not necessarily prescribed a specific technology, but it does require that the operation of the technology be monitored during the operational phase of the project. This means a quality monitoring and compliance programme must be considered during the planning, design, implementation and operation of the technology.

The method by which sludge is to be handled and disposed of also needs to be considered during the design stage and can thus also influence the selection of the final technology.

The South African National Strategy and Action Plan for Sustainable Development

The NSAPSD promotes sustainable development and thus the consideration of the soft issues such as Environmental, Social and Economic factors during the planning stages of project. The final technology selection should thus consider sustainability factors, which according to VD Merwe et al. (2012), is not given sufficient attention at present. The author is also in agreement with VD Merwe et al. (2012).

Certain steps in the Technology Selection process, as illustrated in **Figure** 4-4 requires some further elaboration:

Step 1: Identify the need for a new STP

Early community and stakeholder consultation can assist in identifying any technology options or STP locations which are either preferred or fatally flawed. These can help steer the overall planning of the project. Activities such as infrastructure masterplanning and IDP roadshows are good platforms for such initial engagements.

Step 2: Appoint PSP to design the STP

Routine meetings between the WSA, PSP and DWS is recommended to understand the legislative conditions and any other requirements which have been placed on the project.

Step 3: Determine parameters within which the STP need to operate

The following parameters must be determined before technology options can be considered:

1. Is sufficient electricity available?
2. How will effluent be disposed of? (eg. evaporation, discharge to rivers, aquifer release, agriculture)
3. Disposal technique of sludge and any potential for sludge re-use?
4. What water catchment will the site reside in?
5. Any RWQO that are applicable, or will a General Authorisation apply?
6. What is the WSPr's capabilities and technology preferences

Engagements with DWS will be required to confirm the RWQO's which apply to catchment.

Step 4: Select the STP technology to be applied

The PSP should identify at least three technologies (1 preferred and 2 alternatives) for final consideration by the WSPr and WSA. These options are evaluated as part of a feasibility study, which needs to address aspects of sustainability as well.

The PSP responsible for the Environmental Authorisation will have to work closely with the technical PSP in order to make sure all aspects ito the NEMA and NEMWA has been fully addressed.

Where required, specialist studies focussing on specific impacts the technologies can have on the receiving environment (eg. receiving river ecology, aquifers and impact of sludge on soil composition), needs to be executed.

Step 5: Obtain institutional authorisation

The three main institutional authorisations are:

1. Project funding
2. Environmental Authorisation
3. Water Use License

Without these, the project will not be able to continue. Depending on the funding models, there are those which will only release funding once it has been proven that a workable solution has been developed and implementation can easily be done. An example of this is the Municipal Infrastructure Grant (MIG), which is administered by COGTA with technical input by DWS. It is the author's experience that DWS has started to place a condition on this funding in that they would like to be part of the technology selection process.

Annexure 10: Excerpt from 2012 Green Drop Report (DWS 2013)

The next step in the Green Drop strategy was to gradually expand the programme to also include **privately owned and other public wastewater facilities**. As result of the benchmarking opportunities associated with Green Drop Certification, many privately owned facilities recognise the value proposition and positive exposure that comes from participation with the Green Drop programme. The Department has subsequently identified a select few privately owned plants, as well as treatment facilities owned and operated by the Department of Public Works (e.g. schools, correctional services, hospitals). In addition, a targeted regulatory intervention is undertaken in catchment such as the Hartbeespoort and Berg River catchments to fast-track risk mitigation by the water users.

Risk-based Regulation in South Africa

The Green Drop criteria has been designed to assess the entire business of the municipal wastewater services. Wastewater treatment still remains the key risk component within this production chain, and as such present a critical barrier in preventing pollution of natural resources. Wastewater risk abatement planning and implementation is part of this set of Green Drop criteria and is using the Cumulative Risk Ratios (CRR) to track progress on a year-to-year basis. This allows the Regulator to have insight into the treatment component of the municipal, private- and public wastewater treatment business.

Risk-based regulation allows the municipality to identify and prioritise the critical risk areas within its wastewater treatment process and to take corrective measures to abate these. Risk analysis is used by the Regulator to identify, quantify and manage the corresponding risks according to their potential impact on the water resource and to ensure a prioritised and targeted regulation of municipalities whose facilities fall in high and critical risk parameters. Such 'risk' is defined and calculated as follows:

Cumulative Risk Rating (CRR) = A x B + C + D

where:
A = Design Capacity of plant which also represent the hydraulic loading onto the receiving water body
B = Operational flow exceeding-, on- and below capacity
C = Number of non-compliance trends in terms of effluent quality as discharged to the receiving water body
D = Compliance or non-compliance i.t.o. technical skills

A CRR value is calculated for each municipal wastewater treatment facility in South Africa, as provided in this Green Drop Progress Report. From 2012, private- and public plants are also included in this profile.

A CRR %deviation is used throughout the Report to indicate that variance of a CRR value before it reaches its maximum CRR value. The higher the CRR %deviation value, the closer the CRR risk is to the maximum value it can obtain. Example 1: a 95% CRR %deviation value means the plant has only 5% space remaining before the system will reach its maximum critical state (100%). Example 2: a 25% CRR %deviation value means the plant holds a low and manageable risk position and is not close to the limits that define a critical state (90-100%).

CRR %deviation is calculated as ***CRR value / CRRmax X100 = CRR %deviation (as %)***

Wastewater Risk Abatement Planning (W_2RAP)

Wastewater treatment is the first barrier in a multi-barrier system of ensuring public- and environmental health. In the same way that the Water Safety Plan identifies, plan and manage the risks in the drinking water treatment and supply systems, does the W_2RAP identify, plan and manage risks in the wastewater collection and treatment system.

Assessment Areas	WWTW	
Technology	Activated sludge-BNR Anaerobic sludge digestion	
Design Capacity (Ml/d)	200	A
Operational % i.t.o. Design Capacity	111%	B
i) Microbiological Compliance	75.5%	
ii) Chemical Compliance	95.4%	
iii) Physical Compliance	99.5%	
Annual Average Effluent Quality Compliance	96.2%	C
Wastewater Risk Rating (%CRR/CRRmax)	62.3% (↓)	CRR
Highest Risk Area	Flow exceed design capacity, effluent quality (disinfection)	
Risk Abatement Process	Draft W_2RAP	
Capital & Refurbishment expenditure in 2010/2011	R 21 million	
Description of Projects' Expenditure	Refurbishment of digesters, sludge dredging from maturation ponds	
Wastewater Risk Abatement planning	A CRR-based W_2RAP has been prepared by the WSA which identified the key risk pertaining to plant capacity, effluent quality and technical skill within the municipality. The plan prioritise the high risk hazards and list mitigation measures, funds, responsibility and timeframes against the risk area to ensure abatement of risks.	

Plant name and technology description for liquid and sludge phase of wastewater

CRR = A*B+C+D where A, B, C and D is provided

This score indicates the risk % as a deviation of the maximum risk that could possibly achieved. An orange and red score indicate that the plant is already in high- or critical risk that warrants urgent attention. A ↑ arrow shows a trend of increase risk (digression), whilst a ↓ shows risk is being reduced (improved) upon comparison with the

Funds and actions undertaken by the WSI to mitigate the identified risks

More information on the status of the W_2RAP and the approach taken to risk management

The PAT Assessment and Scoring Criteria

PAT assessments are conducted by a team of five Lead Inspectors, who are qualified competent persons in wastewater management. The team selection is based on the outcomes of a Green Drop Examination which verified the candidate's knowledge and competence in the subject field before assigning the responsibilities of Lead Inspector. Each PAT scorecard is moderated by an independent Moderator to ensure quality control and correctness of interpretation.

The process consisted of the circulation of (pre-populated) PATs with explanatory FACTSHEETS to the WSIs via the Regional DWA offices. A window period of 2 months was provided during which PATs were returned to DWA. Confirmation assessment were conducted to verify the information provided by WSIs in the PATs and to collect any outstanding information that impact on the CRR values.

Important notice: The PAT Progress assessment period was done on compliance data and actions during July 2010 to June 2011, which represents the year immediately following the Green Drop 2011 assessment period.

PAT Progress Assessment Period : 1 July 2010 – 30 June 2011

The following table provides the content of the Green Drop Progress Assessment Tool:

#	Green Drop Criteria	Description of Criteria	Additional information to assist completion
1	Confirmed Plant Classification	Class of Works	Choose the applicable Class Works from the options provided in the dropdown list
		Type/s of effluent treatment technology	3 columns are provided, each have a dropdown list to choose the applicable technology for effluent treatment. If a combination of technologies are applied, then make such options under the next

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			columns
		Type/s of sludge treatment technology	3 columns are provided, each have a dropdown list to choose the applicable technology for effluent treatment. If a combination of technologies are applied, then make such options under the next columns
2	Design Capacity (Ml/d)	As captured on GDS	Provide the hydraulic design capacity, as reflected on the GDS. *If 'No Information' is available or the unit is unknown to the municipality – zero compliance is assumed*
		Confirmed capacity	Provide the actual and confirmed hydraulic design capacity, which might be different or the same as the GDS value. *If' No Information' is available or the unit is unknown to the municipality, zero compliance is assumed*
3	Operational Capacity (Ml/d)	Frequency of inflow measurement	State in one word the frequency of inflow measurement to the plant – this could be: monthly, weekly, daily, hourly, 15 minutes, etc.
		Measured daily inflow (Ml/d)	Provide a *value* only, which states the daily inflow recorded to the plant. This value is best represented by the average flow to the plant over the period 1 July 2010 – 30 June 2011. *If 'No Information' is available or the unit is unknown to the municipality, zero compliance is assumed*
		Operational Capacity (%)	This cell is blocked and will automatically calculate the % capacity utilised as follows: (*measured flow / confirmed capacity)*100*
4	Process Control Skills *Compliance with R2834*	Supervisor + Process Controllers + Maintenance (1)	Using Regulation 2834 as guideline, choose the appropriate staff combinations applicable to your the staff set-up at the specific plant, the choose the number in bracket next to the chosen option and insert in yellow cell. Example: If the plant have a Supervisor, Process Controller and Maintenance crew that complies in full with Regulation 2934, then insert '1'.
		Supervisor + Maintenance & No Process Control (2)	
		Process Control + Maintenance & No Supervisor (2)	
		Process Control + Supervisor & No Maintenance (2)	
		Supervisor & No Maintenance & No PC's (3)	
		Process Controllers & No Maintenance & No Supervisor (3)	
		Maintenance & No PC's & No Supervisor (3)	
		No Supervisor & No Maintenance & No PCs (4)	
5	Wastewater Quality Compliance	Number of determinands that do not comply 90% of the time with Authorization Limits	No need to complete, this will be verified by the Green Drop Assessor
		Annual Compliance record (%)	
		E. coli / Faecal coliform	Calculate the % compliance for E coli OR Faecal coliform over the period 1 July 2010 – 30 June 2011. Refer to Annex A for guidance on this calculation if in doubt. If: • DWA authorisation do not require monitoring of this determinant, insert NMR • No information, insert NI
		Ammonia as Nitrogen	Same as above, but for specific to NH_3-N
		Chemical Oxygen Demand	Same as above, but for specific to COD
		Nitrate/Nitrite as Nitrogen	Same as above, but for specific to $NO_{2/3}$
		Ortho-Phosphate as Phosphorus	Same as above, but for specific to PO_4
		pH	Same as above, but for specific to pH
		Electrical Conductivity	Same as above, but for specific to EC
		Suspended Solids	Same as above, but for specific to SS
6	W_2RAP	Is there a W_2RAP in place (Yes / No)	'Yes' if a W_2RAP (wastewater risk abatement plan) process have commenced and evidence of resources can be provided. If not, 'No'
		Format (Rough = R /Draft = D/Finalised = F)	R=planning and rough outline done D=draft document is in place as evidence F=final document is in place in conforming to the WRC "W_2RAP Guideline" for municipalities (TT489/11)

		W_2RAP comments	Details of the type or W_2RAP that is under development or completed, with some details to attest to the findings and implementation.
7	**Capital Projects**	Capital & refurbishment projects - expenditure (Rand in million over 2010/11 financial year)	Capital Expenditure (in Rand) that has been expended over the past FY in terms of upgrading, refurbishment or replacement (capital only) against this specific system. (values in Rmillion)
		Brief description of the nature of projects	Details of the project under the 'Description box" that might include: project name, funding source, period, main activities undertaken (e.g. upgrade with 3 M/d capacity), refurbish settling tanks, construct chlorine building, etc)
8	**Green Drop Action Plan**	Brief description of Corrective Action Plan adopted based upon 2011 Green Drop Report	Details of the type of Corrective Action Plan in place whereby the gaps and corrective measures are outlined against the Green Drop Report June 2011. Some examples would include: Green Drop Improvement Plan, Corrective Action Plan, W_2RAP chapter, Work Plan, etc
		Name action targets achieved	Gaps identified which have been RECTIFIED since June 2011 – give specific details in evidence of rectification
Cumulative Risk Rating (CRR)			This block indicate the system's CRR value
$CRR_{maximum}$			Based on the above information and data, this block will indicate the maximum CRR that the system potentially could reach
WW Risk Rating (% CRR/CRR_{max})			This cell will reflect the CRR/CRR_{max} % value, using the input from the above 2 values
Microbiological Compliance (%)			This cell will depict the % compliance based on the data provided by the municipality against the E coli or Faecal coliform parameter
Chemical Compliance (%)			This cell will depict the % compliance based on the data provided by the municipality against the COD, NH_3, $NO_{3/2}$, O-PO_4 parameters
Physical Compliance (%)			This cell will depict the % compliance based on the data provided by the municipality against the SS, pH and EC parameters
Average Compliance (%)			The cell will display the average compliance of the discharge effluent quality

"It always seems impossible until it's done."

Nelson Mandela

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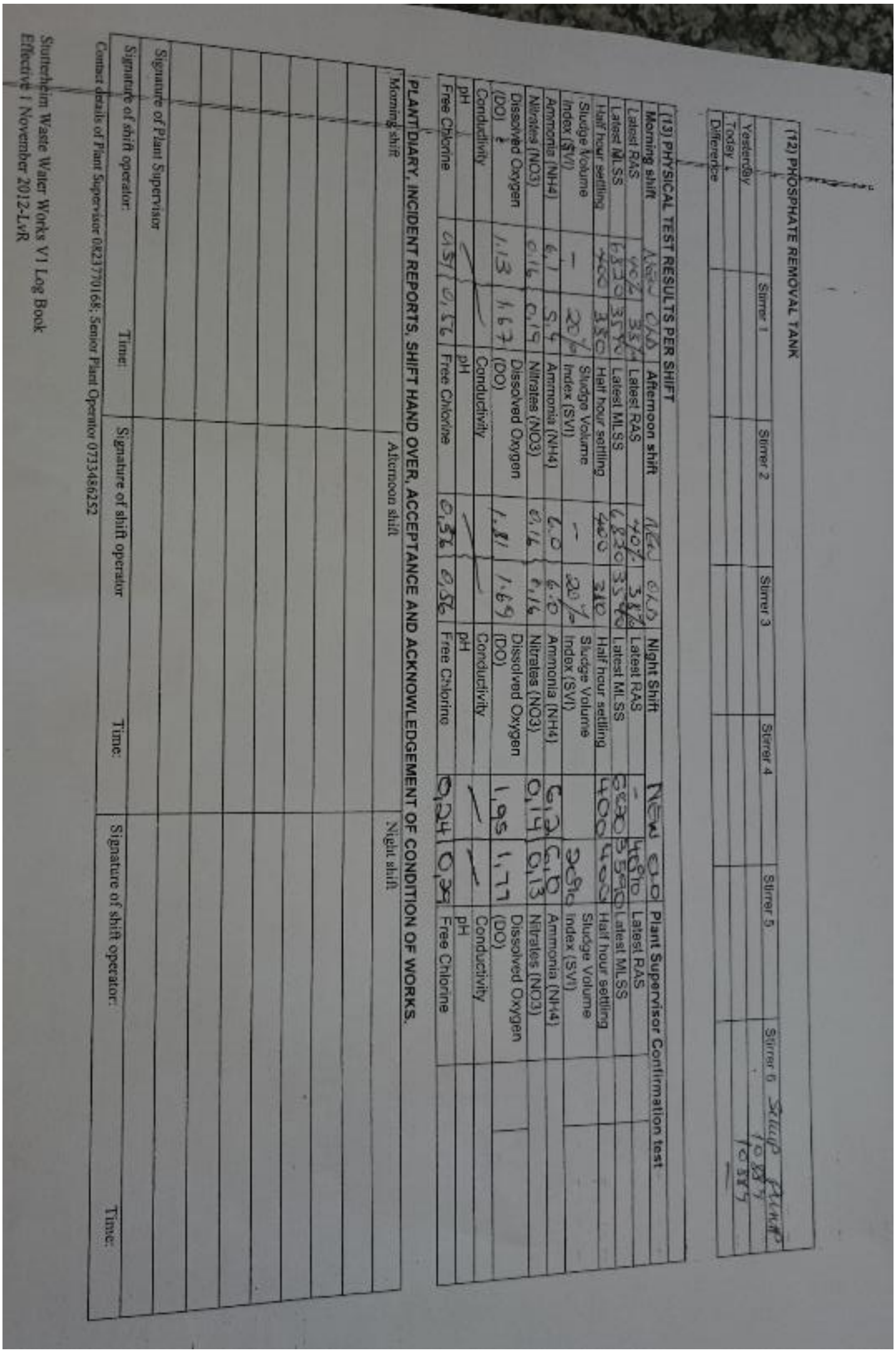
Annexure 11: Stutterheim Field Investigation Findings



(12) PHOSPHATE REMOVAL TANK

	Stirrer 1	Stirrer 2	Stirrer 3	Stirrer 4	Stirrer 5	Stirrer 6 Setup Pump
Yesterday						10887
Today						10889
Difference						—

(13) PHYSICAL TEST RESULTS PER SHIFT

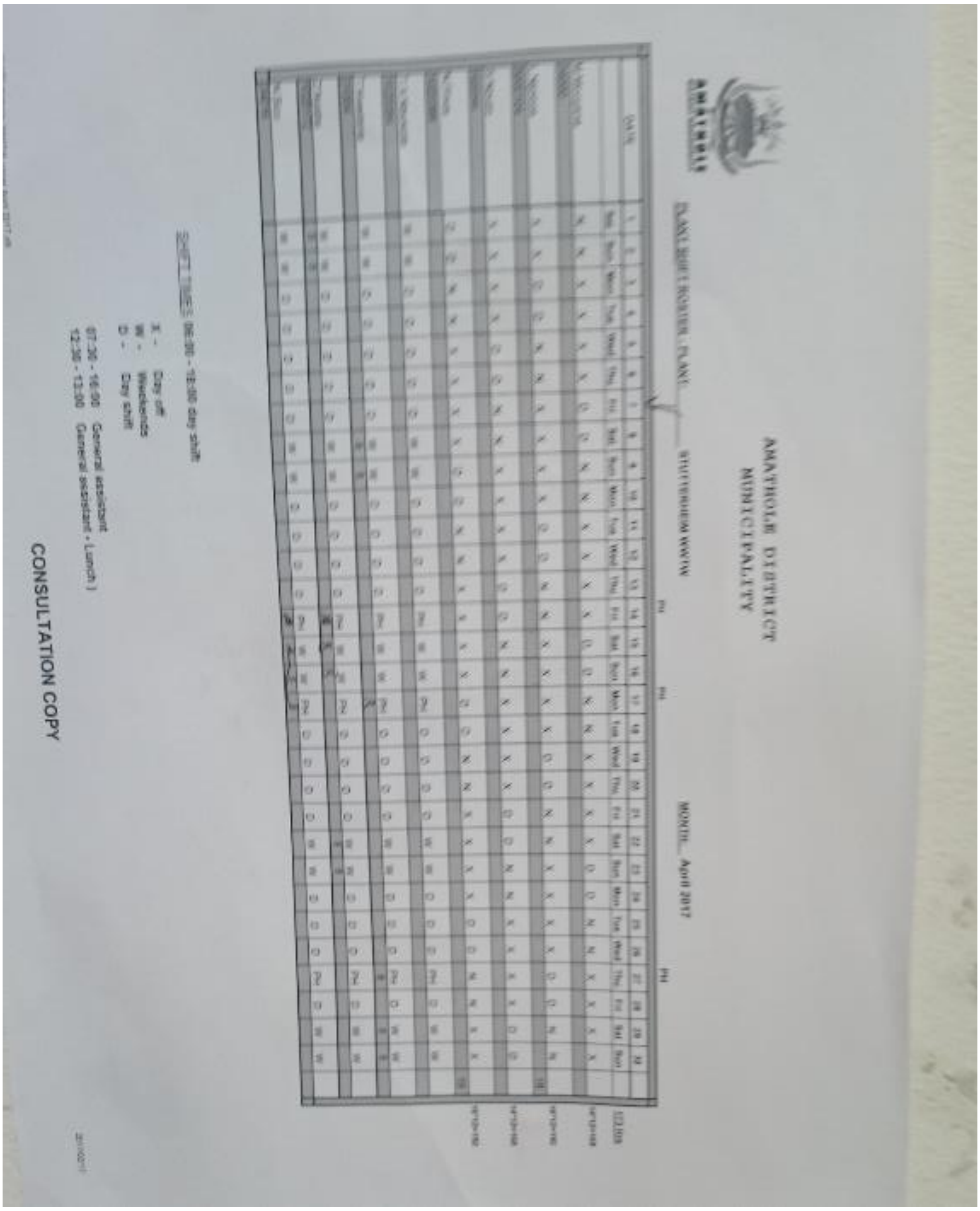
Morning shift	New	Old	Afternoon shift	New	Old	Night Shift	New	Old	Plant Supervisor Confirmation test		
Latest RAS	40%	35%	Latest RAS	40%	38%	Latest RAS	—	40%	Latest RAS		
Latest MLSS	6820	3570	Latest MLSS	6820	3570	Latest MLSS	6820	5590	Latest MLSS		
Half hour settling	400	350	Half hour settling	400	310	Half hour settling	400	400	Half hour settling		
Sludge Volume Index (SVI)	—	20%	Sludge Volume Index (SVI)	—	20%	Sludge Volume Index (SVI)		20%	Sludge Volume Index (SVI)		
Ammonia (NH4)	6.1	5.4	Ammonia (NH4)	6.0	6.0	Ammonia (NH4)	6,2	6,0	Ammonia (NH4)		
Nitrates (NO3)	0.16	0.19	Nitrates (NO3)	0.16	0.16	Nitrates (NO3)	0,14	0,13	Nitrates (NO3)		
Dissolved Oxygen (DO)	1.13	1.67	Dissolved Oxygen (DO)	1.81	1.69	Dissolved Oxygen (DO)	1,95	1,77	Dissolved Oxygen (DO)		
Conductivity	—	—	Conductivity	—	—	Conductivity	—	—	Conductivity		
pH			pH			pH			pH		
Free Chlorine	0.57	0.56	Free Chlorine	0.56	0.56	Free Chlorine	0,24	0,29	Free Chlorine		

PLANT DIARY, INCIDENT REPORTS, SHIFT HAND OVER, ACCEPTANCE AND ACKNOWLEDGEMENT OF CONDITION OF WORKS.

Morning shift	Afternoon shift	Night shift
Signature of Plant Supervisor		
Signature of shift operator: Time:	Signature of shift operator Time:	Signature of shift operator: Time:

Contact details of Plant Supervisor 0823770168; Senior Plant Operator 0733486252

Stutterheim Waste Water Works V1 Log Book
Effective 1 November 2012-LvR

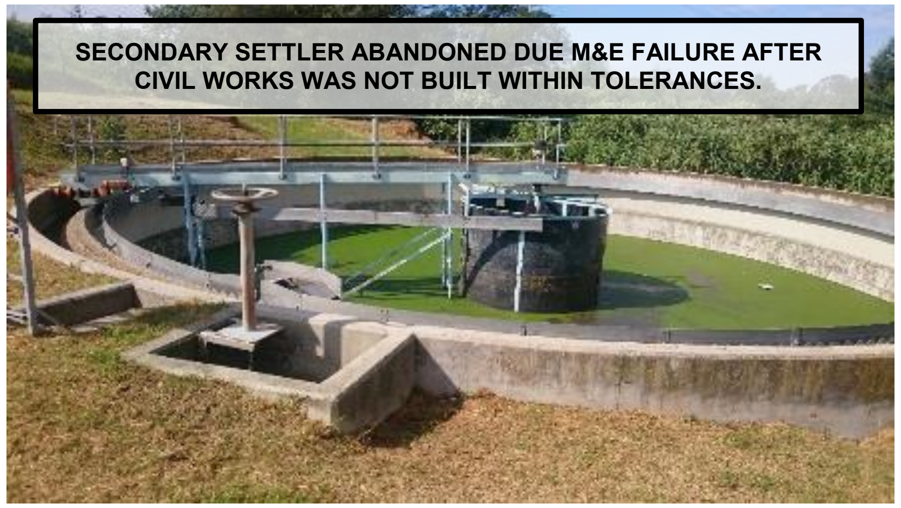

AMATHOLE DISTRICT
MUNICIPALITY
MONTH April 2017
SHIFT TIMES 06:00 - 18:00 day shift
X - Day off
W - Weekends
D - Day shift
07:30 - 16:00 General assistant
12:30 - 13:00 General assistant - Lunch)
CONSULTATION COPY


INLET WORKS WITH ONE MECHANICALLY RAKED SCREEN AND ONE MANUAL SCREEN FOR BACK-UP


DUAL OXIDATION DITCHED, EACH WITH 1.5Ml/d CAPACITY, BUT CAN ACCOMMODATE INCREASED LOADING IF ONE DITCH FAILS


ABANDONED PHOSPHATE REMOVAL PROCESS


SECONDARY SETTLER WITH CHLORINE CONTACT TANK IN BACKGROUND.


SECONDARY SETTLER ABANDONED DUE M&E FAILURE AFTER CIVIL WORKS WAS NOT BUILT WITHIN TOLERANCES.


SLUDGE DRYING BEDS

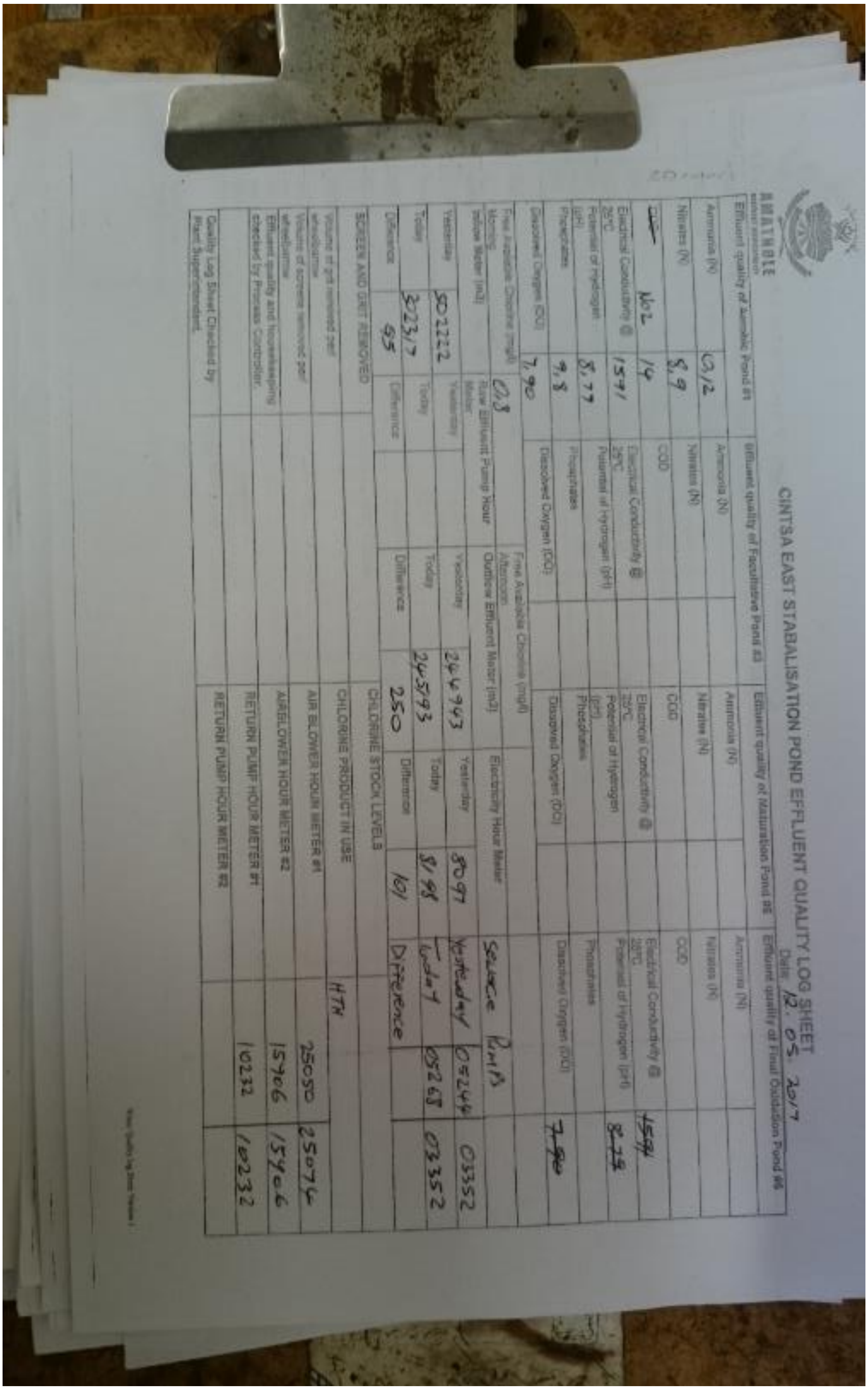

CHLORINATION BUILDING WITH CHLORINE CONTACT TANK. EFFLUENT DISCHARGE INTO RIVER IN BACKGROUND


ON-SITE LABORATORY

PLANT CLASSIFICATION AND PROCESS CONTROLLER QUALIFICATION CERTIFICATES

FIELD INVESTIGATION FEEDBACK		
STP Visited: Stutterheim STP		
Visit Date: 2 May 2017		
Item	**Questions**	**Answers**
1	Process Description:	WAS, Inlet works to Oxidation Ditches to Secondary Settlers to Chlorine Contact Tank. Phosphor system brought in for sludge from ditches. Treated sludge back into ditches.
2	Design Capacity	3Ml/d
3	Flow Rate	1.82Ml/d
4	How frequently is flow rate monitored	three times a day by process controllers
5	Is the STP in a good condition and if not, why not?	Yes, except for components not working
6	How many staff work at the plant and qualifications	
6.1	Supervisor	1 Rotating
6.2	Process Controller	3 full time, once senior and two junior
6.3	Maintenance Team	Rotating team
7	Is there an O&M Manual in place?	No
8	Does DWS visit the plant?	Once a month to perform effluent samples
9	How safe is the effluent discharged and where does it go?	Goes into river, not all parameters are tested for. Kubusi River - A lot of water hyacinth is seen. (Supervisor says this is because of Sewage Spills) Goes into Wriggleswade Dam - use for Potable Water from there.
10	How is effluent quality monitored?	On-site, three times a day. Only certain parameters
11	How frequently is effluent monitored and by whom?	three times a day by process controllers
12	What effluent parameters are tested?	
12.1	E.Coli / Faecal Coliforms	No
12.2	Ammonia and Nitrogen	Yes. Apparantly at end 5, where at start it is 17.
12.3	COD	No
12.4	Nitrate/Nitrite and Nitrogen	Yes
12.5	Ortho-Phosphate as Phosphorous	No
12.6	pH	No - No equipment
12.7	Elctrical Conductivity	No - No Equipment
12.8	SS	No - A lot of turbulence seen in effluent. Apparantly appeared after ditches were cleaned.
12.9	Free Chlorine	Yes
13	Influent monitoring also done? (How, when, who)	No
14	Is any sludge disposal happening and how is it done?	After sludge drying beds it goes to landfill (old ponds). Sludge development not a lot.
15	What are the typical O&M Activities that should be performed and how frequently?	Cutting grass, removing screenings and disposing of sludge. All other done as and when required with maximum a 30 day waiting period for spare periods.
16	What practical tips recommended to improve the STPs use and performance?	Phosphate removal system is not working well. System needs to improve, or better training. Problems with gear box failure when sludge is heavy laden. Installled in 2009, gave problems from the start.
17	What is the most difficult part of work at the STP?	None
18	What are the typical problems experienced	General labourers have physical labour. Theft of fences . Electrical cables were not sized correctly - not for larger motors, so had to be replaced. Clarifier's civil works was not installed correctly, thus M&E cannot function.
19	What other technologies has operators/supervisors heard of and should be investigated?	None
20	Is any community benefitting from this STP and how.	No
21	Would the community like to use the effluent / sludge	Not sure
22	Does the operators/supervisors believe this is the best technology to use?	Don't know any others
23	What are their opinion about rather using pond systems?	Available Land
24	How effective are institutions currently at operating and maintaining wastewater treatment works?	Very good
25	Any other creative ways for the community to be involved or benefit?	Not sure
26	How do they see STPs managed in a rural village set-up	Not sure

Annexure 12: Cintsa East STP Field Investigation Findings



AMATHOLE

CINTSA EAST STABALISATION POND EFFLUENT QUALITY LOG SHEET

Date 12.05.2017

	Effluent quality of Aerobic Pond #1		Effluent quality of Facultative Pond #3		Effluent quality of Maturation Pond #5		Effluent quality of Final Oxidation Pond #6	
Ammonia (N)	0.12	Ammonia (N)		Ammonia (N)		Ammonia (N)	
Nitrates (N)	8.9	Nitrates (N)		Nitrates (N)		Nitrates (N)	
COD	102	COD		COD		COD	
Electrical Conductivity @ 25°C	1591	Electrical Conductivity @ 25°C		Electrical Conductivity @ 25°C		Electrical Conductivity @ 25°C	1594
Potential of Hydrogen (pH)	8.77	Potential of Hydrogen (pH)		Potential of Hydrogen (pH)		Potential of Hydrogen (pH)	8.79
Phosphates	9.8	Phosphates		Phosphates		Phosphates	
Dissolved Oxygen (DO)	7.90	Dissolved Oxygen (DO)		Dissolved Oxygen (DO)		Dissolved Oxygen (DO)	7.90

Free Available Chlorine (mg/l) Morning	0.8	Free Available Chlorine (mg/l) Afternoon					
Inflow Water (m3)		Raw Effluent Pump Hour Meter		Outflow Effluent Meter (m3)		Electricity Hour Meter		Service Pump
Yesterday	302222	Yesterday		Yesterday	244943	Yesterday	8097	Yesterday 05244	03352
Today	302317	Today		Today	245193	Today	8198	Today 05268	03352
Difference	95	Difference		Difference	250	Difference	101	Difference	

SCREEN AND GRIT REMOVED		CHLORINE STOCK LEVELS	
Volume of grit removed per wheelbarrow		CHLORINE PRODUCT IN USE	HTH
Volume of screens removed per wheelbarrow		AIR BLOWER HOUR METER #1	25050 / 25076
Effluent quality and housekeeping checked by Process Controller		AIRBLOWER HOUR METER #2	15906 / 15906
		RETURN PUMP HOUR METER #1	10232
Quality Log Sheet Checked by Plant Superintendent		RETURN PUMP HOUR METER #2	10232

Amatola Water Amanzi - *Water is life*

Scientific Services Department

Final Water Quality Report

Report Number: 69529

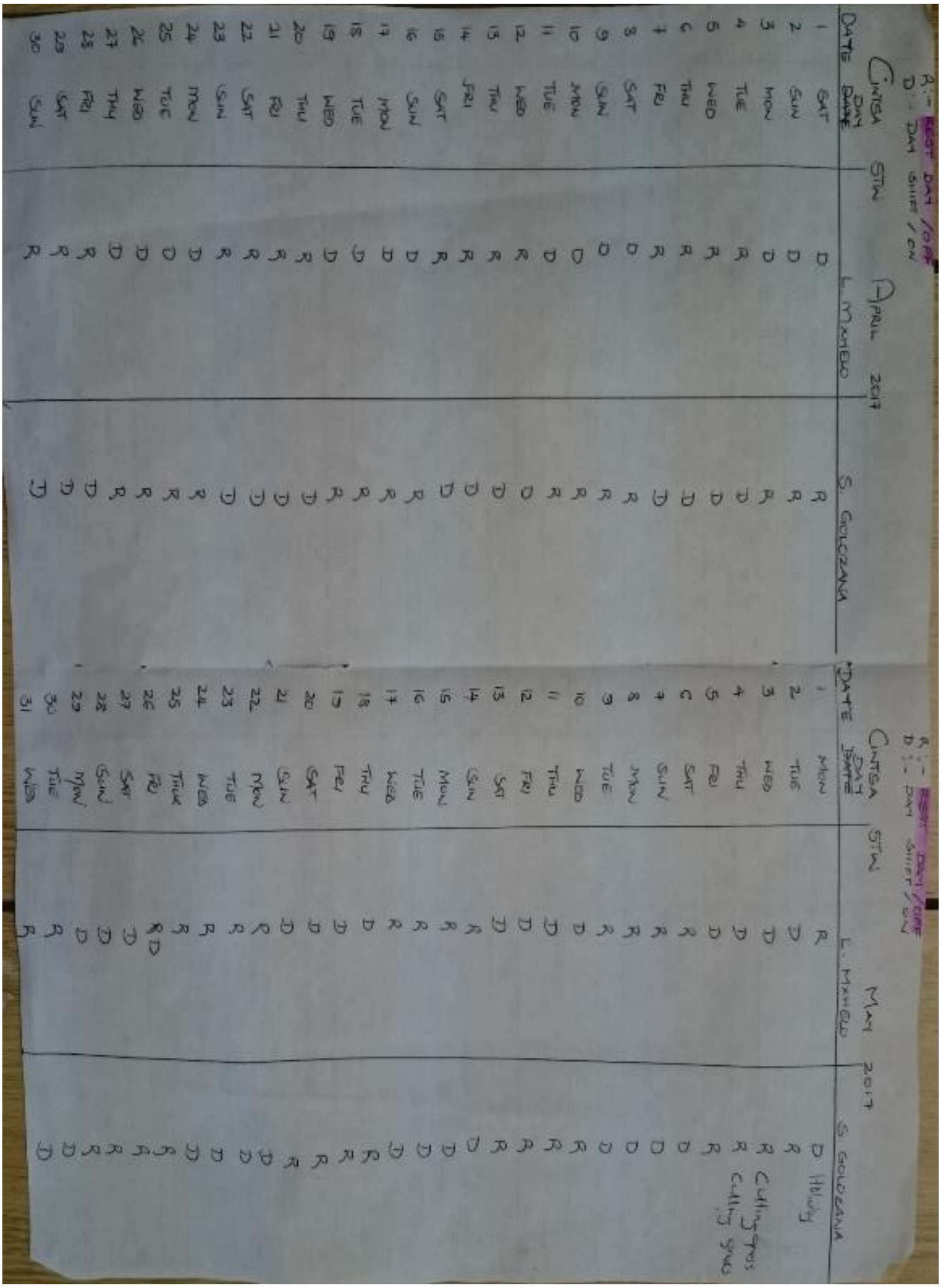
Test List: MMP_S1
Scheme: MMP Great Kei LM
Received Date: 20/07/2015

Sample Number			129233
Sample Description			12313
Sample Received Date			20/07/2015
Sample Completed Date			30/07/2015
Comment			Final Oxidation Pond Kei Mouth Samples recieved in good condition for testing
Test	**Units**	**Method No**	
Ammonia as N	mg/l	C32	18.07
Chemical Oxygen Demand - DR2800	mg/l	C50	70
Chlorine - Cllent	mg/l		0.65
E coli waste water(colllert)	MPN/100ML	M01	1414
EC @ 25°C	mS/m	C15	65.6
Nitrate as N	mg/l		0.48
Ortho phosphate - Aquakem	mg/l	C37	4.38
PH @ 25°C	-	C14	7.45
Solids - Total suspended	mg/l	C46	9

Test List: MMP_S1
Scheme: MMP Great Kei LM
Received Date: 28/07/2015

Sample Number			129301	129305
Sample Description			12303	12308
Sample Received Date			28/07/2015	28/07/2015
Sample Completed Date			04/08/2015	04/08/2015
Comment			Final Oxidation Ponds Cintsa East Samples recieved in good conditions for testing	WWTW Komga Samples recieved in good conditions for testing
Test	**Units**	**Method No**		
Ammonia as N	mg/l	C32	17.96	0
Chemical Oxygen Demand - DR2800	mg/l	C50	63	31
Chlorine - Cllent	mg/l		0.56	3.48
E coli waste water(colilert)	MPN/100ML	M01	<1	<1
EC @ 25°C	mS/m	C15	122.6	106.2
Nitrate as N	mg/l		2.05	13
Ortho phosphate - Aquakem	mg/l	C37	6.4	2.19
PH @ 25°C	-	C14	7.64	7.38
Solids - Total suspended	mg/l	C46	1	8

Key: (s) - Subcontracted | (T) - New result | (TT) - Result updated



R :- REST DAY / OFF
D :- DAY SHIFT / ON

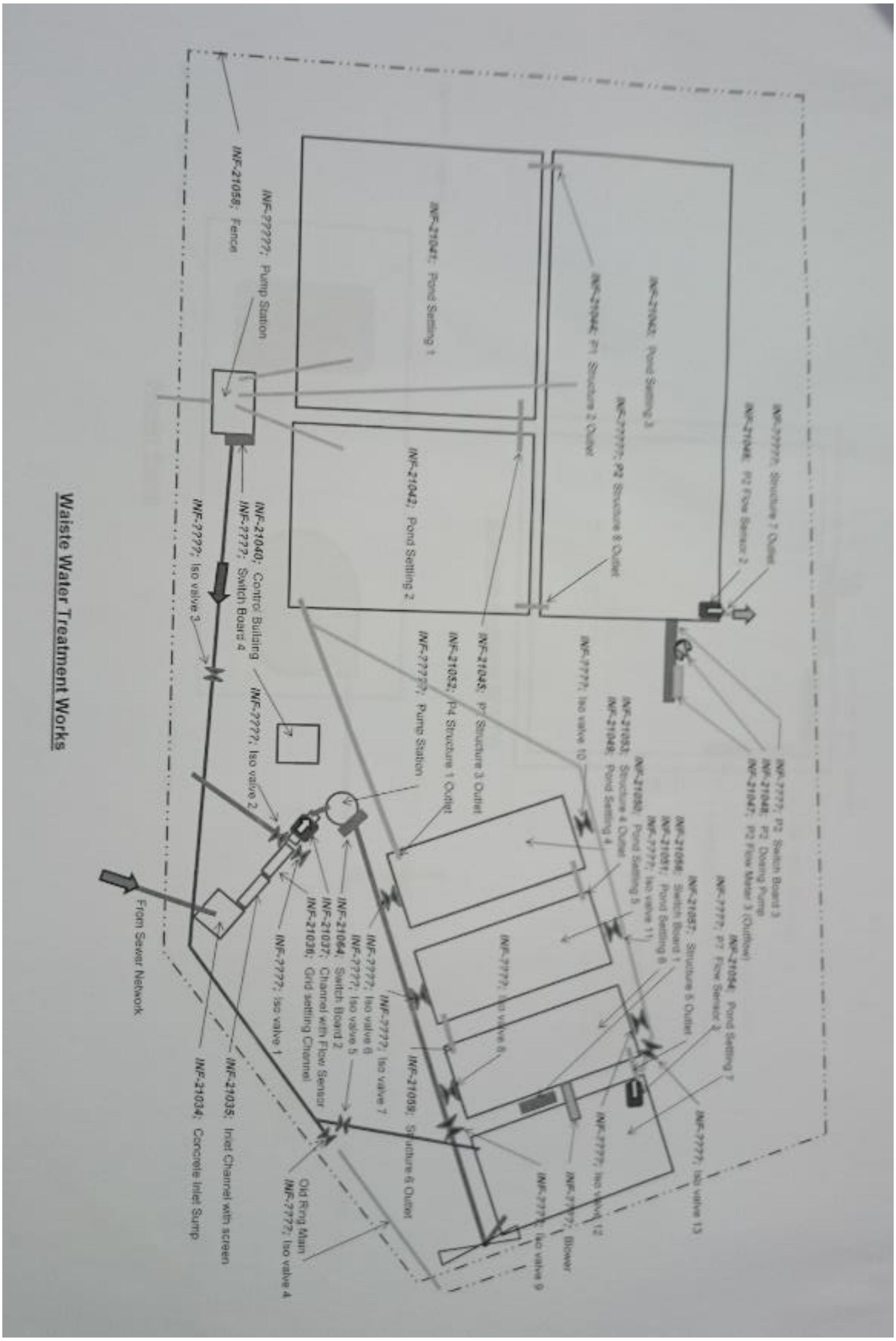
CINTSA STW APRIL 2017

DATE	DAY	L. MXHELO	S. GOLOZANA
1	SAT	D	R
2	SUN	D	R
3	MON	D	R
4	TUE	R	D
5	WED	R	D
6	THU	R	D
7	FRI	R	D
8	SAT	D	R
9	SUN	D	R
10	MON	D	R
11	TUE	D	R
12	WED	R	D
13	THU	R	D
14	FRI	R	D
15	SAT	R	D
16	SUN	D	R
17	MON	D	R
18	TUE	D	R
19	WED	D	R
20	THU	R	D
21	FRI	R	D
22	SAT	R	D
23	SUN	R	D
24	MON	D	R
25	TUE	D	R
26	WED	D	R
27	THU	D	R
28	FRI	R	D
29	SAT	R	D
30	SUN	R	D

R :- REST DAY / OFF
D :- DAY SHIFT / ON

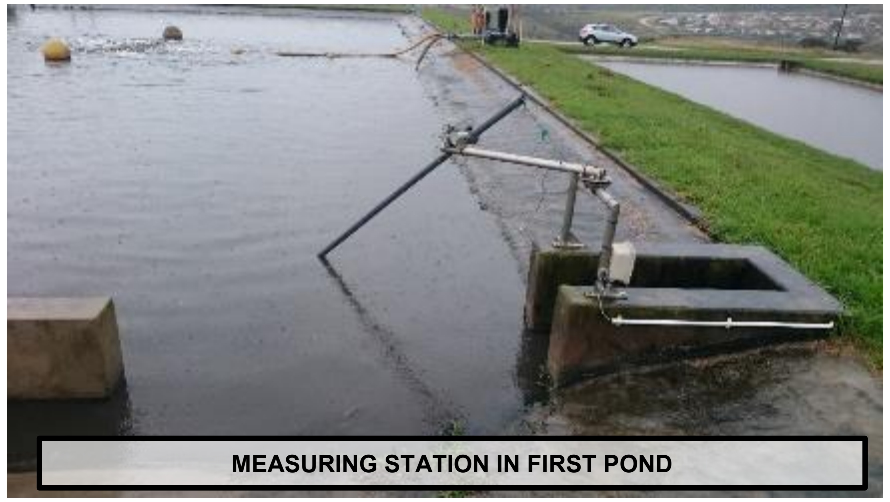
CINTSA STW MAY 2017

DATE	DAY	L. MXHELO	S. GOLOZANA
1	MON	R	D Holiday
2	TUE	D	R
3	WED	D	R Cutting grass
4	THU	D	R Cutting grass
5	FRI	D	R
6	SAT	R	D
7	SUN	R	D
8	MON	R	D
9	TUE	R	D
10	WED	D	R
11	THU	D	R
12	FRI	D	R
13	SAT	D	R
14	SUN	R	D
15	MON	R	D
16	TUE	R	D
17	WED	R	D
18	THU	D	R
19	FRI	D	R
20	SAT	D	R
21	SUN	D	R
22	MON	R	D
23	TUE	R	D
24	WED	R	D
25	THU	R	D
26	FRI	R D	R
27	SAT	D	R
28	SUN	D	R
29	MON	D	R
30	TUE	R	D
31	WED	R	D


Waiste Water Treatment Works
INF-21058; Fence
INF-?????; Pump Station
INF-21041; Pond Setting 1
INF-21043; Pond Setting 3
INF-21044; P1 Structure 2 Outlet
INF-?????; P2 Structure 8 Outlet
INF-?????; Structure 7 Outlet
INF-21046; P2 Flow Sensor 2
INF-21042; Pond Setting 2
INF-?????; Switch Board 4
INF-????; Iso valve 3
INF-21045; P1 Structure 3 Outlet
INF-21052; P4 Structure 1 Outlet
INF-????; Iso valve 10
INF-????; Iso valve 2
From Sewer Network
INF-21035; Inlet Channel with screen
INF-21034; Concrete Inlet Sump
INF-????; Iso valve 1
INF-21036; Grid settling Channel
INF-21037; Channel with Flow Sensor
INF-21064; Switch Board 2
Old Ring Main
INF-????; Iso valve 4
INF-21059; Structure 6 Outlet
INF-????; Iso valve 9
INF-????; Iso valve 13


INLET WORKS WITH MANUAL SCREEN AND HONEY SUCKER DISCHARGE


MECHNICALLY AERATED OXIDATION POND


MEASURING STATION IN FIRST POND


FACULTATIVE PONDS WITH OPERATOR OFFICES IN BACKGROUND


SLUDGE HOLDING POND WITH SUPERNATANT RETURN PUMP STATION


MATURATION PONDS

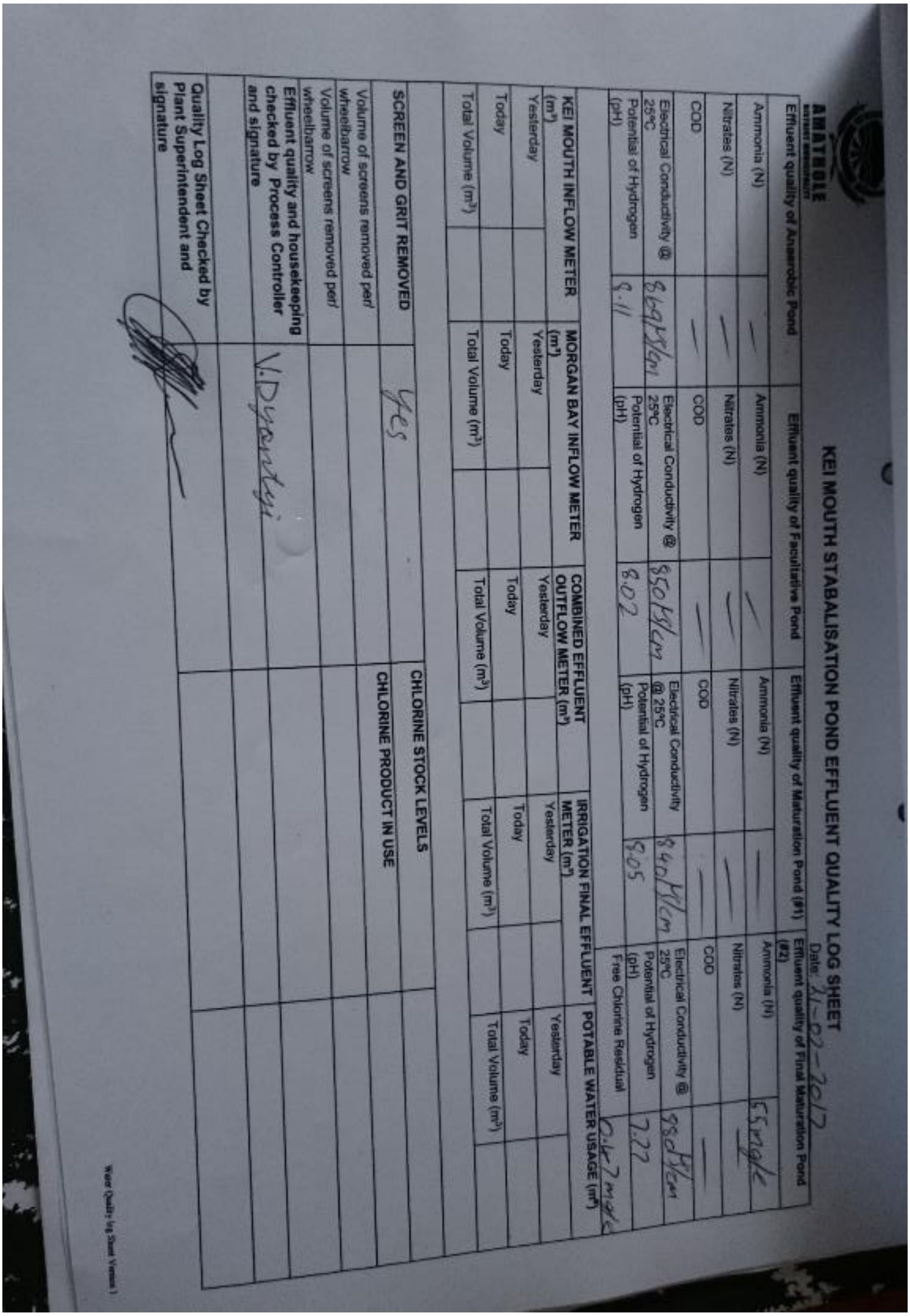

CHLORINATION POINT AND FLOW MEASUREMENT STATION


ON-SITE LABORATORY


PLANT CLASSIFICATION AND PROCESS CONTROLLER QUALIFICATION CERTIFICATES

FIELD INVESTIGATION FEEDBACK		
STP Visited: Cintsa East STP		
Visit Date: 12 May 2017		
Item	**Questions**	**Answers**
1	Process Description:	Inlet works with hand raked screen, then leading to Aerated Pond, then to three Facultative Ponds, then three Maturation Ponds. Chlorination by means of Sodium Hypochlride Solution.
2	Design Capacity	
3	Flow Rate	
4	How frequently is flow rate monitored	Once a day by process controllers
5	Is the STP in a good condition and if not, why not?	Yes, grass cutting and general pond maintenance should be done.
6	How many staff work at the plant and qualifications	
6.1	Supervisor	1 Rotating
6.2	Process Controller	2 on rotating day shifts
6.3	Maintenance Team	Central team rotating between different STPs
7	Is there an O&M Manual in place?	Yes, but only a partial one prepared by WSPr
8	Does DWS visit the plant?	Once a month to perform effluent samples
9	How safe is the effluent discharged and where does it go?	Goes into river, not all parameters are tested for. DWS has granted irrigation quality effluent standard. Before Aeration the STP's effluent quality did not comply.
10	How is effluent quality monitored?	On-site, once a day. Only certain parameters
11	How frequently is effluent monitored and by whom?	Once a day by process controllers
12	What effluent parameters are tested?	
12.1	E.Coli / Faecal Coliforms	No
12.2	Ammonia and Nitrogen	Yes.
12.3	COD	No - DO is tested for.
12.4	Nitrate/Nitrite and Nitrogen	Yes
12.5	Ortho-Phosphate as Phosphorous	Yes
12.6	pH	Yes
12.7	Elctrical Conductivity	Yes
12.8	SS	No
12.9	Free Chlorine	Yes
13	Influent monitoring also done? (How, when, who)	No
14	Is any sludge disposal happening and how is it done?	Sludge is discharged to sludge holding ponds. No intention at present to re-use sludge.
15	What are the typical O&M Activities that should be performed and how frequently?	Keeping concrete edges of ponds clean, removing duckweed. Screening Removals. Sampling.
16	What practical tips recommended to improve the STPs use and performance?	Construction of holding pond for emergencies. Chlorine contact tank. Grit channel at Inlet Works. (This can reduce sludge build up)
17	What is the most difficult part of work at the STP?	Desludging of ponds
18	What are the typical problems experienced	Reduction of Ammonia - cannot easily be regulated with pond systems. Removal of duckweed.
19	What other technologies has operators/supervisors heard of and should be investigated?	None
20	Is any community benefitting from this STP and how.	No
21	Would the community like to use the effluent / sludge	Sludge has got good agricultural potential, but WSPr not willing to authorise this.
22	Does the operators/supervisors believe this is the best technology to use?	Correct for local application but Supervisor's preference is Activated Sludge due to the easier control and adjustment of effluent quality.
23	What are their opinion about rather using pond systems?	Has good safety buffer but effluent quality cannot easily be adjusted.
24	How effective are institutions currently at operating and maintaining wastewater treatment works?	Very good
25	Any other creative ways for the community to be involved or benefit?	No Comment
26	How do they see STPs managed in a rural village set-up	Local villagers to perform day to day work, with WSPr assisting with frequent STP visits. Capacity development programme will be important.

Annexure 13: Kei Mouth STP Field Investigation Findings



AMATHOLE DISTRICT MUNICIPALITY

KEI MOUTH STABALISATION POND EFFLUENT QUALITY LOG SHEET

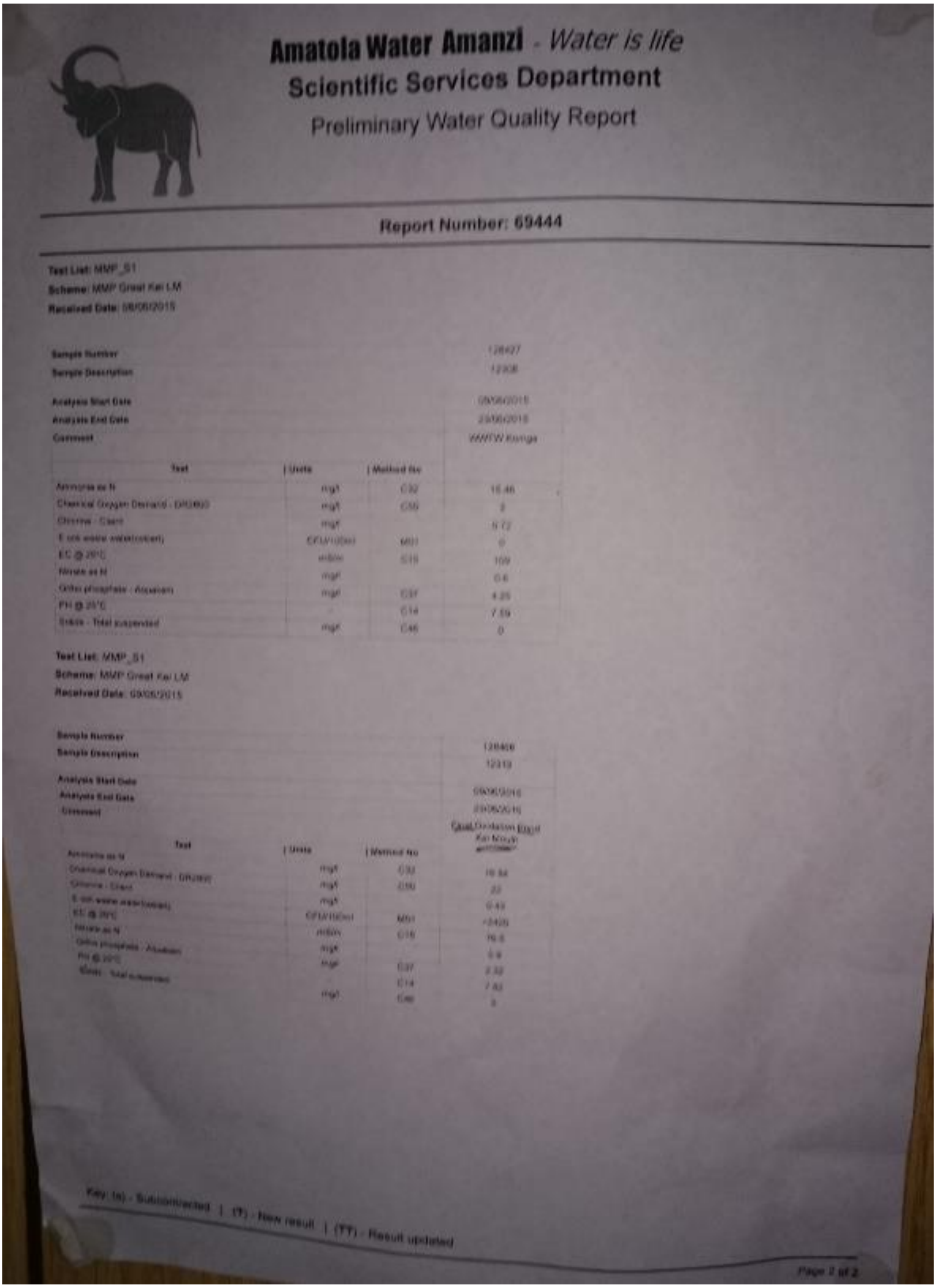
Date: 21-02-2017

Effluent quality of Anaerobic Pond		Effluent quality of Facultative Pond		Effluent quality of Maturation Pond (#1)		Effluent quality of Final Maturation Pond (#2)	
Ammonia (N)	—	Ammonia (N)	—	Ammonia (N)	—	Ammonia (N)	55mg/l
Nitrates (N)	—	Nitrates (N)	—	Nitrates (N)	—	Nitrates (N)	—
COD	—	COD	—	COD	—	COD	—
Electrical Conductivity @ 25°C	869µS/cm	Electrical Conductivity @ 25°C	850µS/cm	Electrical Conductivity @ 25°C	840µS/cm	Electrical Conductivity @ 25°C	980µS/cm
Potential of Hydrogen (pH)	8.11	Potential of Hydrogen (pH)	8.02	Potential of Hydrogen (pH)	8.05	Potential of Hydrogen (pH)	7.72
						Free Chlorine Residual	0.47mg/l

KEI MOUTH INFLOW METER (m³)		MORGAN BAY INFLOW METER (m³)		COMBINED EFFLUENT OUTFLOW METER (m³)		IRRIGATION FINAL EFFLUENT METER (m³)		POTABLE WATER USAGE (m³)	
Yesterday		Yesterday		Yesterday		Yesterday		Yesterday	
Today		Today		Today		Today		Today	
Total Volume (m³)		Total Volume (m³)		Total Volume (m³)		Total Volume (m³)		Total Volume (m³)	

SCREEN AND GRIT REMOVED	Yes	CHLORINE STOCK LEVELS	
		CHLORINE PRODUCT IN USE	
Volume of screens removed per/ wheelbarrow			
Volume of screens removed per/ wheelbarrow			
Effluent quality and housekeeping checked by Process Controller and signature	V.Dyantyi		
Quality Log Sheet Checked by Plant Superintendent and signature	[signature]		

Water Quality log Sheet Version 1



Amatola Water Amanzi - *Water is life*

Scientific Services Department

Preliminary Water Quality Report

Report Number: 69444

Test List: MMP_S1
Scheme: MMP Great Kei LM
Received Date: 08/06/2015

Sample Number	128427
Sample Description	12308
Analysis Start Date	09/06/2015
Analysis End Date	23/06/2015
Comment	WWTW Komga

Test	Units	Method No	
Ammonia as N	mg/l	C32	15.46
Chemical Oxygen Demand - DR3900	mg/l	C50	8
Chlorine - Cl2	mg/l		0.72
E coli waste water(colilert)	CFU/100ml	M01	0
EC @ 25°C	mS/m	C15	109
Nitrate as N	mg/l		0.6
Ortho phosphate - Aquakem	mg/l	C37	4.25
PH @ 25°C	-	C14	7.59
Solids - Total suspended	mg/l	C46	0

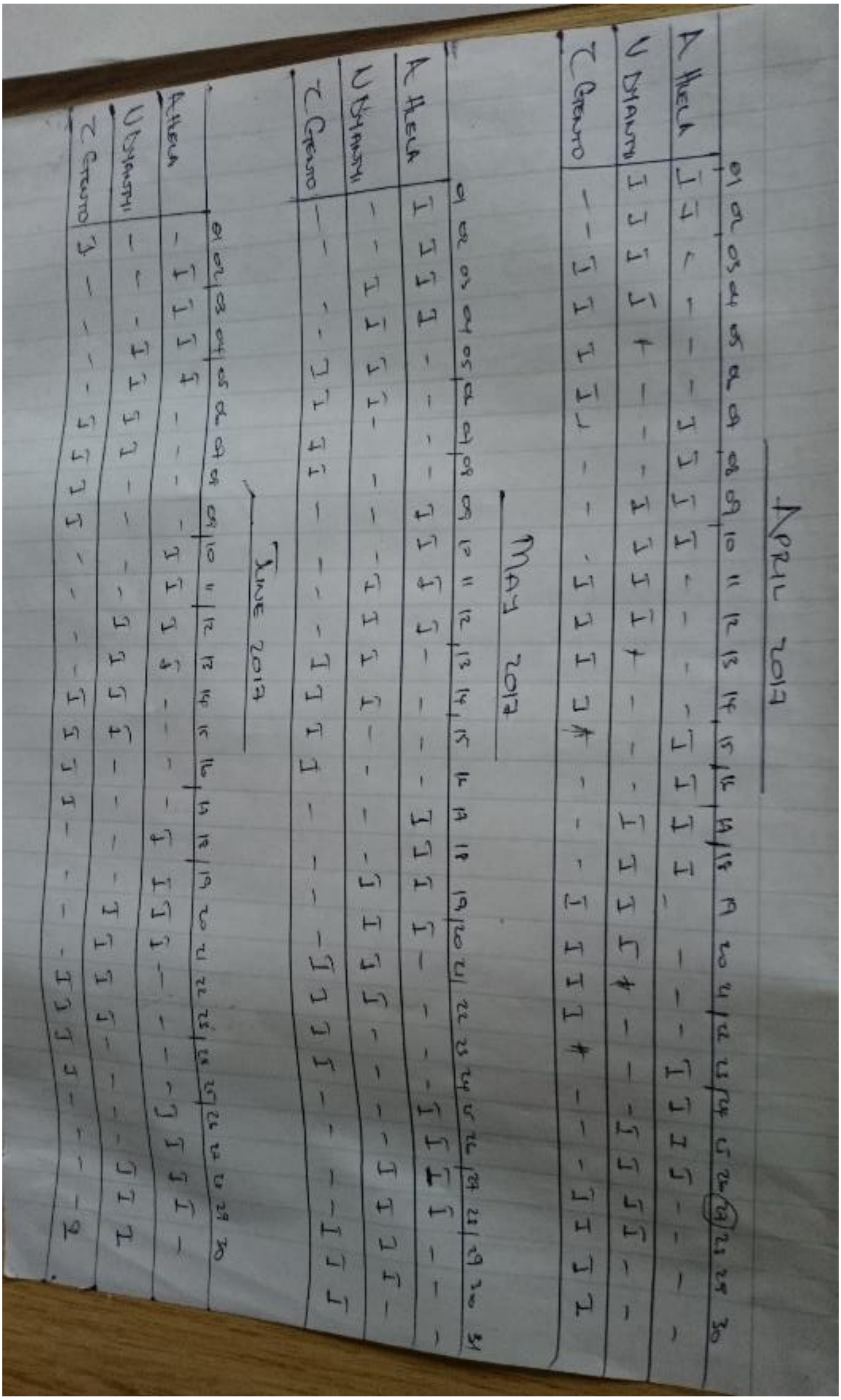
Test List: MMP_S1
Scheme: MMP Great Kei LM
Received Date: 09/06/2015

Sample Number	128466
Sample Description	12319
Analysis Start Date	09/06/2015
Analysis End Date	23/06/2015
Comment	Oxidation Pond Kei Mouth

Test	Units	Method No	
Ammonia as N	mg/l	C32	16.84
Chemical Oxygen Demand - DR3900	mg/l	C50	22
Chlorine - Cl2	mg/l		0.43
E coli waste water(colilert)	CFU/100ml	M01	>2420
EC @ 25°C	mS/m	C15	76.8
Nitrate as N	mg/l		0.8
Ortho phosphate - Aquakem	mg/l	C37	2.32
PH @ 25°C	-	C14	7.83
Solids - Total suspended	mg/l	C46	8

Key: (s) - Subcontracted | (T) - New result | (TT) - Result updated

Page 2 of 2


APRIL 2017
A Hlela
V Dyantyi
T Gcento
MAY 2017
A Hlela
U Dyantyi
T Gcento
JUNE 2017
A Hlela
U Dyantyi
T Gcento

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

PO BOX 7019 EAST LONDON 5200	☎ 043 701 0208	Enquiries: Mr. L Mini
E-mail: minil@dwa.gov.za	FAX : 043 722 6152	Ref:27/2/2/R130/6

The Municipal Manager
Amathole District Municipality
P.O. Box 320
EAST LONDON
5201

Attention: **Mr. Lester van Rooyen**

GENERAL AUTHORISATION IN TERMS OF SECTION 39 OF THE NATIONAL WATER ACT, (ACT 36 OF 1998): 21(e) IRRIGATION OF ANY LAND WITH WASTE OR WATER CONTAINING WASTE GENERATED THROUGH ANY INDUSTRIAL ACTIVITY OR BY A WATERWORK 21(g) DISPOSING OF WASTE IN A MANNER WHICH MAY DETRIMENTALLY IMPACT ON A WATER RESOURCE: KEI MOUTH WASTEWATER TREATMENT WORKS

Acknowledgement of the above water use activity is hereby confirmed and a Registration Certificate will be forwarded to you in due course.

In terms of Section 39 of the National Water Act 1998, (No. 36 of 1998) read in conjunction with Government Gazette No.665 of 6 September 2013 you are generally authorised to:

1. **Irrigate on any given day a total maximum quantity of ten point five (10.5 m^3/day) cubic metres of water containing waste. The geographical location of the area under irrigation is: S32° 41' 41.04" and E28° 21' 48.15"**

2. **Dispose on any given day a total maximum quantity of one hundred and seventy (170 m^3/day) cubic meters of water containing waste at Kei Mouth Waste Water Treatment Works.**

The property in respect of which the water use is authorised is Communal Land

You are required to fully comply with the <u>conditions</u> of the above Government Gazette as specified in Schedules 2 (attached for your convenience). This department requests you to take note of sections **1.11(1) - Record keeping and disclosure of information and 1.13 – Inspections** of the attached General Authorisation.

Page 1 of 2

Please take note that failure to comply with the conditions of the General Authorisation constitutes an offence and is subject to the penalty set out in section 151(2) of the National Water Act.

Your attention is further drawn to the following:

1. This Authorisation is valid until the **5 September 2018** unless:

   1.1 It is amended by the responsible authority at any review period;
   1.2 The period is extended by a Government Notice in the Gazette;
   1.3 It is replaced by another General Authorisation; or
   1.4 The water user is required to apply for a licence in terms of the National Water Act

2. The said water use activities do not impact on a water resource, another person's water use, property or land.

3. The activities are not detrimental to the health and safety of the public in the vicinity of the activities.

4. The responsible person for these activities shall immediately inform the Director: Institutional Establishment of any change in the name, address and/ or premises and legal status.

5. Sewage sludge and other solids sewage waste ,for instance grit and screenings shall be handled ,stored ,transported, utilised or disposed of in such a manner as not to cause any odour ,flies or other nuisance ,any health hazards or secondary pollution and shall be disposed of to the satisfaction of the Director :Institutional Establishment ,guided by the document "Guideline for the utilisation and Disposal of Wastewater Sludge: Volume 1:Selection of Management Options ,March 2006 " and Guideline for the inspection of Wastewater Treatment Works.(Attached for your convenience).

6. Compliance with Guide: Permissible utilization and disposal of treated sewage effluent: Department of National Health and Population Development, 30 May 1978.Ref 11/2/5/3.

7. The final effluent shall not contain any faecal coliforms per colonies per 100 millilitres.

8. This Authorisation shall not be construed as exempting the owner of this works from compliance with any other applicable Act, Ordinance, Regulation or By-law.

Please take note that if you increase the disposed volume to **2000m³** or more on any given day you will be required to apply for a water use licence.

Yours faithfully

CHIEF DIRECTOR: EASTERN CAPE

DATE: 10 November 2014

GENERAL AUTHORISATION IN TERMS OF SECTION 39 OF THE NATIONAL WATER ACT, (ACT 36 OF 1998): 21(e) IRRIGATION OF ANY LAND WITH WASTE OR WATER CONTAINING WASTE GENERATED THROUGH ANY INDUSTRIAL ACTIVITY OR BY A WATERWORK 21(g) DISPOSING OF WASTE IN A MANNER WHICH MAY DETRIMENTALLY IMPACT ON A WATER RESOURCE: KEI MOUTH WASTEWATER TREATMENT WORKS

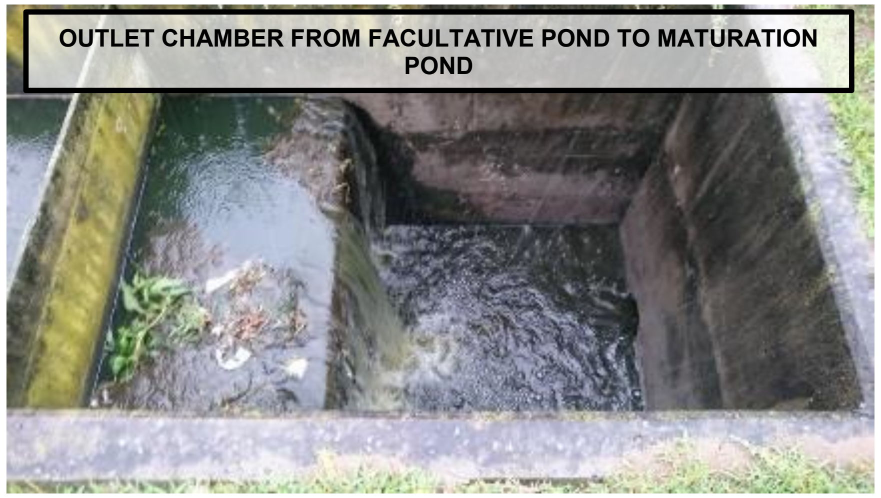
Page 2 of 2

INLET WORKS WITH MANUAL SCREENAND DOWNSTREAM SPLITTER BOX

PLANT CLASSIFICATION AND PROCESS CONTROLLER QUALIFICATION CERTIFICATES

OUTLET CHAMBER WITH DISINFECTION USING SODIUM HYPOCHLORITE TABLETS

FACULTATIVE PONDS WITH POSSIBLE SHORT CIRCUITING OCCURING IN NEAREST CORNER. INLET WORKS IN BACKGROUND



OUTLET CHAMBER FROM FACULTATIVE POND TO MATURATION POND

MATURATION PONDS WITH OUTLET CHAMBER AND IRRIGATION ABSTRACTION PUMP STATION IN BACKGROUND

FIELD INVESTIGATION FEEDBACK

STP Visited: Kei Mouth STP

Visit Date: 12 May 2017

Item	Questions	Answers
1	Process Description:	Inlet works with hand raked screen, then leading to two Facultative Ponds, then two Maturation Ponds. Chlorination by means of HTH Tablets.
2	Design Capacity	
3	Flow Rate	
4	How frequently is flow rate monitored	Once a day by process controllers
5	Is the STP in a good condition and if not, why not?	Yes, very good.
6	How many staff work at the plant and qualifications	
6.1	Supervisor	1 Rotating
6.2	Process Controller	3 on rotating day shifts
6.3	Maintenance Team	Central team rotating between different STPs
7	Is there an O&M Manual in place?	Yes, but only a partial one prepared by WSPr
8	Does DWS visit the plant?	Once a month to perform effluent samples
9	How safe is the effluent discharged and where does it go?	Goes into river, not all parameters are tested for. DWS has granted dual discharge standards (irrigation quality and water source discharge effluent standard). Golf Course uses some effluent, but not all effluent can be used.
10	How is effluent quality monitored?	On-site, once a day. Only certain parameters
11	How frequently is effluent monitored and by whom?	Once a day by process controllers
12	What effluent parameters are tested?	
12.1	E.Coli / Faecal Coliforms	No
12.2	Ammonia and Nitrogen	Yes.
12.3	COD	No
12.4	Nitrate/Nitrite and Nitrogen	No
12.5	Ortho-Phosphate as Phosphorous	No
12.6	pH	Yes
12.7	Elctrical Conductivity	Yes
12.8	SS	No
12.9	Free Chlorine	Yes
13	Influent monitoring also done? (How, when, who)	No
14	Is any sludge disposal happening and how is it done?	No sludge discharge is being done
15	What are the typical O&M Activities that should be performed and how frequently?	Keeping concrete edges of ponds clean, removing duckweed. Screening Removals. Sampling.
16	What practical tips recommended to improve the STPs use and performance?	Construction of holding pond for emergencies. Chlorine contact tank. Grit channel at Inlet Works. (This can reduce sludge build up)
17	What is the most difficult part of work at the STP?	Desludging of ponds
18	What are the typical problems experienced	Reduction of Ammonia - cannot easily be regulated with pond systems. Removal of duckweed.
19	What other technologies has operators/supervisors heard of and should be investigated?	None
20	Is any community benefitting from this STP and how.	Yes - TSE is used by local golf course for irrigation
21	Would the community like to use the effluent / sludge	Sludge has got good agricultural potential, but WSPr not willing to authorise this.
22	Does the operators/supervisors believe this is the best technology to use?	Correct for local application but Supervisor's preference is Activated Sludge due to the easier control and adjustment of effluent quality.
23	What are their opinion about rather using pond systems?	Has good safety buffer but effluent quality cannot easily be adjusted.
24	How effective are institutions currently at operating and maintaining wastewater treatment works?	Very good
25	Any other creative ways for the community to be involved or benefit?	No Comment
26	How do they see STPs managed in a rural village set-up	Local villagers to perform day to day work, with WSPr assisting with frequent STP visits. Capacity development programme will be important.

Annexure 14: Stakeholder Questionnaire Templates

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

1. INTRODUCTORY NOTES: TECHNICAL QUESTIONNAIRE **Section 1 of 3**

Questionnaire in support of research required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research Topic:

"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"

Questionnaire compiled by: George Sebastiaan Nel
Contact No: (+27) 083 640 1311

Thank you very much for taking the time to complete this questionnaire.

This questionnaire forms part of an individual research project that is required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research is being conducted into the hypothetical scenario that all rural villages in the Eastern Cape will in future receive waterborne sanitation. The type of technology which will be required to treat sewage at a village/cluster level needs to be carefully selected. The sewage treatment volume varies between 0.5Ml/d and 2Ml/d. The selection process needs to take into consideration the following aspects:

Social	Financial
Health	Institutional and
Technical	Environmental aspects
Economic	

This questionnaire focusses on Technical aspects of the treatment technology, such as technology selection process and effluent quality. Peripheral issues related to Community, Health, Economic and Institutions are also alluded to, but always from the Technical Perspective.

The research is only required in partial fulfilment of the studies being completed at Loughborough University in the UK and in no way is associated with any project or programme currently being performed in the study area.

This questionnaire is the second step in understanding the local environment within which projects are planned and implemented. The questionnaire will assist in local issues, needs and concerns and will assist in structuring interviews for further in-depth analysis of the local conditions.

Your involvement in the study area makes your involvement in and contribution to this research of utmost value and I would sincerely appreciate it if you can take the time to complete this questionnaire.

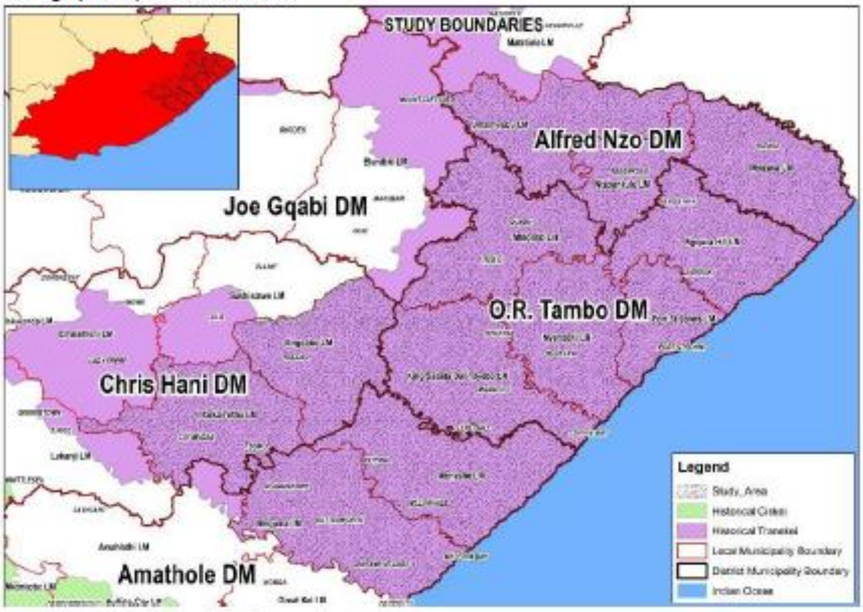
The study area focusses on the previous Transkei area but excludes the major towns and large urban areas. Considering the jurisdiction of the various Water Services Authorities, the study area boundaries have been set to coincide with those local municipalities located within the old Transkei Area. Rural villages within the following local municipalities are thus focussed on:

Mnquma LM	King Sabata Dalindyebo LM	Inguza Hill LM
Mbhashe LM	Nyandeni LM	Mbizana LM
Intsika Yethu LM	Mhlontlo LM	Ntabankulu LM
Engcobo LM	Port St Johns LM	Umzimvubu LM

1 - Introduction Sheet 1 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
<u>Technical Questionnaire</u>

The Study Area is graphically illustrated below:



This document consists of the following three sections:

1 - Introduction (This Section)
2 - Questionnaire
3 - Supportive Notes

The supportive notes are to assist in providing any clarity or background information to certain questions asked in the Questionnaire. Should anything remain unclear, please contact me and I will provide further detail.

In this questionnaire, questions have been grouped together into five main categories, as follows:

1 - Direct / Factual Questions
Basic questions requiring a "Yes" or "No", or selection from a list.
2 - Multiple Choice
Selection of the most appropriate answers from a predetermined list
3 - Ranking
Possible answers are to be ranked, based on your opinion on relevance.
4 - Scale of association (Also termed "Semantic Differentials")
An answer that most represents your view on a topic must be selected.
5 - Open ended questions
A detailed answer on a question, in your own words, needs to be provided.

Please understand there are no wrong answers and if you do not have a opinion on a question, please leave the question un-answered.

Thank you very much for taking the time to answer these questions.

George Nel (Student A814549, Tel: (+27) 083 640 1311)

1 - Introduction Sheet 2 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

2. TECHNICAL QUESTIONNAIRE — Section 2 of 3

Kindly answer the following questions to the best of your abilities after you have read the Introduction (Section 1) and Supportive Notes (Section 3). Supportive notes have been provided to establish background to some questions. Please do not hesitate to contact the researcher if you require any further information/clarity.

Please remember to answer these questions based on your own personal preferences and experience and from the perspective of designing and selecting the final treatment technology.

NO QUESTION

1 In which of the following areas have you been involved with, with respect to sanitation service delivery:

Mark all which are applicable, with an "X":

- [ ] Programme Manager
- [ ] Design of Wastewater Treatment Works
- [ ] Technical Advisor to Water Services Authority / Water Services Provider
- [ ] Researcher
- [ ] Water Scientist
- [ ] Environmental Practitioner
- [ ] Other - Please Specify: ____________________

2 Are communities currently being consulted during the Wastewater Treatment Works planning process?

Mark which one is applicable, with an "X":

Yes: [ ] No: [ ]

3 Do you think rural communities are able to afford to pay for the construction / capital costs of their own Wastewater Treatment Works?

Mark which one is applicable, with an "X":

Yes: [ ] No: [ ]

4 Do you think rural communities are able to contribute to paying for the operation and maintenance of a Wastewater Treatment Works?

Mark which one is applicable, with an "X":

Yes: [ ] No: [ ]

5 Select the three most likely sanitation technologies applied in the study area (see attached introductory notes for a definition of the study area):

Select the top three, each with an "X":

- [ ] Nothing (Open Defaecation)
- [ ] Bucket systems
- [ ] Unimproved Pit Latrines
- [ ] Ventilated Improved Pit Latrines
- [ ] Urine Diversion Structures
- [ ] Flushing Toilets

2 - Questionnaire — Sheet 3 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

6 Select the three most typical operation and maintenance problems experienced at existing Wastewater Treatment Works in the study area:

Select the top three, each with an "X":

	Compliance monitoring not being performed
	Effluent quality does not comply with discharge standards
	Operators are not adequately trained
	Wastewater Treatment Works is overloaded
	Operation and Maintenance is not being performed
	Failed components are not being replaced/repaired

7 Select the three most likely activities which the community can be involved with, during the operation and maintenance of the Wastewater Treatment Works:

Select the top three, each with an "X":

	Cutting of grass on embankments
	Removal and burying of screenings
	Routine maintenance of Mechanical and Electrical Equipment
	Routine removal of sludge from Wastewater Treatment Works
	Effluent sampling and compliance monitoring
	Repairs to concrete structures

8 Rank the following aspects of sustainability from the most to least important, during the technology selection process:

Rank the following, where "1" is the most important and "6" is the least important:

	Social
	Health
	Technical
	Economic / Financial
	Institutional
	Environmental

9 Rank the effluent quality created by the following technologies (refer to attached Supportive Notes for a definition of all technologies listed below) :

Rank the following, where "1" has the smallest and "10" the largest impact on receiving water resources:

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

2 - Questionnaire
Sheet 4 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

10 Rank the adverse impact the following technologies have on the environment:

Rank the following, where "1" has the smallest and "10" the largest adverse impact on the environment:

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

11 Rank the costs to operate and maintain the following technologies from high to low, for the various sewage treatment capacities (refer to attached Supportive Notes for a definition of all technologies listed below):

Rank the following, where "1" has the highest and "10" the lowest operation and maintenance costs, per treatment capacity:

Sewage Treatment Capacity:	0.5 Ml/d	1 Ml/d	2 Ml/d
Waste Stabilisation Ponds			
Settled Sewerage Systems			
Upflow Anaerobic Sludge Blankets (UASB)			
Constructed Wetlands			
Infiltration Percolation System with Nitrification Basin			
Activated Sludge Treatment			
Biofiltration (Percolating filters)			
Rotating Biological Contactors (Biodiscs)			
Integrated Algal Pond System			
PETRO System			

12 Rank the following technologies from most to least suitable for a rural application, for the various sewage treatment capacities (assuming correctly built and maintained):

Rank the following, where "1" is the most suitable and "10" is the least suitable, for each of the sewage treatment capacities:

Sewage Treatment Capacity:	0.5 Ml/d	1 Ml/d	2 Ml/d
Waste Stabilisation Ponds			
Settled Sewerage Systems			
Upflow Anaerobic Sludge Blankets (UASB)			
Constructed Wetlands			
Infiltration Percolation System with Nitrification Basin			
Activated Sludge Treatment			
Biofiltration (Percolating filters)			
Rotating Biological Contactors (Biodiscs)			
Integrated Algal Pond System			
PETRO System			

13 In general, Wastewater Treatment Works in the rural areas are operated:

Place a "X" in the space that most represents your view (Only select one answer)

	Not at all
	Below standard
	Satisfactory, but it can be improved
	Fully compliant to all requirements
	Excels in its operation

2 - Questionnaire Sheet 5 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*

Technical Questionnaire

14 A rural community is able to operate and maintain the following type of Wastewater Treatment Works the best:

Place a "X" in the space that most represents your view (Only select one answer)

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

15 In general, a suitable Wastewater Treatment Works has the following impact on the environment:

Place a "X" in the space that most represents your view (Only select one answer)

	No adverse impact
	Only minimal loss of vegetation on the Wastewater Treatment Works site
	Reduced water resource quality, but within acceptable limits
	Minor impact on local ecology, but ecology will be able to adapt
	Major impact on local ecology, with permanent changes to the ecological balance

16 Consider the following statement: "The General Authorisation for sewage discharge in the rural environment needs to be amended."

Place a "X" in the space that most represents your view

	Disagree
	The volume of sewage treated by ponds should be increased in the General Authorisation
	Exemption process should rather be more clearly defined
	Volume limits should be increased in the General Authorisation, but with stricter compliance monitoring
	Pond Treatment should be encouraged in the General Authorisation
	Effluent standards in remote areas should be given their own criteria/relaxed

17 Consider the following statement: "The National Water Act discharge policies are restricting development in the rural areas."

Place a "X" in the space that most represents your view

	Disagree
	The types of technology which can guarantee the effluent quality are too advanced for a rural application
	The application process for exemption from the National Water Act discharge standards does not consider the rural setting.
	Designers do not understand how exemption can be applied for
	DWS does not easily approve exemptions
	High effluent discharge standards are forced onto sanitation schemes without considering the merit of individual applications

18 What other treatment technologies have you heard of and you believe should be considered in this study?

2 - Questionnaire

Sheet 6 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

19 What are the worst treatment technologies you have seen implemented in South Africa (with preference to the Eastern Cape and in particular the Study Area) and why?

20 Do you believe it should be considered to amend the National Water Act discharge standards for applications in rural areas? Please also explain how such an amendment would be structured, if applicable?

21 How effective does the technology selection process currently consider soft issues such as institutional capacity, community involvement and funding models?

22 Please explain how affordability and community funding are currently being considered during the technology selection process?

23 How is the National Sanitation Policy being applied in selecting the most appropriate technology for a rural setting?

24 Any last comments or points of clarity you wish to provide?

2 - Questionnaire Sheet 7 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

3. SUPPORTIVE NOTES: TECHNICAL QUESTIONNAIRE Section 3 of 3

To assist in the providing background and context to the Questionnaire. Once you have read these supportive notes and the Introduction (Section 1), kindly answer the Questionnaire in Section 2. Feel free to return to these Supportive Notes at any time during the process of answering the questionnaire

ABBREVIATIONS / DEFINITIONS:

LOS: Level of Service (eg. Water or Sanitation infrastructure such as water taps)
NSP: National Sanitation Policy
NWA: National Water Act
O&M: Operation and Maintenance
STP: Sewage Treatment Plant. (Collective name for all types of technologies)
WWTW: Waste Water Treatment Works (Synonym for STP)

Waste Water Pond System: Dams / System of dams designed to collect and *treat (primary and secondary), from which treated effluent is disposed of.*

Rural Villages: Eastern Cape rural villages falling within the Study Area.

Communities Eastern Cape rural communities falling within the Study Area.

1 NATIONAL SANITATION POLICY

The National Sanitation Policy was drafted in 1996 and confirms the following:

- The right of all to basic sanitation
- The need to provide, improve and maintain suitable sanitation services
- The selected LOS must actually be improving the health of the community
- The community must be involved in the planning, organisation and implementation of Sanitation projects.
- Sanitation systems must not harm the environment and must be properly operated and maintained.
- The selected technology must be affordable.
- It is the household's responsibility to obtain adequate sanitation, with local government responsible to assist them.
- The selected technology must be suitable for the local application.

To select the most suitable sanitation system, the following must be considered:

- Is the proposed system affordable to the user, the service supplier and the government?
- What kind of organisation will be needed? How complicated must it be?
- What will be the risks to the environment?
- Is it acceptable to people (bearing in mind the cost to them)?
- What is the water supply like? Is it adequate? Can it support the proposed sanitation system?
- Will the system be reliable in this situation?
- Can it be upgraded, when people can afford a more expensive system?
- How much of the system can be built and maintained by local people using materials locally available?
- Does the housing layout make some systems more difficult to build or run?

Reference document: NSP 1996

3 - Supportive Notes Sheet 8 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

2 NATIONAL WATER ACT: GENERAL AUTHORISATIONS

The National Water Act (NWA) came into effect in 1998, with amendments to it being issued from time to time. In September 2013, the General Authorisation forming part of the NWA was amended. Under this General Authorisation, certain water related activities are permitted without a license being required, but provided they comply with certain prescriptions.

The following is a short summary of which waste related activities pertain to sewage treatment in the study area.

General Authorisations are issued with respect to the following:

Volume of treated sewage being irrigated with
Volume of waste water pond systems
Volume and location of treated sewage effluent being disposed of

Volume of treated sewage being irrigated with

Different effluent quality parameters are set for each of three discharge volumes (0 - 0.05Ml/d; 0.05 - 0.5Ml/d; 0.5 - 2Ml/d)
The General Authorisation only applies to irrigation up to 2Ml/d
Precautionary measures in terms of O&M requirements are stipulated
A compliance monitoring regime is required.

Volume of waste water pond systems

For the re-use of treated effluent (eg irrigation), storage of up to 5Ml will be permitted.

For the disposal of sewage, up to 50Ml of sewage may be stored in a wastewater pond system

For the disposal of sewage into a pond system, up to 1Ml of sewage per day
The General Authorisation only applies to areas outside of certain legislated sensitive aquifers.

Volume and location of treated sewage effluent being disposed of

Under the General Authorisation, up to 2Ml/d of sewage may be discharged into a water resource

Depending on where the water resource is located, either the General or Special Discharge Standards will apply.
Storage needs to be allowed for, in case discharge is not possible. The storage volume conditions are as per the summary above.

Compliance monitoring will be required, the testing parameters and compliance limits vary for the different discharge volumes (0.01 - 0.1; 0.1 - 1; 1 - 2Ml/d)

Reference document: NWA (2013)

3 - Supportive Notes

Sheet 9 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*

Technical Questionnaire

3 NATIONAL WATER ACT: DISCHARGE STANDARDS

As per section 3 above, either the General or the Special Standards will apply for effluent discharge into a receiving water resource. This forms part of the General Authorisation for discharge up to 2Ml/d. The table below compares the effluent quality limits:

SUBSTANCE/PARAMETER		GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 ml)		1000	0
Chemical Oxygen Demand (mg/l)		75 (i)	30(i)
pH		5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)		6	2
Nitrate/Nitrite as Nitrogen (mg/l)		15	1,5
Chlorine as Free Chlorine (mg/l)		0,25	0
Suspended Solids (mg/l)		25	10
Electrical Conductivity (mS/m)		70 mS/m above intake *	50 mS/m **
Ortho-Phosphate as phosphorous (mg/l)		10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)		1	1
Soap, oil or grease (mg/l)		2,5	0
Dissolved Arsenic (mg/l)		0,02	0,01
Dissolved Cadmium (mg/l)		0,005	0,001
Dissolved Chromium (VI) (mg/l)		0,05	0,02
Dissolved Copper (mg/l)		0,01	0,002
Dissolved Cyanide (mg/l)		0,02	0,01
Dissolved Iron (mg/l)		0,3	0,3
Dissolved Lead (mg/l)		0,01	0,006
Dissolved Manganese (mg/l)		0,1	0,1
Mercury and its compounds (mg/l)		0,005	0,001
Dissolved Selenium (mg/l)		0,02	0,02
Dissolved Zinc (mg/l)		0,1	0,04
Boron (mg/l)		1	0,5

* - To a maximum of 150 mS/m

** - Above background receiving water, to a maximum of 100 mS/m

3 - Supportive Notes

Sheet 10 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

4 LOW TECHNOLOGY OPTIONS

Name: Waste Stabilisation Ponds

Description:

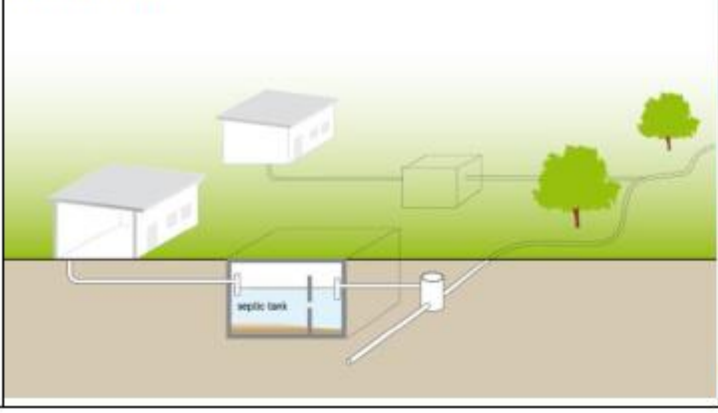
A system of ponds, preceded by primary treatment (Screens and Grit Removal) consisting of three types of ponds. These are Anaerobic, Facultative and Maturation Ponds. The ponds can be lined and sewage treatment occurs through encouraging natural processes by means of gravity and solar radiation.

Typical illustration:	Typical O&M Activities:
 Image Source: www.researchgate.net (August 2016)	Cut grass on embankments. Scum and macrophytes such as duckweed needs to be routinely removed. Weed and insect control. Removal and burial of Screenings. Bird Scaring. Repair of damage to embankments, external fences and gates. Removal of sludge every 5 years or so.

Name: Settled Sewerage Systems (also termed "Small Bore Sewerage")

Description:

A sewer drainage system connected to an Anaerobic Digester (septic tank) and discharging of effluent at a centralised location for further treatment. Various treatment technologies exist.

Typical illustration:	Typical O&M Activities:
	As per above for Septic Tanks but excluding soakaway. Inspection of pipes and manholes. Removal of roots intrusions in pipes. Repairs to manholes. Image Source: www.sswm.info (August 2016)

3 - Supportive Notes Sheet 11 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

Name: Upflow Anaerobic Sludge Blankets (UASB)

Description:

Primary treatment (Screens and Grit Removal) followed by a UASB reactor. Anaerobic processes occur in a reinforced concrete structure. Raw sewage flows upwards through the base of the structure, through a suspended sludge layer. Polishing ponds with estimated depth of 1.25m is thereafter required for improving the effluent quality.

General WWTW Layout:

Image Source: Mara (2003)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Removal of sludge every 1-2 weeks.

Name: Constructed Wetlands

Description:

Following primary treatment, effluent trickles through the reed bed. In the root zone sewage is treated by the biological action of micro-organisms. The granular growth medium allows for aerobic, anaerobic and anoxic treatment. Horizontal, Vertical and Floating Wetlands are different types of Constructed Wetland technologies being used over the world.

Typical illustration: (Recently planted wetland with reeds still to become established)

Image Source: FREESE and NOZAIC (2009)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of pipes and manholes.
Removal of roots intruding into pipes.
Repairs to manholes.
Inspection of and repair to bedding liner.
Replacement of gravel bed media.
Trimming/replacement of reeds

3 - Supportive Notes | Sheet 12 of 16

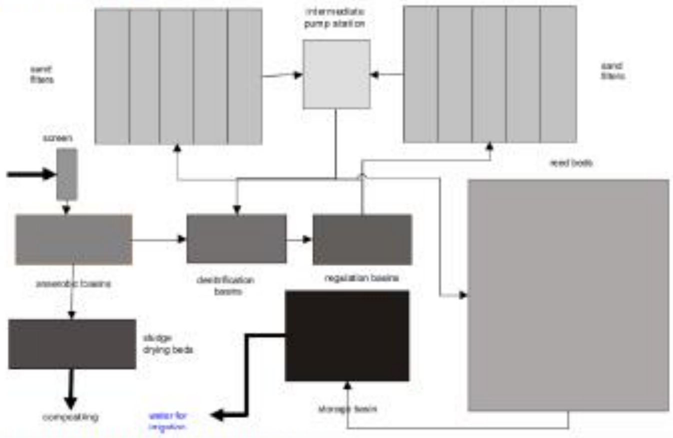
Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

Name: Infiltration Percolation System with Nitrification Basin

Description:

Following primary treatment and an anaerobic pond, sewage is further treated in a denitrification basin where nitrogen is removed by heterotrophic bacteria operating in an anoxic environment. This effluent is then dosed onto a recirculating sand filters to remove ammonia. Some effluent will need to be recirculated via pump.

Typical illustration:



Typical O&M Activities:

Cut grass on embankments.
Weed and insect control.
Repair of damage to embankments, external fences and gates.
Removal of sludge every 5 years or so.
Tilling of Sand Filter media.
Maintenance to pumps.

Image Source: CHOUKR-ALLAH et al. (2003)

5 **ADVANCED TECHNOLOGY OPTIONS**

Name: Activated Sludge Treatment

Description:

Sewage and sludge is aerated by means of surface aeration, diffused air aeration, or a combination of the two. This promotes bacterial growth which accelerates the decomposition of the sewage. Following this process, the effluent is discharged to a settling tank where the sludge is either recycled back to the aeration tank, or pumped away for final treatment and disposal. Examples of such technologies include Waste Activated Sludge and the Sequential Batch Reactor systems.

Typical illustration:

Image Source: FREESE and NOZAIC (2009)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.
Routine removal of sludge from sludge drying beds.

3 - Supportive Notes

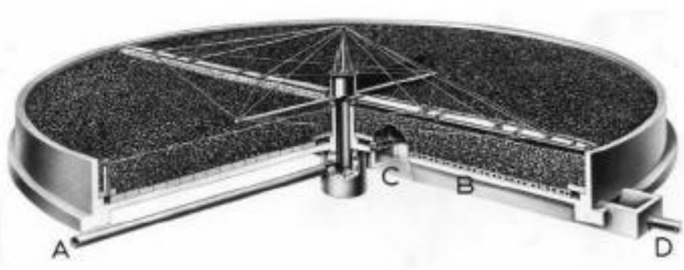
Sheet 13 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

Name: Biofiltration (Percolating filters)

Description:

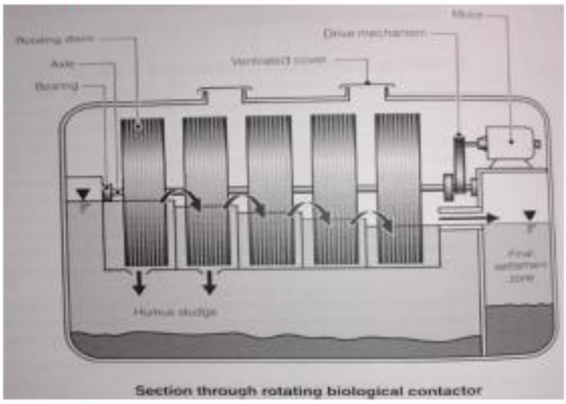
Wastewater is sprinkled on the top of either a circular or rectangular structure containing a coarse media (eg gravel). The media supports a biological film which assists in the purification of the sewage as it gravitates downwards through the media. These systems are used together with primary treatment, settling tanks and tertiary treatment.

Typical illustration:	Typical O&M Activities:
 Note: A, inlet pipe; B, underdrain blocks; C, effluent channel; D, outlet pipe. Image Source: Mara (2003)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment.

Name: Rotating Biological Contactors (Biodiscs)

Description:

A mechanical secondary treatment system similar to the Biofiltration system, except that the biofilm forms on mechanically rotated discs. They require smaller land area and less electricity than biofilters. Primary treatment and further treatment of the effluent will still be required.

Typical illustration:	Typical O&M Activities:
 Image Source: Smith (2011)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment.

3 - Supportive Notes

Sheet 14 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

Name: Integrated Algal Pond System

Description:

After primary treatment, sewage flows into a facultative pond via a "Anaerobic Fermentation Pit". Then effluent is conveyed to a High Rate Algal Pond which is a concrete oval shaped raceway in which algal growth is promoted through a paddle wheel. From there, effluent flows into a algal settling pond before being discharged.

Typical illustration:

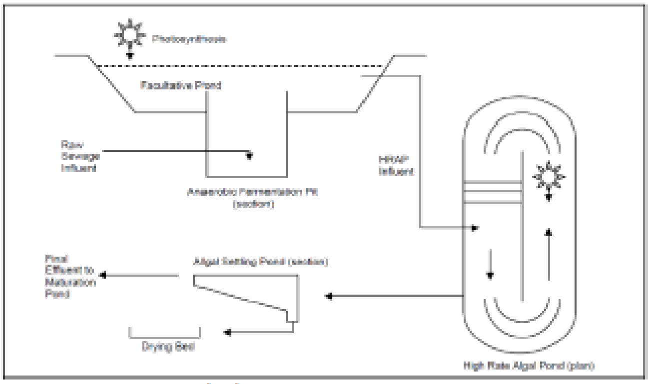


Image Source: Wells et al (nd)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.
Routine removal of settled algae.
Removal of sludge from facultative pond every 5 years.

Name: PETRO System

Description:

PETRO is an acronym for "Pond Enhanced Treatment and Operation" (PETRO) and is basically a waste stabilisation system followed by Biofiltration. Anaerobic and Aerobic biodegradation occurs in the pond system, after which polishing occurs in the Biofilter. Primary treatment (screens etc.) and disinfection is however still recommended.

Typical illustration:

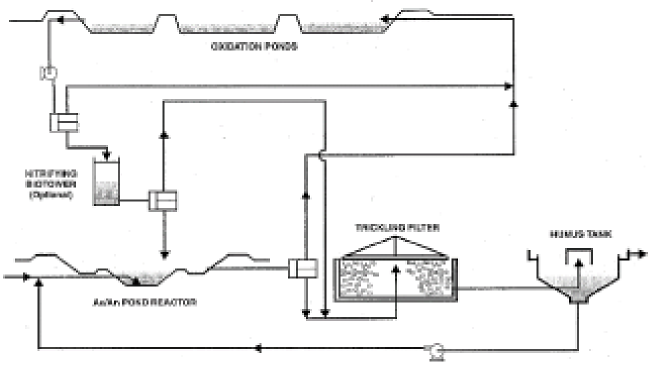


Image Source: Shipin et al (1998)

Typical O&M Activities:

Cut grass on embankments.
Scum and macrophytes needs to be routinely removed.
Weed and insect control.
Removal and burial of Screenings.
Repair of damage to embankments, external fences and gates, cracks in concrete.
Routine removal of sludge.
Inspection of pipes for blockages.
Maintenance to M&E.

3 - Supportive Notes
Sheet 15 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Technical Questionnaire

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3 - Supportive Notes Sheet 16 of 16

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

1. INTRODUCTORY NOTES: INSTITUTIONAL QUESTIONNAIRE **Section 1 of 3**

Questionnaire in support of research required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research Topic:

"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"

Questionnaire compiled by: George Sebastiaan Nel
Contact No: (+27) 083 640 1311

Thank you very much for taking the time to complete this questionnaire.

This questionnaire forms part of an individual research project that is required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research is being conducted into the **hypothetical scenario** that all rural villages in the Eastern Cape will in future receive waterborne sanitation. The type of technology which will be required to treat sewage at a village/cluster level needs to be carefully selected. The sewage treatment volume varies between 0.5Ml/d and 2Ml/d. The selection process needs to take into consideration the following aspects:

Social	Financial
Health	Institutional and
Technical	Environmental aspects
Economic	

This questionnaire focusses on Institutional aspects of the treatment technology, such as service delivery, authorisations and compliance monitoring. Peripheral issues related to Community, Health and Economics are also alluded to, but always from the Institutional Perspective.

The research is only required in partial fulfilment of the studies being completed at Loughborough University in the UK and in no way is associated with any project or programme currently being performed in the study area.

This questionnaire is the second step in understanding the local environment within which projects are planned and implemented. The questionnaire will assist in local issues, needs and concerns and will assist in structuring interviews for further in-depth analysis of the local conditions.

Your involvement in the study area makes your involvement in and contribution to this research of utmost value and I would sincerely appreciate it if you can take the time to complete this questionnaire.

The study area focusses on the previous Transkei area but excludes the major towns and large urban areas. Considering the jurisdiction of the various Water Services Authorities, the study area boundaries have been set to coincide with those local municipalities located within the old Transkei Area. Rural villages within the following local municipalities are thus focussed on:

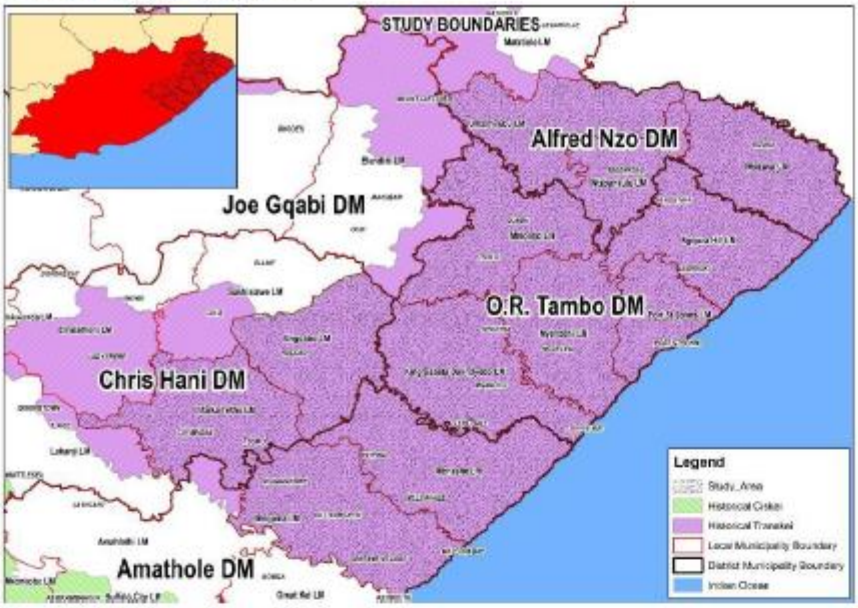
Mnquma LM	King Sabata Dalindyebo LM	Inguza Hill LM
Mbhashe LM	Nyandeni LM	Mbizana LM
Intsika Yethu LM	Mhlontlo LM	Ntabankulu LM
Engcobo LM	Port St Johns LM	Umzimvubu LM

1 - Introduction Sheet 1 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*

<u>Institutional Questionnaire</u>

The Study Area is graphically illustrated below:



This document consists of the following three sections:

1 - Introduction (This Section)
2 - Questionnaire
3 - Supportive Notes

The supportive notes are to assist in providing any clarity or background information to certain questions asked in the Questionnaire. Should anything remain unclear, please contact me and I will provide further detail.

In this questionnaire, questions have been grouped together into five main categories, as follows:

1 - Direct / Factual Questions
Basic questions requiring a "Yes" or "No", or selection from a list.

2 - Multiple Choice
Selection of the most appropriate answers from a predetermined list

3 - Ranking
Possible answers are to be ranked, based on your opinion on relevance.

4 - Scale of association (Also termed "Semantic Differentials")
An answer that most represents your view on a topic must be selected.

5 - Open ended questions
A detailed answer on a question, in your own words, needs to be provided.

Please understand there are no wrong answers and if you do not have a opinion on a question, please leave the question un-answered.

Thank you very much for taking the time to answer these questions.

George Nel (Student A814549, Tel: (+27) 083 640 1311)

1 - Introduction

Sheet 2 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

2. INSTITUTIONAL QUESTIONNAIRE **Section 2 of 3**

Kindly answer the following questions to the best of your abilities after you have read the Introduction (Section 1) and Supportive Notes (Section 3). Supportive notes have been provided to establish background to some questions. Please do not hesitate to contact the researcher if you require any further information/clarity.

Please remember to answer these questions based on your own personal preferences and experience and from the perspective of designing and selecting the final treatment technology.

NO QUESTION

1 In which of the following areas have you been involved with, with respect to Wastewater Treatment Works design:

Mark all which are applicable, with a "X":

	Service Delivery Planning, Provision or Implementation
	Final approval of technical designs
	Support to Water Services Authorities/Water Services Providers
	Input into compiling water and sanitation related legislation (including Policies)
	Compilation/Assessment of applications (eg. Environmental or Water Use Licences)
	Review and approval of applications (eg. Environmental or Water Use Licences)
	Other - Please Specify: ______________________

2 Are communities currently being consulted during the Wastewater Treatment Works planning process?

Mark which one is applicable, with a "X":

Yes: [ ] No: [ ]

3 Do you think rural communities can afford to pay for the construction / capital costs of their own Wastewater Treatment Works?

Mark which one is applicable, with a "X":

Yes: [ ] No: [ ]

4 Do you think rural communities are able to contribute to paying for the operation and maintenance of a Wastewater Treatment Works?

Mark which one is applicable, with a "X":

Yes: [ ] No: [ ]

5 Select the three most likely sanitation technologies currently used in the study area (see attached Introductory Notes for a definition of the study area):

Select the top three, each with an "X":

	Nothing (Open Defaecation)
	Bucket systems
	Unimproved Pit Latrines
	Ventilated Improved Pit Latrines
	Urine Diversion Structures
	Flushing Toilets

2 - Questionnaire Sheet 3 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

6 Select the three most typical operation and maintenance problems experienced at existing Wastewater Treatment Works in the study area:

Select the top three, each with an "X":

	Compliance monitoring not being performed
	Effluent quality does not comply with discharge standards
	Operators are not adequately trained
	Wastewater Treatment Works is overloaded
	Operation and maintenance is not being performed
	Failed components are not being replaced/repaired

7 Select the three most likely activities which the community are able to be involved with, during the operation and maintenance of the Wastewater Treatment Works:

Select the top three, each with an "X":

	Cutting of grass on embankments
	Removal and burying of screenings
	Routine maintenance of Mechanical and Electrical Equipment
	Routine removal of sludge from Wastewater Treatment Works
	Effluent sampling and compliance monitoring
	Repairs to concrete structures

8 Rank the following operation and maintenance activities in order of preference, for the community to be involved with:

Rank the following, where "1" is the most feasible and "6" is the least feasible:

	Repair of damage to embankments, external fences and gates
	Inspection of pipes for and removal of blockages.
	Weed and insect control.
	Routine removal of settled algae.
	Tilling of Sand Filter media.
	Trimming/replacement of reeds

9 Rank the following aspects of sustainability from most to least important for your institution:

Rank the following, where "1" is the most important and "6" is the least important:

	Social
	Health
	Technical
	Economic / Financial
	Institutional
	Environmental

10 Rank the costs to operate and maintain the following technologies from high to low, for the various sewage treatment capacities (refer to attached Supportive Notes for a definition of all technologies listed below):

Rank the following, where "1" has the highest and "10" the lowest operation and maintenance costs, per treatment capacity:

Sewage Treatment Capacity:	0.5 Ml/d	1 Ml/d	2 Ml/d
Waste Stabilisation Ponds			
Settled Sewerage Systems			
Upflow Anaerobic Sludge Blankets (UASB)			
Constructed Wetlands			
Infiltration Percolation System with Nitrification Basin			
Activated Sludge Treatment			
Biofiltration (Percolating filters)			
Rotating Biological Contactors (Biodiscs)			
Integrated Algal Pond System			
PETRO System			

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

11 Rank the following cost recovery options from most to least effective in a rural context:

Rank the following, where "1" is the most and "6" is the least effective:

	No cost recovery (municipality pays all)
	Flat rate paid monthly
	Flat rate subtracted from Social Grants on a monthly basis
	Tariff increasing as a function of size of dwelling, paid monthly
	Tariff increasing as a function of size of dwelling, subtracted monthly from Social Grant
	Community operates and maintains Wastewater Treatment Works for free, in exchange for free services

12 Rank the following technologies from most to least suitable for a rural application, for various sewage treatment capacities:

Rank the following, where "1" is the most suitable and "10" is the least suitable (for the various sewage treatment capacities):

Sewage Treatment Capacity:	0.5 Ml/d	1 Ml/d	2 Ml/d
Waste Stabilisation Ponds			
Settled Sewerage Systems			
Upflow Anaerobic Sludge Blankets (UASB)			
Constructed Wetlands			
Infiltration Percolation System with Nitrification Basin			
Activated Sludge Treatment			
Biofiltration (Percolating filters)			
Rotating Biological Contactors (Biodiscs)			
Integrated Algal Pond System			
PETRO System			

13 Rank the effluent quality created by the following technologies:

Rank the following, where "1" has the smallest and "10" the largest impact on receiving water resources:

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

14 Rank the preferred maximum capacity of a Wastewater Treatment Works, for application in the following rural settings:

Rank the following, where "1" is the most preferred capacity/location and "10" the least preferred:

	Less than 0.5Ml/d (Only service the local village/community)
	Less than 1Ml/d (Service a local cluster of villages)
	Less than 2Ml/d (Service a larger, but local cluster of villages)
	Larger than 2Ml/d (Service a region of village clusters)
	No preference - the capacity will be determined on an ad-hoc basis, as the immediate need requires it
	The most economically viable option will determine the size of the Wastewater Treatment Works

2 - Questionnaire

Sheet 5 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

15 In general, Wastewater Treatment Works in the rural areas are operated:

Place a "X" in the space that most represents your view

	Not at all
	Below standard
	Satisfactory, but it can be improved
	Fully compliant to all requirements
	Excels in its operation

16 The community can operate and maintain the following type of Wastewater Treatment Works the best:

Place a "X" in the space that most represents your view

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

17 Consider the following statement: "The General Authorisation for sewage discharge in the rural environment needs to be amended."

Place a "X" in the space that most represents your view

	Disagree
	The volume of sewage treated by ponds should be increased in the General Authorisation
	Exemption process should rather be more clearly defined
	Volume limits should be increased in the General Authorisation, but with stricter compliance monitoring
	Pond Treatment should be encouraged in the General Authorisation
	Effluent standards in remote areas should be given their own criteria/relaxed

18 Consider the following statement: "The National Water Act discharge policies are restricting development in the rural areas."

Place a "X" in the space that most represents your view

	Disagree
	The types of technology which can guarantee the effluent quality are too advanced for the area
	The application process for exemption from the National Water Act discharge standards does not consider the rural setting.
	Designers do not understand how exemption can be applied for
	DWS does not easily approve exemptions
	High effluent discharge standards are forced onto sanitation schemes without considering the merit of individual applications

19 Consider the following statement: "Water Services Providers are willing to transfer the operation and maintenance responsibility of the Wastewater Treatment Works to a private company."

Place a "X" in the space that most represents your view

	Disagree
	Disagree, no private companies exist to outsource to
	This has been tried but the private companies have failed
	Possible, but political interference can cause complications
	Possible, but no private companies exist to outsource to
	Agree, if an adequate service level agreement and performance monitoring programme can be set up

2 - Questionnaire
Sheet 6 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

20 Consider the following statement: "Water Services Providers are willing to transfer the operation and maintenance responsibility of the Wastewater Treatment Works to the local community."

Place a "X" in the space that most represents your view

	Disagree
	Communities are already involved in operation and maintenance at some Wastewater Treatment Works
	Partnerships can be developed
	Water Services Providers can help set-up Community Based Organisations to run the Wastewater Treatment Works
	Only some responsibilities can be given to the community since training will be difficult
	Possible, but political interference can cause complications

21 What are the worst treatment technologies you have seen and why?

22 Do you believe it should be considered to amend the National Water Act discharge standards for applications in rural areas? Please also explain how such an amendment would be structured, if applicable?

23 How effectively does the technology selection process currently consider soft issues such as institutional capacity, community involvement and funding models?

24 Please explain how affordability and community funding is currently being considered during the technology selection process?

25 How can Wastewater Treatment Works in a rural environment be privatised or run by a Community Based Organisation? Please substantiate your answer.

2 - Questionnaire

Sheet 7 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

26 **How is the National Sanitation Policy being applied in selecting the most appropriate technology for a rural setting?**

27 **Any last comments or points of clarity you wish to provide?**

2 - Questionnaire
Sheet 8 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

3. SUPPORTIVE NOTES: INSTITUTIONAL QUESTIONNAIRE **Section 3 of 3**

To assist in the providing background and context to the Questionnaire. Once you have read these supportive notes and the Introduction (Section 1), kindly answer the Questionnaire in Section 2. Feel free to return to these Supportive Notes at any time during the process of answering the questionnaire

ABBREVIATIONS / DEFINITIONS:

CBO: Community Based Organisation
DWS: Department of Water and Sanitation
DEDEAT: Department of Economic Development, Environmental Affairs and Tourism
GA: General Authorisation
LOS: Level of Service (eg. Water or Sanitation infrastructure such as water taps)
NSP: National Sanitation Policy
NWA: National Water Act
O&M: Operation and Maintenance
STP: Sewage Treatment Plant. (Collective name for all types of technologies)
WSA: Water Services Authority
WSP: Water Services Provider
WWTW: Wastewater Treatment Works (Synonym for STP)

Waste Water Pond System: Dams / System of dams designed to collect and *treat (primary and secondary), from which treated effluent is disposed of.*

Rural Villages: Eastern Cape rural villages falling within the Study Area.

Communities Eastern Cape rural communities falling within the Study Area.

1 COMMUNITY BASED ORGANISATION

Definition: A non-profit group organised at local (village/cluster) level to provide for the need not being met by either local government or private enterprises. They look at the local needs, operate at a neighbourhood level and take a while to become proficient.

Reference Document: Coates et al (2008)

2 NATIONAL SANITATION POLICY

The National Sanitation Policy was drafted in 1996 and confirms the following:

The right of all to basic sanitation
The need to provide, improve and maintain suitable sanitation services
The selected LOS must actually be improving the health of the community
The community must be involved in the planning, organisation and implementation of Sanitation projects.
Sanitation systems must not harm the environment and must be properly operated and maintained.
The selected technology must be affordable.
It is the household's responsibility to obtain adequate sanitation, with local government responsible to assist them.
The selected technology must be suitable for the local application.

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

To select the most suitable sanitation system, the following must be considered:

Is the proposed system affordable to the user, the service supplier and the government?

What kind of organisation will be needed? How complicated must it be?
What will be the risks to the environment?
Is it acceptable to people (bearing in mind the cost to them)?
What is the water supply like? Is it adequate? Can it support the proposed sanitation system?

Will the system be reliable in this situation?
Can it be upgraded, when people can afford a more expensive system?
How much of the system can be built and maintained by local people using materials locally available?
Does the housing layout make some systems more difficult to build or run?

Reference document: NSP 1996

3 NATIONAL WATER ACT: GENERAL AUTHORISATIONS

The National Water Act (NWA) came into effect in 1998, with amendments to it being issued from time to time. In September 2013, the General Authorisation forming part of the NWA was amended. Under this General Authorisation, certain water related activities are permitted without a license being required, but provided they comply with certain prescriptions.

The following is a short summary of which waste related activities pertain to sewage treatment in the study area.

General Authorisations are issued with respect to the following:

Volume of treated sewage being irrigated with
Volume of waste water pond systems
Volume and location of treated sewage effluent being disposed of

Volume of treated sewage being irrigated with

Different effluent quality parameters are set for each of three discharge volumes (0 - 0.05Ml/d; 0.05 - 0.5Ml/d; 0.5 - 2Ml/d)
The General Authorisation only applies to irrigation up to 2Ml/d
Precautionary measures in terms of O&M requirements are stipulated
A compliance monitoring regime is required.

Volume of waste water pond systems

For the re-use of treated effluent (eg irrigation), storage of up to 5Ml will be permitted.

For the disposal of sewage, up to 50Ml of sewage may be stored in a wastewater pond system

For the disposal of sewage into a pond system, up to 1Ml of sewage per day
The General Authorisation only applies to areas outside of certain legislated sensitive aquifers.

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

Volume and location of treated sewage effluent being disposed of

Under the General Authorisation, up to 2Ml/d of sewage may be discharged into a water resource

Depending on where the water resource is located, either the General or Special Discharge Standards will apply.
Storage needs to be allowed for, in case discharge is not possible. The storage volume conditions are as per the summary above.

Compliance monitoring will be required, the testing parameters and compliance limits vary for the different discharge volumes (0.01 - 0.1; 0.1 - 1; 1 - 2Ml/d)

Reference document: NWA (2013)

4 NATIONAL WATER ACT: DISCHARGE STANDARDS

As per section 3 above, either the General or the Special Standards will apply for effluent discharge into a receiving water resource. This forms part of the General Authorisation for discharge up to 2Ml/d. The table below compares the effluent quality limits:

SUBSTANCE/PARAMETER		GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 ml)		1000	0
Chemical Oxygen Demand (mg/l)		75 (i)	30(i)
pH		5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)		6	2
Nitrate/Nitrite as Nitrogen (mg/l)		15	1,5
Chlorine as Free Chlorine (mg/l)		0,25	0
Suspended Solids (mg/l)		25	10
Electrical Conductivity (mS/m)		70 mS/m above intake *	50 mS/m **
Ortho-Phosphate as phosphorous (mg/l)		10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)		1	1
Soap, oil or grease (mg/l)		2,5	0
Dissolved Arsenic (mg/l)		0,02	0,01
Dissolved Cadmium (mg/l)		0,005	0,001
Dissolved Chromium (VI) (mg/l)		0,05	0,02
Dissolved Copper (mg/l)		0,01	0,002
Dissolved Cyanide (mg/l)		0,02	0,01
Dissolved Iron (mg/l)		0,3	0,3
Dissolved Lead (mg/l)		0,01	0,006
Dissolved Manganese (mg/l)		0,1	0,1
Mercury and its compounds (mg/l)		0,005	0,001
Dissolved Selenium (mg/l)		0,02	0,02
Dissolved Zinc (mg/l)		0,1	0,04
Boron (mg/l)		1	0,5

* - To a maximum of 150 mS/m

** - Above background receiving water, to a maximum of 100 mS/m

3 - Supportive Notes

Sheet 11 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*

Institutional Questionnaire

5 LOW TECHNOLOGY OPTIONS

Name: Waste Stabilisation Ponds

Description:

A system of ponds, preceded by primary treatment (Screens and Grit Removal) consisting of three types of ponds. These are Anaerobic, Facultative and Maturation Ponds. The ponds can be lined and sewage treatment occurs through encouraging natural processes by means of gravity and solar radiation.

Typical illustration:

Image Source: www.researchgate.net (August 2016)

Typical O&M Activities:

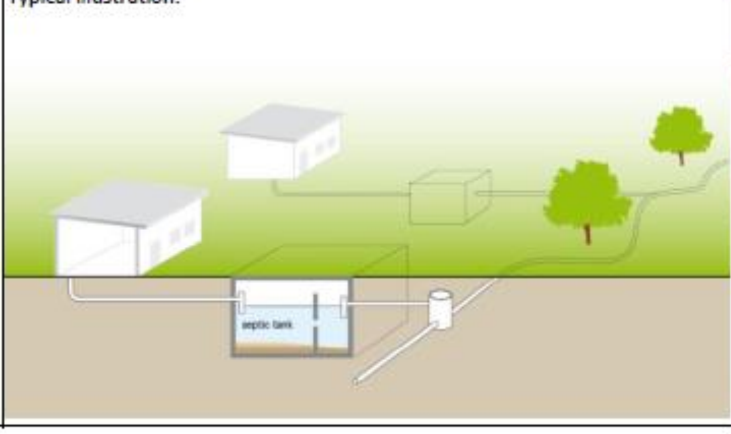
Cut grass on embankments.
Scum and macrophytes such as duckweed needs to be routinely removed.
Weed and insect control.
Removal and burial of Screenings.
Bird Scaring.
Repair of damage to embankments, external fences and gates.
Removal of sludge every 5 years or so.

Name: Settled Sewerage Systems (also termed "Small Bore Sewerage")

Description:

A sewer drainage system connected to an Anaerobic Digester (septic tank) and discharging of effluent at a centralised location for further treatment. Various treatment technologies exist.

Typical illustration:



Typical O&M Activities:

As per above for Septic Tanks but excluding soakaway.
Inspection of pipes and manholes.
Removal of roots intrusions in pipes.
Repairs to manholes.

Image Source: www.sswm.info (August 2016)

3 - Supportive Notes

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

Name: Upflow Anaerobic Sludge Blankets (UASB)

Description:

Primary treatment (Screens and Grit Removal) followed by a UASB reactor. Anaerobic processes occur in a reinforced concrete structure. Raw sewage flows upwards through the base of the structure, through a suspended sludge layer. Polishing ponds with estimated depth of 1.25m is thereafter required for improving the effluent quality.

General WWTW Layout:

Image Source: Mara (2003)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Removal of sludge every 1-2 weeks.

Name: Constructed Wetlands

Description:

Following primary treatment, effluent trickles through the reed bed. In the root zone sewage is treated by the biological action of micro-organisms. The granular growth medium allows for aerobic, anaerobic and anoxic treatment. Horizontal, Vertical and Floating Wetlands are different types of Constructed Wetland technologies being used over the world.

Typical illustration: (Recently planted wetland with reeds still to become established)

Image Source: FREESE and NOZAIC (2009)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of pipes and manholes.
Removal of roots intruding into pipes.
Repairs to manholes.
Inspection of and repair to bedding liner.
Replacement of gravel bed media.
Trimming/replacement of reeds

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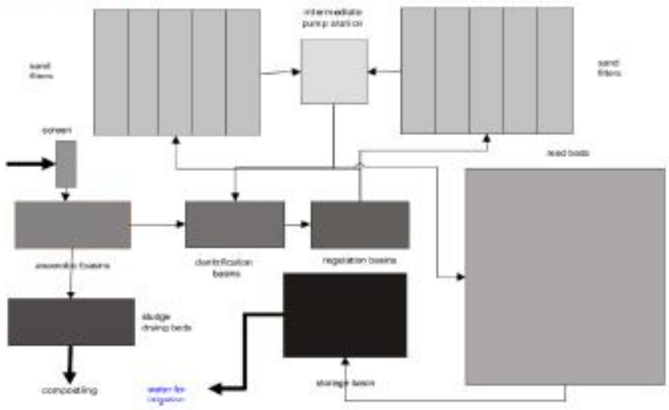
Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

Name: Infiltration Percolation System with Nitrification Basin

Description:

Following primary treatment and an anaerobic pond, sewage is further treated in a denitrification basin where nitrogen is removed by heterotrophic bacteria operating in an anoxic environment. This effluent is then dosed onto a recirculating sand filters to remove ammonia. Some effluent will need to be recirculated via pump.

Typical illustration:



Typical O&M Activities:

Cut grass on embankments.
Weed and insect control.
Repair of damage to embankments, external fences and gates.
Removal of sludge every 5 years or so.
Tilling of Sand Filter media.
Maintenance to pumps.

Image Source: CHOUKR-ALLAH et al. (2003)

6 ADVANCED TECHNOLOGY OPTIONS

Name: Activated Sludge Treatment

Description:

Sewage and sludge is aerated by means of surface aeration, diffused air aeration, or a combination of the two. This promotes bacterial growth which accelerates the decomposition of the sewage. Following this process, the effluent is discharged to a settling tank where the sludge is either recycled back to the aeration tank, or pumped away for final treatment and disposal. Examples of such technologies include Waste Activated Sludge and the Sequential Batch Reactor systems.

Typical illustration:

Image Source: FREESE and NOZAIC (2009)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.
Routine removal of sludge from sludge drying beds.

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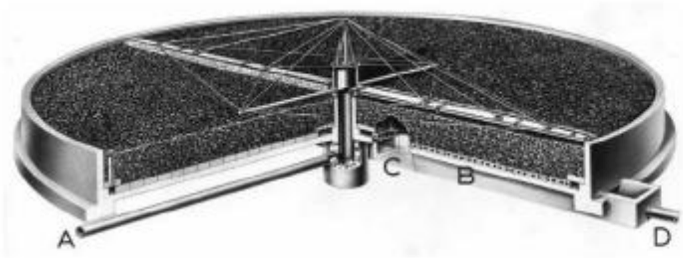
Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*

Institutional Questionnaire

Name: Biofiltration (Percolating filters)

Description:

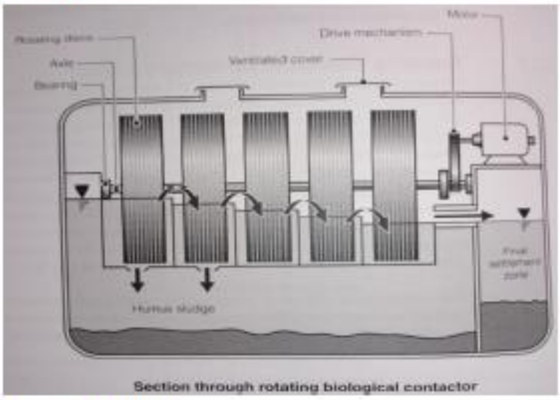
Wastewater is sprinkled on the top of either a circular or rectangular structure containing a coarse media (eg gravel). The media supports a biological film which assists in the purification of the sewage as it gravitates downwards through the media. These systems are used together with primary treatment, settling tanks and tertiary treatment.

Typical illustration:	Typical O&M Activities:
 Note: A, inlet pipe; B, underdrain blocks; C, effluent channel; D, outlet pipe. Image Source: Mara (2003)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment.

Name: Rotating Biological Contactors (Biodiscs)

Description:

A mechanical secondary treatment system similar to the Biofiltration system, except that the biofilm forms on mechanically rotated discs. They require smaller land area and less electricity than biofilters. Primary treatment and further treatment of the effluent will still be required.

Typical illustration:	Typical O&M Activities:
 Image Source: Smith (2011)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment.

3 - Supportive Notes

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

Name: Integrated Algal Pond System

Description:

After primary treatment, sewage flows into a facultative pond via a "Anaerobic Fermentation Pit". Then effluent is conveyed to a High Rate Algal Pond which is a concrete oval shaped raceway in which algal growth is promoted through a paddle wheel. From there, effluent flows into a algal settling pond before being discharged.

Typical illustration:

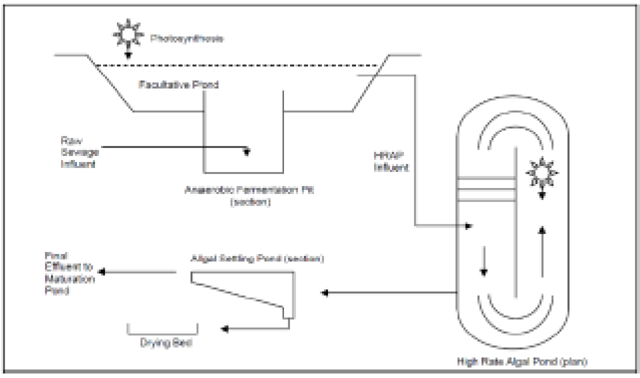

Image Source: Wells et al (nd)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.
Routine removal of settled algae.
Removal of sludge from facultative pond every 5 years.

Name: PETRO System

Description:

PETRO is an acronym for "Pond Enhanced Treatment and Operation" (PETRO) and is basically a waste stabilisation system followed by Biofiltration. Anaerobic and Aerobic biodegradation occurs in the pond system, after which polishing occurs in the Biofilter. Primary treatment (screens etc.) and disinfection is however still recommended.

Typical illustration:

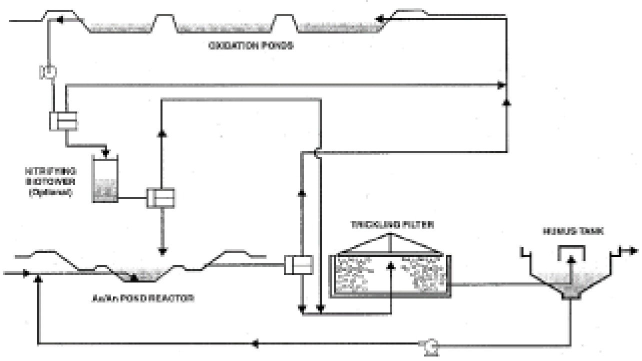

Image Source: Shipin et al (1998)

Typical O&M Activities:

Cut grass on embankments.
Scum and macrophytes needs to be routinely removed.
Weed and insect control.
Removal and burial of Screenings.
Repair of damage to embankments, external fences and gates, cracks in concrete.
Routine removal of sludge.
Inspection of pipes for blockages.
Maintenance to M&E.

3 - Supportive Notes

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Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Institutional Questionnaire

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3 - Supportive Notes

Sheet 17 of 17

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

1. INTRODUCTORY NOTES: SOCIAL QUESTIONNAIRE **Section 1 of 3**

Questionnaire in support of research required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research Topic:

"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"

Questionnaire compiled by: George Sebastiaan Nel
Contact No: (+27) 083 640 1311

Thank you very much for taking the time to complete this questionnaire.

This questionnaire forms part of an individual research project that is required in partial fulfilment of the requirements for the award of the degree of Master of Science

Research is being conducted into the **hypothetical scenario** that all rural villages in the Eastern Cape will in future receive waterborne sanitation. The type of technology which will be required to treat sewage at a village/cluster level needs to be carefully selected. The sewage treatment volume varies between 0.5Ml/d and 2Ml/d. The selection process needs to take into consideration the following aspects:

Social	Financial
Health	Institutional and
Technical	Environmental aspects
Economic	

This questionnaire focusses on Social aspects of technology selection, such as community involvement in the selection process, involvement during the operation and maintenance of the Wastewater Treatment Works (WWTW) and any financial contributions the community can make. Peripheral issues related to Health, Economic and Institutions are also alluded to, but always from the Social Perspective.

The research is only required in partial fulfilment of the studies being completed at Loughborough University in the UK and in no way is associated with any project or programme currently being performed in the study area.

This questionnaire is the second step in understanding the local environment within which projects are planned and implemented. The questionnaire will assist in local issues, needs and concerns and will assist in structuring interviews for further in-depth analysis of the local conditions.

Your involvement in the study area makes your involvement in and contribution to this research of utmost value and I would sincerely appreciate it if you can take the time to complete this questionnaire.

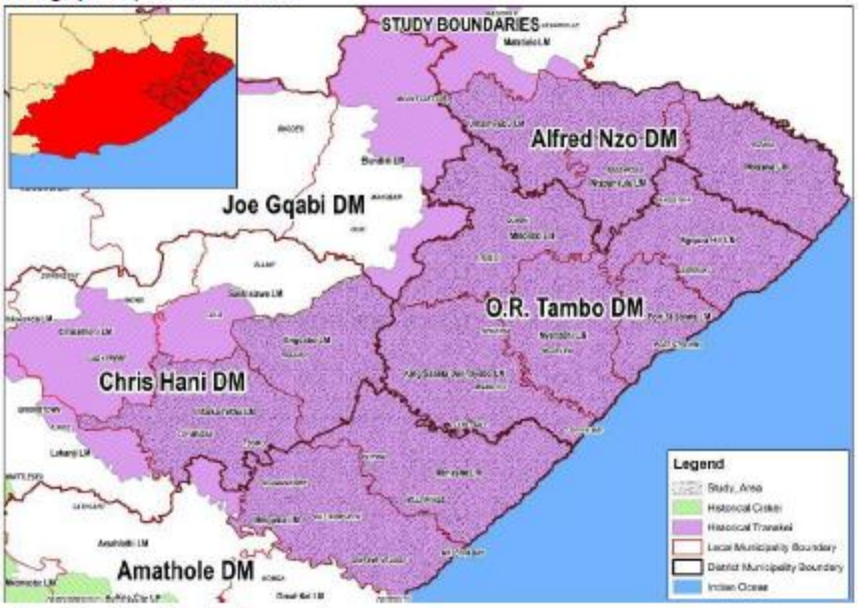
The study area focusses on the previous Transkei area but excludes the major towns and large urban areas. Considering the jurisdiction of the various Water Services Authorities, the study area boundaries have been set to coincide with those local municipalities located within the old Transkei Area. Rural villages within the following local municipalities are thus focussed on:

Mnquma LM	King Sabata Dalindyebo LM	Inguza Hill LM
Mbhashe LM	Nyandeni LM	Mbizana LM
Intsika Yethu LM	Mhlontlo LM	Ntabankulu LM
Engcobo LM	Port St Johns LM	Umzimvubu LM

1 - Introduction Sheet 1 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

The Study Area is graphically illustrated below:



This document consists of the following three sections:

1 - Introduction (This Section)
2 - Questionnaire
3 - Supportive Notes

The supportive notes are to assist in providing any clarity or background information to certain questions asked in the Questionnaire. Should anything remain unclear, please contact me and I will provide further detail.

In this questionnaire, questions have been grouped together into five main categories, as follows:

1 - Direct / Factual Questions
Basic questions requiring a "Yes" or "No", or selection from a list.
2 - Multiple Choice
Selection of the most appropriate answers from a predetermined list
3 - Ranking
Possible answers are to be ranked, based on your opinion on relevance.
4 - Scale of association (Also termed "Semantic Differentials")
An answer that most represents your view on a topic must be selected.
5 - Open ended questions
A detailed answer on a question, in your own words, needs to be provided.

Please understand there are no wrong answers and if you do not have a opinion on a question, please leave the question un-answered.

Thank you very much for taking the time to answer these questions.

George Nel (Student A814549, Tel: (+27) 083 640 1311)

1 - Introduction | Sheet 2 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

2. SOCIAL QUESTIONNAIRE — **Section 2 of 3**

Kindly answer the following questions to the best of your abilities after you have read the Introduction (Section 1) and Supportive Notes (Section 3). Supportive notes have been provided to establish background to some questions. Please do not hesitate to contact the researcher if you require any further information/clarity.

Please remember to answer these questions based on your own personal experiences of engaging with the relevant communities.

NO QUESTION

1 **In which of the following areas have you historically had engagements with rural communities:**

Mark all which are applicable with an "X":

	Mnquma LM		Mhlontlo LM
	Mbhashe LM		Port St Johns LM
	Intsika Yethu LM		Inguza Hill LM
	Engcobo LM		Mbizana LM
	King Sabata Dalindyebo LM		Ntabankulu LM
	Nyandeni LM		Umzimvubu LM

2 **Are communities currently being consulted during the Wastewater Treatment Works planning process?**

Mark which one is applicable with an "X":
Yes: ____ No: ____

3 **Would communities like to be consulted during the Wastewater Treatment Works planning process?**

Mark which one is applicable with an "X":
Yes: ____ No: ____

4 **Do you think rural communities are able to afford to pay for the construction / capital costs of their own Wastewater Treatment Works?**

Mark which one is applicable with an "X":
Yes: ____ No: ____

5 **Do you think the rural community will be willing to operate and maintain their own Wastewater Treatment Works?**

Mark which one is applicable with an "X":
Yes: ____ No: ____

6 **Do you think rural communities are able contribute to paying for the operation and maintenance of a Wastewater Treatment Works?**

Mark which one is applicable with an "X":
Yes: ____ No: ____

2 - Questionaire
Sheet 3 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

7 Select the three most likely activities which the community can be involved with, during the operation and maintenance of the Wastewater Treatment Works:

Select the top three, each with an "X":

	Cutting of grass on embankments
	Removal and burying of screenings
	Routine maintenance of Mechanical and Electrical Equipment
	Routine removal of sludge from Wastewater Treatment Works
	Effluent sampling and compliance monitoring
	Repairs to concrete structures

8 Select the three most likely challenges faced by the community, if they are to operate and maintain the Wastewater Treatment Works:

Select the top three, each with an "X":

	Insufficient knowledge to perform tasks
	Lack of tools & materials to perform repairs with
	Cannot contribute financially
	Lack of commitment to continue with tasks
	Political interference
	Lack of management capability to control tasks

9 Select the three most likely benefits the community will have from operating and maintaining the Wastewater Treatment Works:

Select the top three, each with an "X":

	Re-use of effluent for agricultural purposes
	Political control of community members
	Economic development
	Job creation and skills development
	Social status
	Better control of the community's health

10 Select the three most likely Wastewater Treatment Works technologies which the community will prefer (refer to attached Supportive Notes for a definition of all technologies listed below):

Select the top three, each with an "X":

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

2 - Questionaire Sheet 4 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

11 Select the three most likely Wastewater Treatment Works technologies you believe the community can operate and maintain:

Select the top three, each with an "X":

	Waste Stabilisation Ponds
	Settled Sewerage Systems
	Upflow Anaerobic Sludge Blankets (UASB)
	Constructed Wetlands
	Infiltration Percolation System with Nitrification Basin
	Activated Sludge Treatment
	Biofiltration (Percolating filters)
	Rotating Biological Contactors (Biodiscs)
	Integrated Algal Pond System
	PETRO System

12 Rank the following operation and maintenance activities in order of preference, for the community to be involved with:

Rank the following, where "1" is the most preferred and "6" is the least preferred:

	Repair of damage to embankments, external fences and gates
	Inspection of pipes for and removal of blockages.
	Weed and insect control.
	Routine removal of settled algae.
	Tilling of Sand Filter media.
	Trimming/replacement of reeds

13 Rank the following aspects of sustainability from most to least important for the community:

Rank the following, where "1" is the most important and "6" is the least important:

	Social
	Health
	Technical
	Economic / Financial
	Institutional
	Environmental

14 Rank the following sanitation options from most to least common in the Study Area (see attached introductory notes for a definition of the study area):

Rank the following, where "1" is the most common and "6" is the least common:

	Nothing (Open Defaecation)
	Bucket systems
	Pit Latrines
	Urine Diversion Structures
	Flushing Toilets to Septic Tank
	Flushing Toilets to Waterborne Sewer

15 Rank the following cost recovery options from most to least likely to be accepted by the community:

Rank the following, where "1" is the most likely and "6" is the least likely:

	No cost recovery (municipality pays all)
	Flat rate paid monthly
	Flat rate subtracted from Social Grants on a monthly basis
	Tariff increasing as a function of size of dwelling, paid monthly
	Tariff increasing as a function of size of dwelling, subtracted monthly from Social Grant
	Community operates and maintains Wastewater Treatment Works for free, in exchange for free services

2 - Questionaire
Sheet 5 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

16 How much would a rural household be willing to pay per month for the waterborne sanitation?

Place a "X" in the most suitable rate bracket (Only select one answer):

	R0 - R50
	R50 - R150
	R150 - R300
	R300 - R500
	R500 - R1000
	more than R1000

17 The community's ability to learn new skills is as follows:

Place a "X" in the space that most represents your view (Only select one answer):

	Not interested in providing any assistance
	Able to only do general labour work
	Can learn administrative skills
	Can learn to work on mechanical and electrical components of the Wastewater Treatment Works
	Can learn all skills to perform operation and maintenance comprehensively
	Can learn all skills to manage the plant including all operation and maintenance requirements

18 How can the community contribute during the planning process of the Wastewater Treatment Works?

19 How can the community benefit from the Wastewater Treatment Works?

20 Please explain what community based funding options exist for an improved Level of Service?

21 Explain in which way the community would like to be involved in the operation and maintenance of the Wastewater Treatment Works?

2 - Questionaire
Sheet 6 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

22 Any last comments or points of clarity you wish to provide?

2 - Questionaire

Sheet 7 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

3. SUPPORTIVE NOTES: SOCIAL QUESTIONNAIRE Section 3 of 3

To assist in the providing background and context to the Questionnaire. Once you have read these supportive notes and the Introduction (Section 1), kindly answer the Questionnaire in Section 2. Feel free to return to these Supportive Notes at any time during the process of answering the questionnaire

ABBREVIATIONS / DEFINITIONS:

CBO:	Community Based Organisation
LOS:	Level of Service (eg. Water or Sanitation infrastructure such as water taps)
NSP:	National Sanitation Policy
O&M:	Operation and Maintenance
STP:	Sewage Treatment Plant. (Collective name for all types of technologies)
WWTW:	Waste Water Treatment Works (Synonym for STP)

Waste Water Pond System: Dams / System of dams designed to collect and *treat (primary and secondary), from which treated effluent is disposed of.*

Rural Villages: Eastern Cape rural villages falling within the Study Area.

Communities Eastern Cape rural communities falling within the Study Area.

1 LOW TECHNOLOGY OPTIONS

Name: Waste Stabilisation Ponds

Description:

A system of ponds, preceded by primary treatment (Screens and Grit Removal) consisting of three types of ponds. These are Anaerobic, Facultative and Maturation Ponds. The ponds can be lined and sewage treatment occurs through encouraging natural processes by means of gravity and solar radiation.

Typical illustration:

Image Source: www.researchgate.net (August 2016)

Typical O&M Activities:

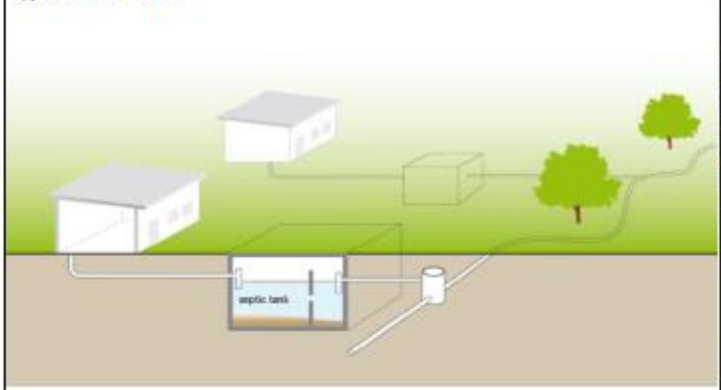
Cut grass on embankments.
Scum and macrophytes such as duckweed needs to be routinely removed.
Weed and insect control.
Removal and burial of Screenings.
Bird Scaring.
Repair of damage to embankments, external fences and gates.
Removal of sludge every 5 years or so.

3 - Supportive Notes Sheet 8 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

Name: Settled Sewerage Systems (also termed "Small Bore Sewerage")
Description:
A sewer drainage system connected to an Anaerobic Digester (septic tank) and discharging of effluent at a centralised location for further treatment. Various treatment technologies exist.

Typical illustration:



Typical O&M Activities:

As per above for Septic Tanks but excluding soakaway.
Inspection of pipes and manholes.
Removal of roots intrusions in pipes.
Repairs to manholes.

Image Source: www.sswm.info (August 2016)

Name: Upflow Anaerobic Sludge Blankets (UASB)
Description:
Primary treatment (Screens and Grit Removal) followed by a UASB reactor. Anaerobic processes occur in a reinforced concrete structure. Raw sewage flows upwards through the base of the structure, through a suspended sludge layer. Polishing ponds with estimated depth of 1.25m is thereafter required for improving the effluent quality.

General WWTW Layout:

Image Source: Mara (2003)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Removal of sludge every 1-2 weeks.

3 - Supportive Notes | Sheet 9 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

Name: Constructed Wetlands

Description:

Following primary treatment, effluent trickles through the reed bed. In the root zone sewage is treated by the biological action of micro-organisms. The granular growth medium allows for aerobic, anaerobic and anoxic treatment. Horizontal, Vertical and Floating Wetlands are different types of Constructed Wetland technologies being used over the world.

Typical illustration: (Recently planted wetland with reeds still to become established)

Image Source: FREESE and NOZAIC (2009)

Typical O&M Activities:

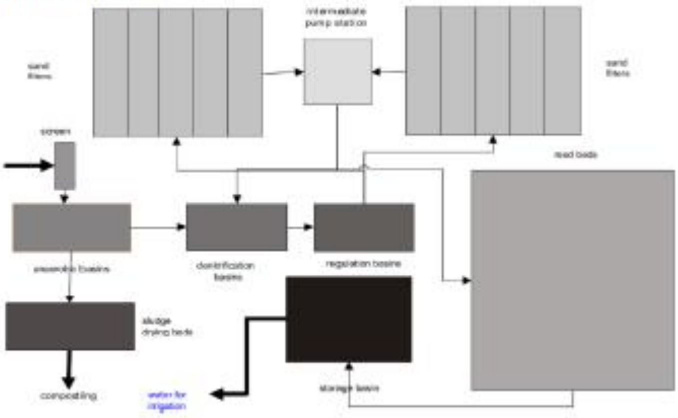
Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of pipes and manholes.
Removal of roots intruding into pipes.
Repairs to manholes.
Inspection of and repair to bedding liner.
Replacement of gravel bed media.
Trimming/replacement of reeds

Name: Infiltration Percolation System with Nitrification Basin

Description:

Following primary treatment and an anaerobic pond, sewage is further treated in a denitrification basin where nitrogen is removed by heterotrophic bacteria operating in an anoxic environment. This effluent is then dosed onto a recirculating sand filters to remove ammonia. Some effluent will need to be recirculated via pump.

Typical illustration:



Typical O&M Activities:

Cut grass on embankments.
Weed and insect control.
Repair of damage to embankments, external fences and gates.
Removal of sludge every 5 years or so.
Tilling of Sand Filter media.
Maintenance to pumps.

Image Source: CHOUKR-ALLAH et al. (2003)

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

2 ADVANCED TECHNOLOGY OPTIONS

Name: Activated Sludge Treatment

Description:

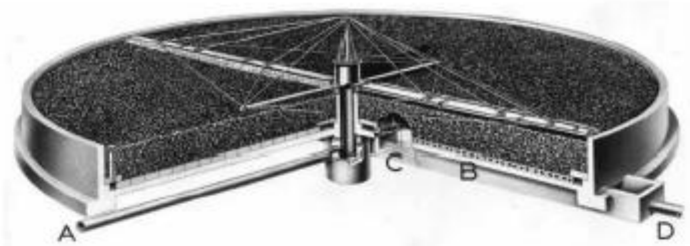
Sewage and sludge is aerated by means of surface aeration, diffused air aeration, or a combination of the two. This promotes bacterial growth which accelerates the decomposition of the sewage. Following this process, the effluent is discharged to a settling tank where the sludge is either recycled back to the aeration tank, or pumped away for final treatment and disposal. Examples of such technologies include Waste Activated Sludge and the Sequential Batch Reactor systems.

Typical illustration:	Typical O&M Activities:
 Image Source: FREESE and NOZAIC (2009)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment. Routine removal of sludge from sludge drying beds.

Name: Biofiltration (Percolating filters)

Description:

Wastewater is sprinkled on the top of either a circular or rectangular structure containing a coarse media (eg gravel). The media supports a biological film which assists in the purification of the sewage as it gravitates downwards through the media. These systems are used together with primary treatment, settling tanks and tertiary treatment.

Typical illustration:	Typical O&M Activities:
 Note: A, inlet pipe; B, underdrain blocks; C, effluent channel; D, outlet pipe. Image Source: Mara (2003)	Inspection of all pipes and removal of any blockages and fat, oil and grease build-up. Inspection of structure of any cracks and repairs to it. Routine maintenance to all mechanical and electrical equipment.

3 - Supportive Notes
Sheet 11 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

Name: Rotating Biological Contactors (Biodiscs)

Description:

A mechanical secondary treatment system similar to the Biofiltration system, except that the biofilm forms on mechanically rotated discs. They require smaller land area and less electricity than biofilters. Primary treatment and further treatment of the effluent will still be required.

Typical illustration:

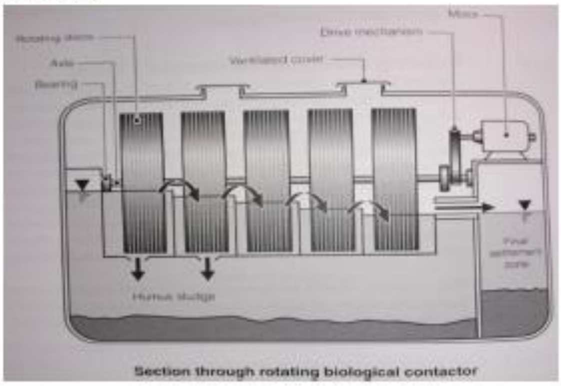


Image Source: Smith (2011)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.

Name: Integrated Algal Pond System

Description:

After primary treatment, sewage flows into a facultative pond via a "Anaerobic Fermentation Pit". Then effluent is conveyed to a High Rate Algal Pond which is a concrete oval shaped raceway in which algal growth is promoted through a paddle wheel. From there, effluent flows into a algal settling pond before being discharged.

Typical illustration:

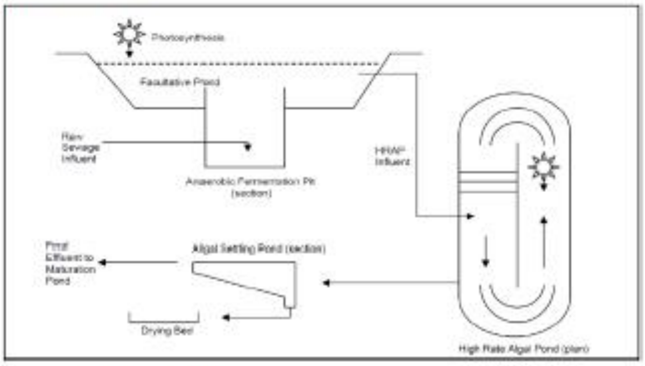


Image Source: Wells et al (nd)

Typical O&M Activities:

Inspection of all pipes and removal of any blockages and fat, oil and grease build-up.
Inspection of structure of any cracks and repairs to it.
Routine maintenance to all mechanical and electrical equipment.
Routine removal of settled algae.
Removal of sludge from facultative pond every 5 years.

3 - Supportive Notes
Sheet 12 of 13

Research Topic: *"Appropriate Technology Selection for Sewage Treatment in the rural Eastern Cape"*
Social Questionnaire

Name: PETRO System

Description:

PETRO is an acronym for "Pond Enhanced Treatment and Operation" (PETRO) and is basically a waste stabilisation system followed by Biofiltration. Anaerobic and Aerobic biodegradation occurs in the pond system, after which polishing occurs in the Biofilter. Primary treatment (screens etc.) and disinfection is however still recommended.

Typical illustration:

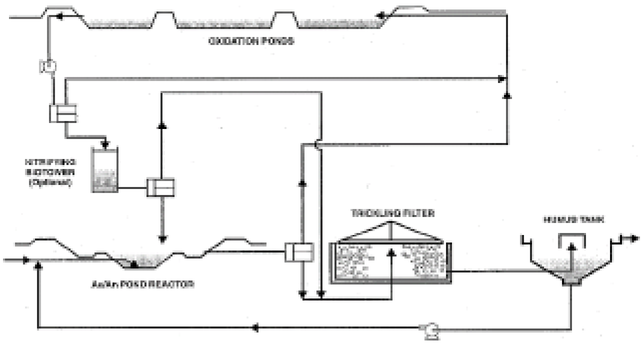


Image Source: Shipin et al (1998)

Typical O&M Activities:

Cut grass on embankments.
Scum and macrophytes needs to be routinely removed.
Weed and insect control.
Removal and burial of Screenings.
Repair of damage to embankments, external fences and gates, cracks in concrete.
Routine removal of sludge.
Inspection of pipes for blockages.
Maintenance to M&E.

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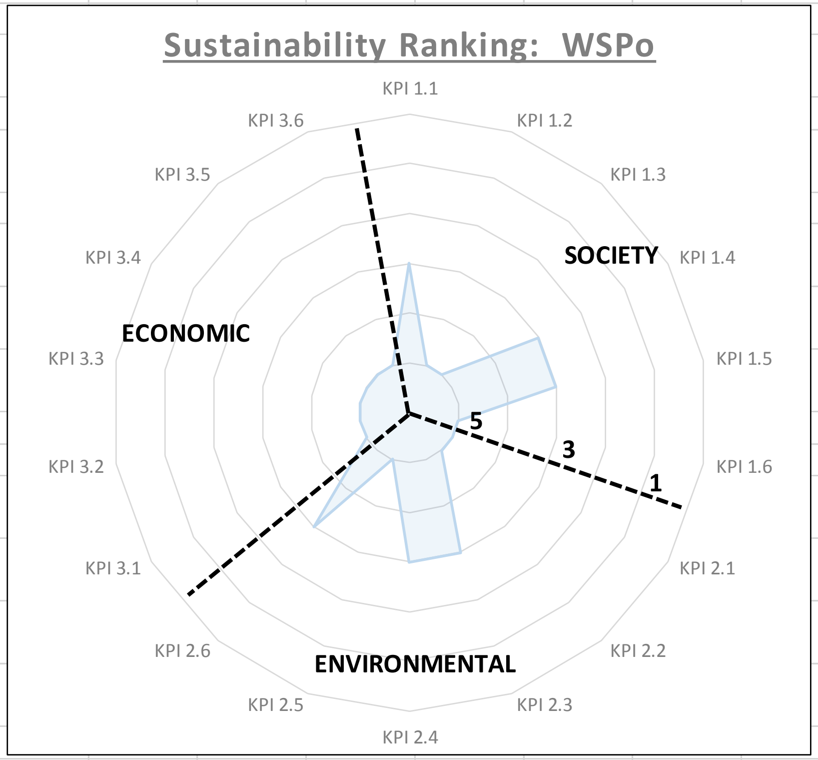
3 - Supportive Notes

Sheet 13 of 13

Annexure 15: Stage 1 Analysis – Sustainability Ranking

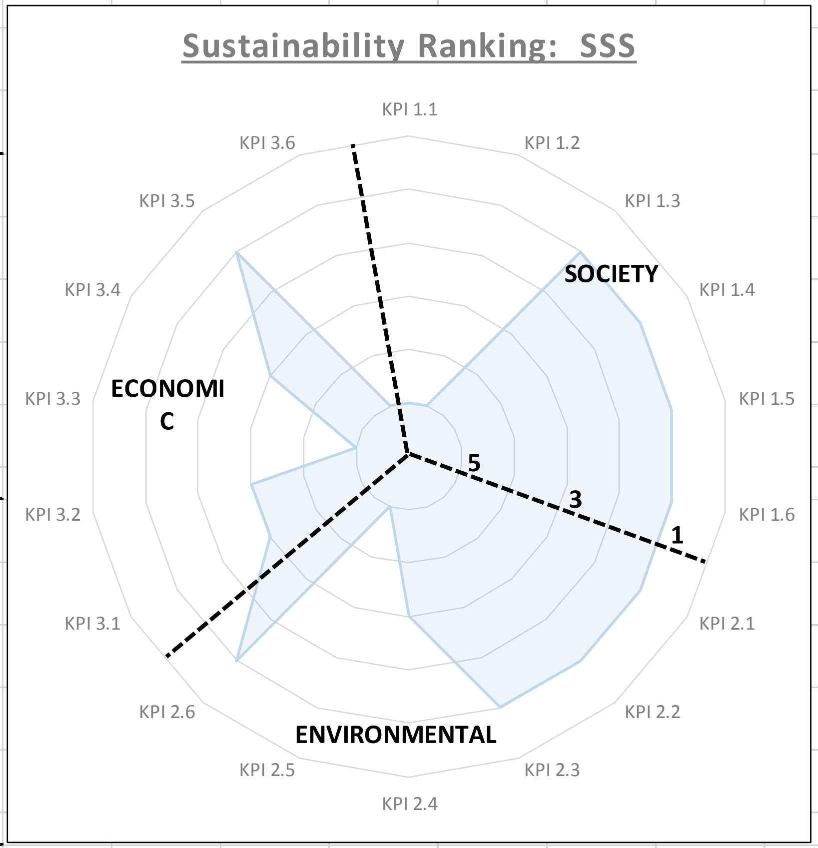
Tech. Description: Waste Stabilisation Ponds (WSPo)

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	M	Pond systems takes up a fair amount of land	3	
	KPI 1.2	STP will help promote community development	H	Community involvement during construction, O&M and increased LOS will help uplift the community	5	
	KPI 1.3	O&M activities suitable for local application	H	Community can be involved with most of the O&M activities	5	
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	Pond maintenance can likely be paid	3	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	M	Community can provide limited assistance, but not detailed scientific support	3	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	24
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	H	Pond systems have high buffer potential in case of component failure / system overload.	5	
	KPI 2.2	Safe processing and disposal of sludge	H	Sludge handling done very seldomly and is very stable.	5	
	KPI 2.3	Technology's ability to comply with water quality requirements	M	Not all parameters can easily be achieved wit pond system	3	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Mostly civil (earth) works, thus local resources used.	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	H	Community engagement during EIA process and additional required for O&M of pond system	5	
	KPI 2.6	Re-use of treated sewage effluent or sludge	M	Effluent and sludge has agricultural re-use potential	3	24
Economic	KPI 3.1	Sustainable job creation opportunities	H	Community can assist with maintaining the ponds.	5	
	KPI 3.2	STP will help promote local economic development	H	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	5	
	KPI 3.3	Efficient use of electricity over operational life of technology	H	System works fully under gravity, thus not dependent on any electricity supply.	5	
	KPI 3.4	STP construction value considerate of client's financing capacity	H	Pond systems are relatively cheap to maintain	5	
	KPI 3.5	Opportunities for value adding by-products from the STP	H	System can easily be retrofitted for further recycling in future (eg Biogas and Aquaculture)	5	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	30
					TOTAL SCORE:	**78**



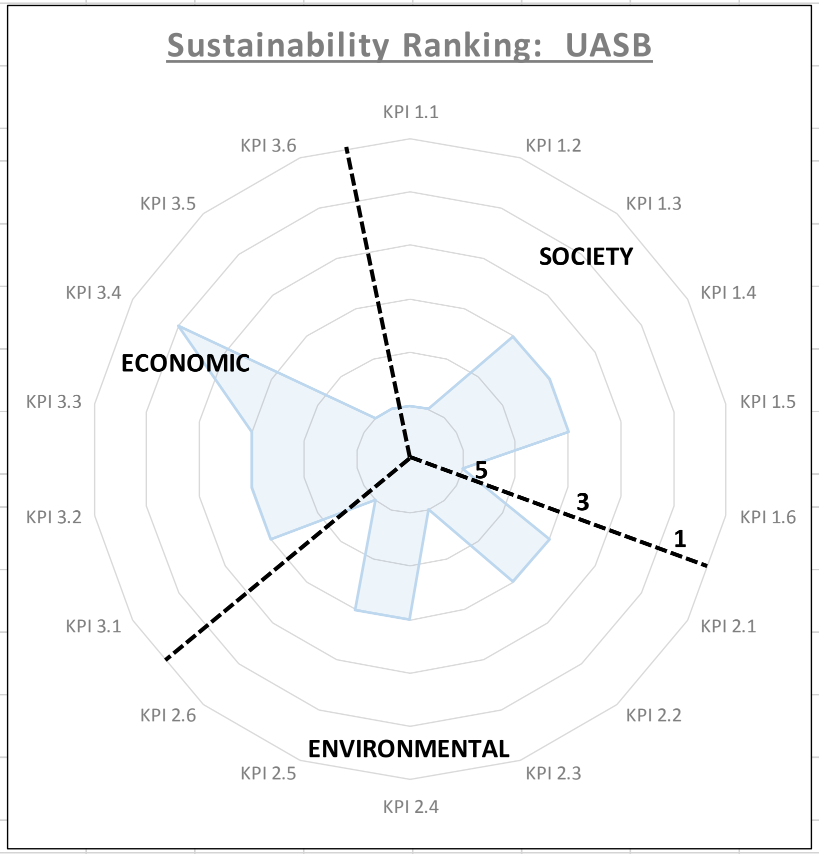
Tech. Description: **Settled Sewerage System (SSS)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	System will be installed in roads and open spaces, as part of the sewer reticulation system	5	
	KPI 1.2	STP will help promote community development	H	Community involvement during construction, O&M and increased LOS will help uplift the community	5	
	KPI 1.3	O&M activities suitable for local application	L	Routine removal of sludge from digesters and unblocking of pipes has historically been a problem in remote areas	1	
	KPI 1.4	Ability of consumer to pay for O&M of STP	L	Routine desludging of digesters can have major cost implications	1	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Not much scientific support required, but intense involvement will be required due to system's sensitivity against being full/blocked	1	
	KPI 1.6	Safe distance between community and STP	L	System will be within community, thus no safe distance and sewage spills can be detrimental to community health.	1	14
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	L	Only safety measure is overflow ponds, but due to proximity of system to community, this is not likely to be easily implemented.	1	
	KPI 2.2	Safe processing and disposal of sludge	L	Sludge is hazardous and will have to be routinely removed for further processing.	1	
	KPI 2.3	Technology's ability to comply with water quality requirements	L	Sewage needs further treatment, thus not compliant	1	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Some assistance for construction of digesters is possible, but most materials will have to be procured from outside of the community.	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	H	Due to proximity of system to households, intense engagement will be required	5	
	KPI 2.6	Re-use of treated sewage effluent or sludge	L	Effluent and sludge is not safe for re-use	1	12
Economic	KPI 3.1	Sustainable job creation opportunities	M	Community can assist with desludging and unblocking pipes, but this will have to be determined as part of public participation.	3	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	H	System works under gravity, thus not dependent on electricity supply.	5	
	KPI 3.4	STP construction value considerate of client's financing capacity	M	High costs for multiple digesters off-set by costs in any case required for waterborne sanitation	3	
	KPI 3.5	Opportunities for value adding by-products from the STP	L	Sewage and sludge still requires further treatment, thus no viable by-products possible.	1	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	20
				TOTAL SCORE:		46



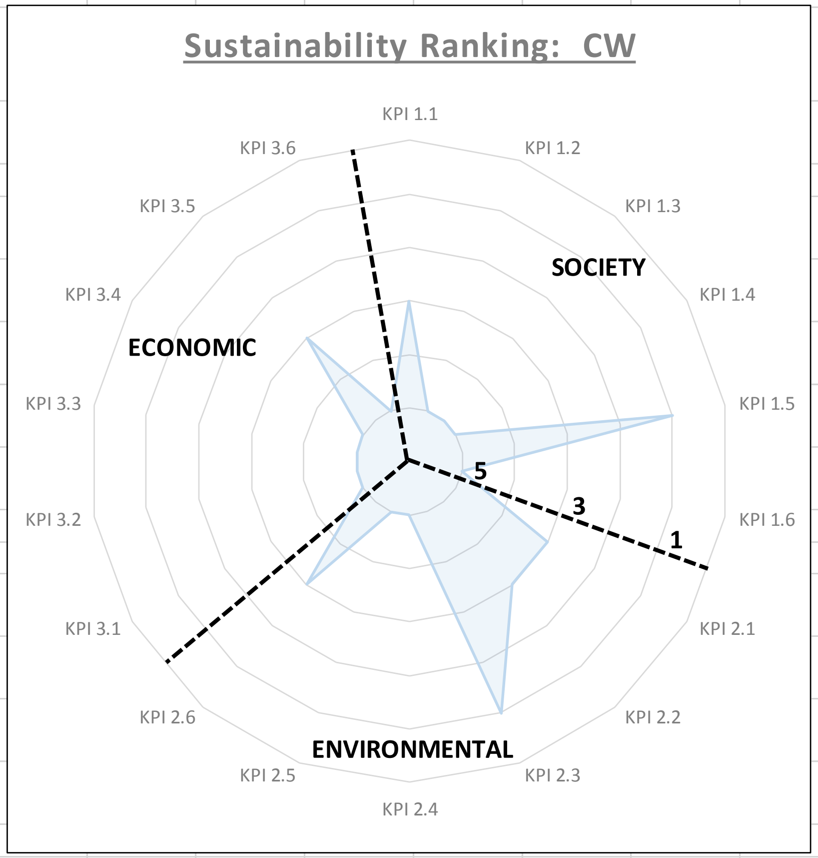
Tech. Description: **Upflow Anaerobic Sludge Blankets (UASB)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	Smaller footprint than a conventional pond system	5	
	KPI 1.2	STP will help promote community development	H	Community involvement during construction, O&M and increased LOS will help uplift the community	5	
	KPI 1.3	O&M activities suitable for local application	M	Community can be involved with some of the O&M activities, but might struggle with some of the Concrete and M&E related activities	3	
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	Pond maintenance can likely be paid, but O&M of UASB itself is likely to be more difficult	3	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	M	Management of sludge blanket is sensitive. Sampling of sewage also not likely to be done by Community	3	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	24
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	M	Polishing plants can function as buffer ponds in case UASB system fails or needs to be by-passed.	3	
	KPI 2.2	Safe processing and disposal of sludge	M	Sludge is hazardous and will have to be routinely removed for further processing.	3	
	KPI 2.3	Technology's ability to comply with water quality requirements	H	UASB system is more effective than WSPo system	5	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Concrete and M&E Work cannot be provided locally	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	M	Standard community engagement during EIA process will be required. Limited additional required for O&M due to complex UASB system	3	
	KPI 2.6	Re-use of treated sewage effluent or sludge	H	Effluent and sludge has agricultural re-use potential	5	22
Economic	KPI 3.1	Sustainable job creation opportunities	M	Community can assist with maintaining the ponds. Will possibly struggle with UASB	3	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	M	System works mostly under gravity, thus not dependent on much electricity supply.	3	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	Not as cheap as a pond system, but has reduced M&E costs as well	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	H	System can easily be retrofitted for further recycling in future (eg Biogas and Aquaculture)	5	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	20
					TOTAL SCORE:	66



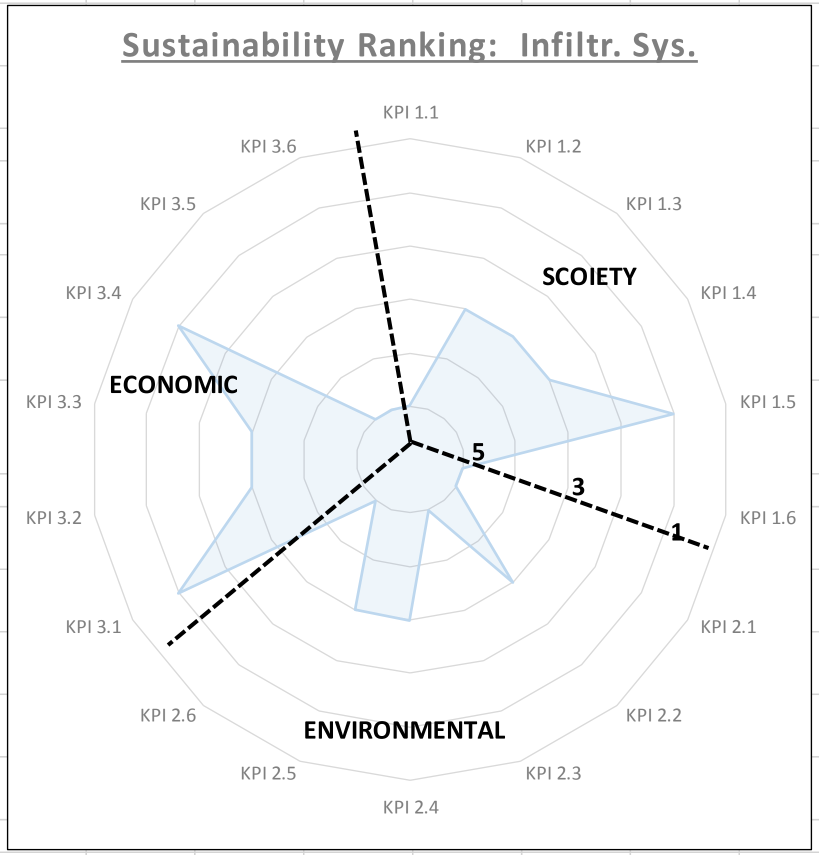
Tech. Description: **Constructed Wetlands (CW)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	M	Terrestrial system will require much land	3	
	KPI 1.2	STP will help promote community development	H	Community involvement during construction, O&M and increased LOS will help uplift the community	5	
	KPI 1.3	O&M activities suitable for local application	H	Community can use their agricultural background to maintain the CW system	5	
	KPI 1.4	Ability of consumer to pay for O&M of STP	H	Due to simplistic and low-maintenance nature of system and agricultural background, community will likely be able to afford to pay O&M in some way or another	5	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Community does not have skills to sample effluent through CW, nor to accutely establish health of CW.	1	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	24
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	M	CW can act as buffer for sewage overload/spills, but overland flooding likely to occur, thus uncontrolled sewage spills likely	3	
	KPI 2.2	Safe processing and disposal of sludge	M	No sludge processing present in system, unless combined with Sludge Treatment Wetlands.	3	
	KPI 2.3	Technology's ability to comply with water quality requirements	L	CW does not comply with all criteria and additional treatment might be required	1	
	KPI 2.4	Consideration of local resources in design and construction of STP	H	Most work can be done locally. Earthworks can also use local resources. Flora to be used in wetland possible sourced from outside.	5	
	KPI 2.5	Degree of Public Participation in Technology Selection	H	Due to agricultural nature of managing a CW, intense community involvement could be possible.	5	
	KPI 2.6	Re-use of treated sewage effluent or sludge	M	Treated effluent can easily re-used.	3	20
Economic	KPI 3.1	Sustainable job creation opportunities	H	Agricultural nature of work can be done by local community	5	
	KPI 3.2	STP will help promote local economic development	H	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	5	
	KPI 3.3	Efficient use of electricity over operational life of technology	H	System works mostly under gravity, thus not dependent on much electricity supply.	5	
	KPI 3.4	STP construction value considerate of client's financing capacity	H	System is on the lower scale of construction values	5	
	KPI 3.5	Opportunities for value adding by-products from the STP	M	No additional by-products possible, unless Flora used can be harvested for economic purposes.	3	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	28
					TOTAL SCORE:	**72**



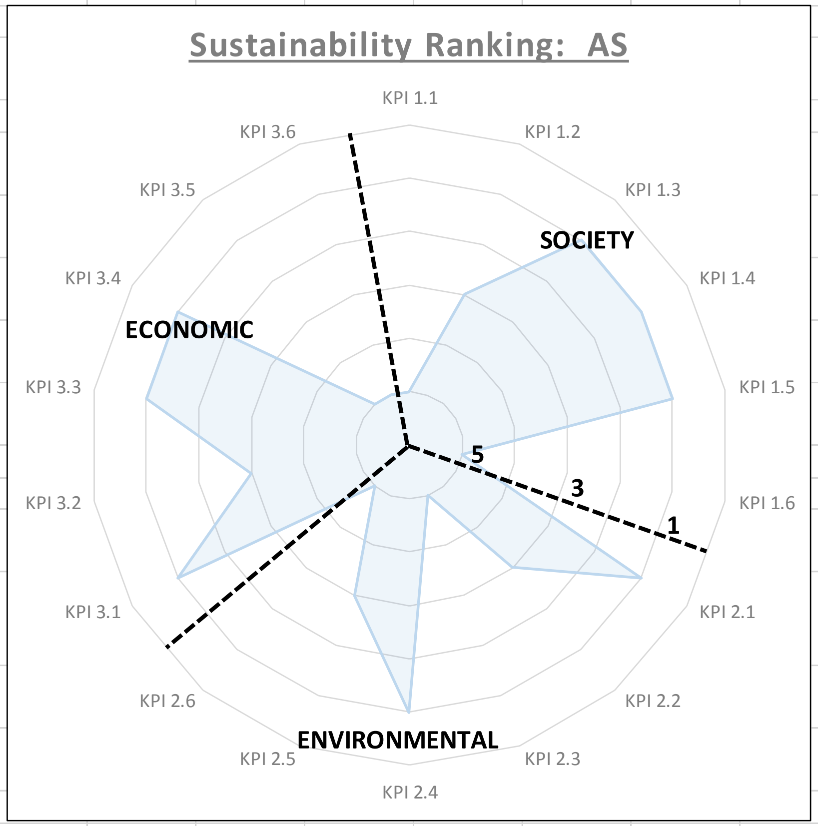
Tech. Description: **Infiltration Percolation System with Nitrification Basin (InfNit)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	Smaller footprint than a conventional pond system	5	
	KPI 1.2	STP will help promote community development	M	Community involvement during construction, O&M and increased LOS will help uplift the community	3	
	KPI 1.3	O&M activities suitable for local application	M	Community can be involved with some of the O&M activities, but might struggle with some of the Concrete and M&E related activities	3	
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	Pond maintenance can likely be paid, but O&M of Mechanical Works, Sand Filters and De-Nitrification Basin likely to be difficult	3	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Management of system could be sensitive and could be difficult for community to contribute to it.	1	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	20
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	H	System consists of ponds and reedbeds with sufficient buffer potential.	5	
	KPI 2.2	Safe processing and disposal of sludge	M	Sludge to be composted. Safety measures will be required.	3	
	KPI 2.3	Technology's ability to comply with water quality requirements	H	System can be designed to compy with water requirements.	5	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Concrete and M&E Work cannot be provided locally	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	M	Standard community engagement during EIA process will be required. Limited additional required for O&M due to complex components of system	3	
	KPI 2.6	Re-use of treated sewage effluent or sludge	H	Effluent and sludge has agricultural re-use potential	5	24
Economic	KPI 3.1	Sustainable job creation opportunities	L	Community can assist with maintaining the ponds and reedbeds. Will possibly struggle with rest of system	1	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	M	System works mostly under gravity, thus not dependent on much electricity supply.	3	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	Not as cheap as a pond system, but has reduced M&E costs as well	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	H	System can easily be retrofitted for further recycling in future (eg Biogas and Aquaculture)	5	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	18
					TOTAL SCORE:	**62**



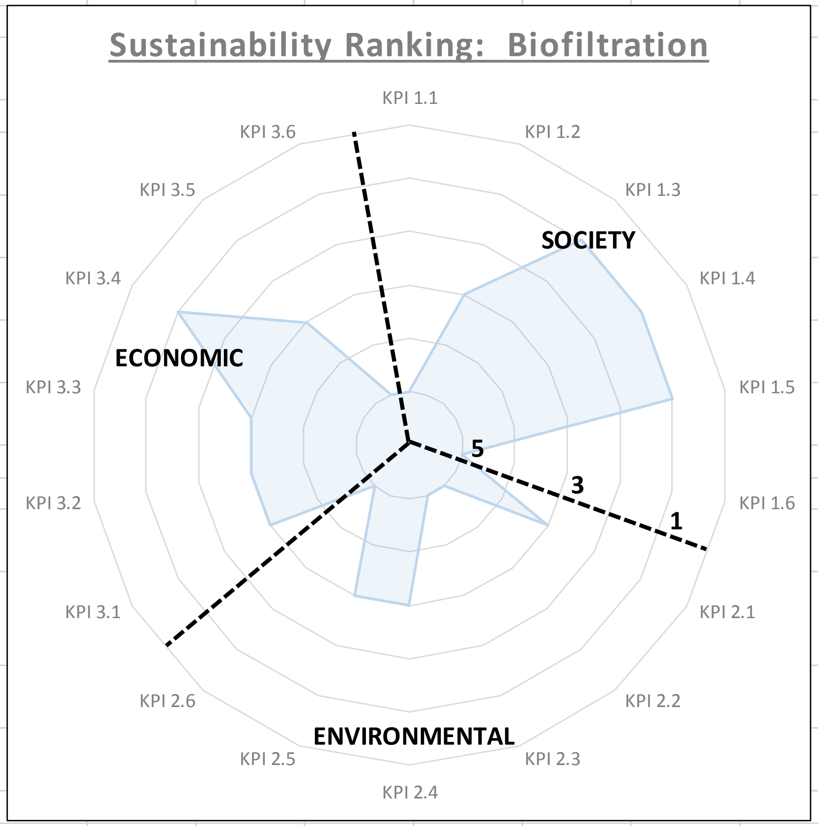
Tech. Description: **Activated Sludge Treatment (AS)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	Smaller footprint than a conventional pond system	5	
	KPI 1.2	STP will help promote community development	M	Community involvement during construction, O&M and increased LOS will help uplift the community. Not as much exposure as with lower tech options.	3	
	KPI 1.3	O&M activities suitable for local application	L	Community can be involved with only some O&M activities, since most is associated with Concrete and M&E related activities	1	
	KPI 1.4	Ability of consumer to pay for O&M of STP	L	Technology too advanced to be afforded by local community	1	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Technology too advanced for scientific support from local community	1	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	16
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	L	STP has low retention time, thus failure of component will lead to immediate system failure.	1	
	KPI 2.2	Safe processing and disposal of sludge	M	Sludge is hazardous and will have to be routinely removed for further processing.	3	
	KPI 2.3	Technology's ability to comply with water quality requirements	H	AS System provides good quality effluent.	5	
	KPI 2.4	Consideration of local resources in design and construction of STP	L	Concrete and M&E Work cannot be provided locally	1	
	KPI 2.5	Degree of Public Participation in Technology Selection	M	Standard community engagement during EIA process will be required. Limited additional required for O&M due to complex AS system	3	
	KPI 2.6	Re-use of treated sewage effluent or sludge	H	Effluent and sludge has agricultural re-use potential	5	18
Economic	KPI 3.1	Sustainable job creation opportunities	L	Limited, basic tasks exist for local community to be involved with	1	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	L	System requires contiuous electrical supply. Even if energy efficient components are used, electricity demand still relatively high compared to other technologies	1	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	One of the more expensive technologies available.	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	H	System can easily be retrofitted for further recycling in future (eg Biogas and Aquaculture)	5	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	16
					TOTAL SCORE:	**50**



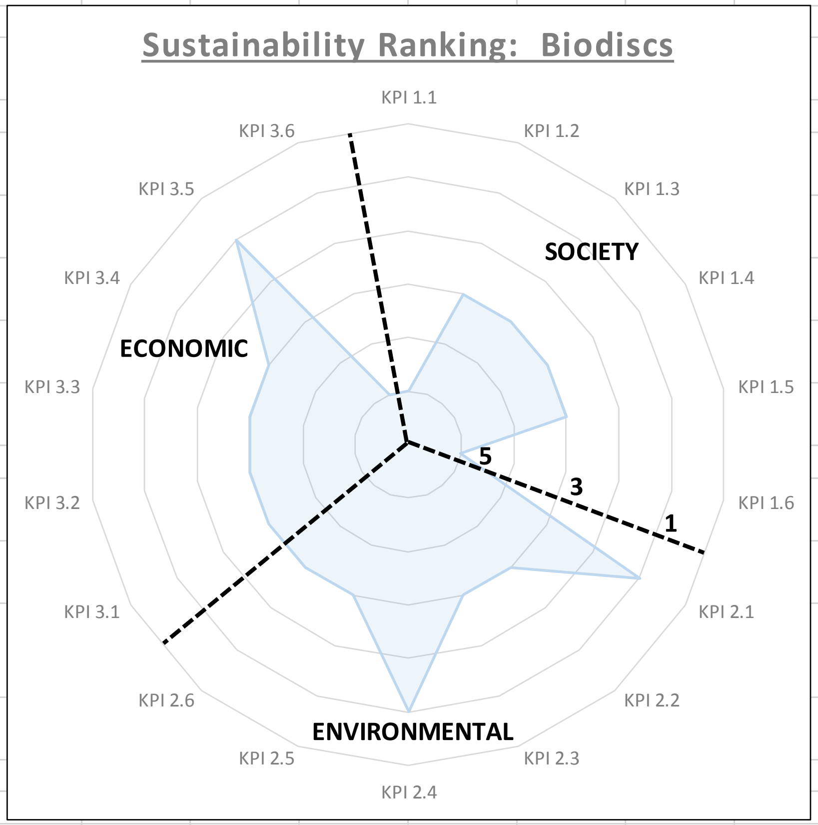
Tech. Description: **Biofiltration (Percolating filters)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	Smaller footprint than a conventional pond system	5	
	KPI 1.2	STP will help promote community development	M	Community involvement during construction, O&M and increased LOS will help uplift the community. Not as much exposure as with lower tech options.	3	
	KPI 1.3	O&M activities suitable for local application	L	Community can be involved with only some O&M activities, since most is associated with Concrete and M&E related activities	1	
	KPI 1.4	Ability of consumer to pay for O&M of STP	L	Technology too advanced to be afforded by local community	1	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Technology too advanced for scientific support from local community	1	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	16
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	M	STP has low retention time, thus failure of component will lead to immediate system failure. A bit more buffer than with AS.	3	
	KPI 2.2	Safe processing and disposal of sludge	H	Sludge is hazardous and will have to be routinely removed for further processing. More stable than with AS	5	
	KPI 2.3	Technology's ability to comply with water quality requirements	H	System provides good quality effluent.	5	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Concrete and M&E Work cannot be provided locally	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	M	Standard community engagement during EIA process will be required. Limited additional required for O&M due to complex AS system	3	
	KPI 2.6	Re-use of treated sewage effluent or sludge	H	Effluent and sludge has agricultural re-use potential	5	24
Economic	KPI 3.1	Sustainable job creation opportunities	M	Limited, basic tasks exist for local community to be involved with	3	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	M	System requires contiuous electrical supply. Even if energy efficient components are used, electricity demand still relatively high compared to other technologies	3	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	One of the more expensive technologies available.	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	M	System can be retrofitted for further recycling in future (eg Biogas and Aquaculture)	3	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	18
					TOTAL SCORE:	**58**



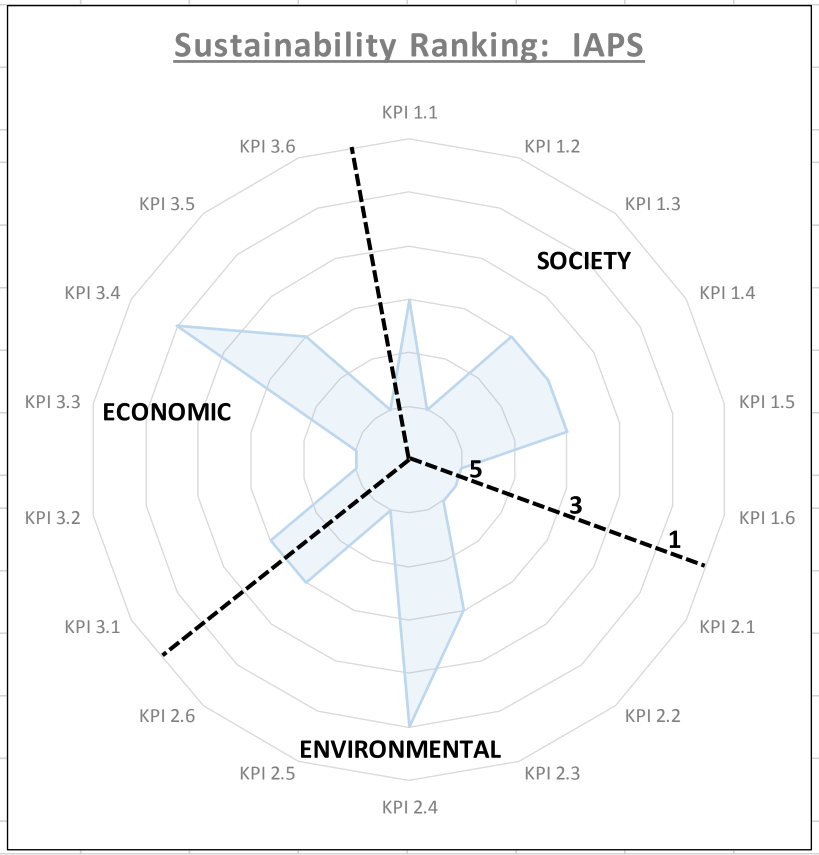
Tech. Description: **Rotating Biological Contactors (Biodiscs)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	H	Smaller footprint than a conventional pond system	5	
	KPI 1.2	STP will help promote community development	M	Community involvement during construction, O&M and increased LOS will help uplift the community. Not as much exposure as with lower tech options.	3	
	KPI 1.3	O&M activities suitable for local application	M	Community can be involved with only some O&M activities, since Biodisc system is an enclosed system and can even be pre-fabricated.	3	
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	Pre-fabricated system could possibly be maintained by community	3	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	M	Technology too advanced for scientific support from local community	3	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	22
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	L	STP has low retention time, thus failure of component will lead to immediate system failure.	1	
	KPI 2.2	Safe processing and disposal of sludge	M	Sludge is hazardous and will have to be routinely removed for further processing.	3	
	KPI 2.3	Technology's ability to comply with water quality requirements	M	System can provide good quality effluent but if it is pre-fabricated then the calibration of the system could compromise the quality.	3	
	KPI 2.4	Consideration of local resources in design and construction of STP	L	Most of the components are either pre-manufactured, or needs to be sourced from outside the study area.	1	
	KPI 2.5	Degree of Public Participation in Technology Selection	M	Standard community engagement during EIA process will be required. Limited additional required for O&M due to complex AS system	3	
	KPI 2.6	Re-use of treated sewage effluent or sludge	M	Effluent and sludge has agricultural re-use potential	3	14
Economic	KPI 3.1	Sustainable job creation opportunities	M	Opportunities revolve mostly around keeping the system up and running without interfering with actual process.	3	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	M	System requires contiuous electrical supply. Even if energy efficient components are used, electricity demand still relatively high compared to other technologies	3	
	KPI 3.4	STP construction value considerate of client's financing capacity	M	Medium construction value, depending on which patent is applied	3	
	KPI 3.5	Opportunities for value adding by-products from the STP	L	Due to closed off system, limited by-products are possible.	1	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	18
					TOTAL SCORE:	**54**



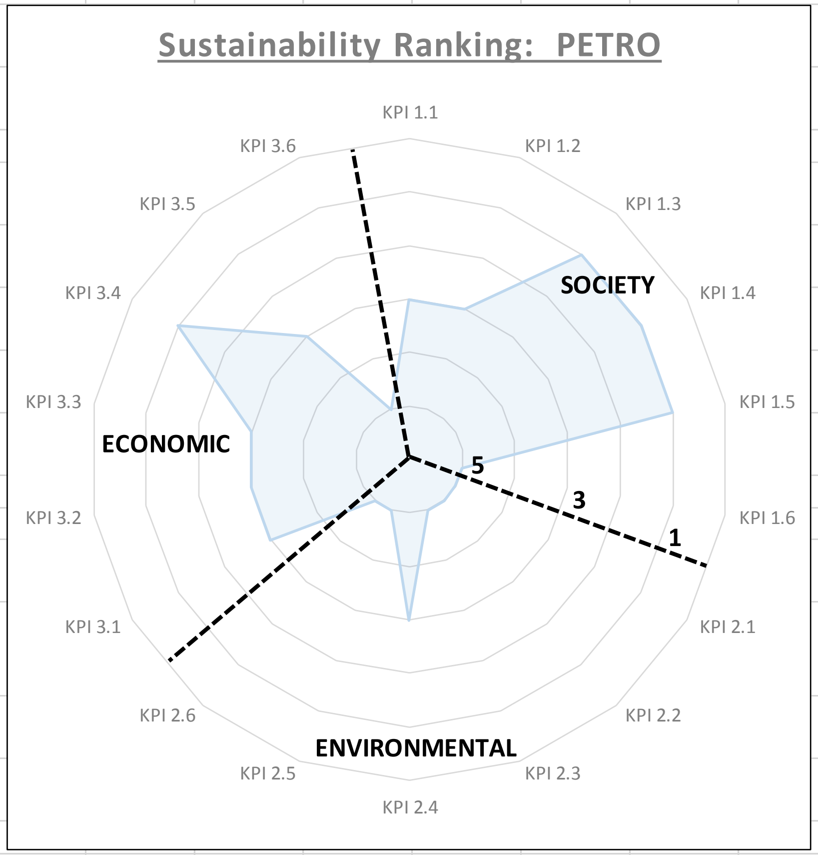
Tech. Description: **Integrated Algal Pond System (IAPS)**

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	M	Smaller footprint than a conventional pond system	3	
	KPI 1.2	STP will help promote community development	H	Community involvement during construction, O&M and increased LOS will help uplift the community	5	
	KPI 1.3	O&M activities suitable for local application	M	Community can be involved with some of the O&M activities, but might struggle with some of the Concrete and M&E related activities	3	
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	Removal of algae and grit possible by local community, but the rest is likely to be more difficult	3	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	M	Limited sciemtific support possible by community.	3	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	22
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	H	Pond systems provide buffer	5	
	KPI 2.2	Safe processing and disposal of sludge	H	Sludge is more stable than with AS, but will have to be routinely removed for further processing.	5	
	KPI 2.3	Technology's ability to comply with water quality requirements	M	IAPS system is more effective than WSPo system	3	
	KPI 2.4	Consideration of local resources in design and construction of STP	L	Concrete and M&E Work cannot be provided locally	1	
	KPI 2.5	Degree of Public Participation in Technology Selection	H	Community engagement during EIA process and additional required for O&M of pond system	5	
	KPI 2.6	Re-use of treated sewage effluent or sludge	M	Effluent and sludge has agricultural re-use potential	3	22
Economic	KPI 3.1	Sustainable job creation opportunities	M	Community can assist with maintaining the ponds. Will possibly struggle with Concrete and M&E works.	3	
	KPI 3.2	STP will help promote local economic development	H	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	5	
	KPI 3.3	Efficient use of electricity over operational life of technology	H	Limited M&E components, but will still require electricity	5	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	Not as cheap as a pond system, but has reduced M&E costs as well	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	M	System can easily be retrofitted for further recycling in future (eg Biogas and Aquaculture)	3	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	22
					TOTAL SCORE:	**66**



Tech. Description: Pond Enhanced Treatment and Operation (PETRO)

KPA	KPI No	KPI Description	Likelihood to Comply	Reason for Score	Score	
Society	KPI 1.1	Sufficient land available for STP	M	Smaller footprint than a conventional pond system	3	
	KPI 1.2	STP will help promote community development	M	Community involvement during construction, O&M and increased LOS will help uplift the community. Not as much exposure as with lower tech options.	3	
	KPI 1.3	O&M activities suitable for local application	L	Community can be involved with only some O&M activities, since most is associated with Concrete and M&E related activities	1	
	KPI 1.4	Ability of consumer to pay for O&M of STP	L	Some parts of the technology is too advanced to be afforded by local community	1	
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	L	Technology too advanced for scientific support from local community	1	
	KPI 1.6	Safe distance between community and STP	H	Sufficient space in a rural area can be made available.	5	14
Environ.	KPI 2.1	Safety measures in place to protect health of local ecosystems.	H	Pond system will provide sufficient buffer in event of failure	5	
	KPI 2.2	Safe processing and disposal of sludge	H	Sludge is relatively stable but will have to be routinely removed for further processing.	5	
	KPI 2.3	Technology's ability to comply with water quality requirements	H	System provides good quality effluent.	5	
	KPI 2.4	Consideration of local resources in design and construction of STP	M	Concrete and M&E Work cannot be provided locally	3	
	KPI 2.5	Degree of Public Participation in Technology Selection	H	Community engagement during EIA process and additional required for O&M of pond system	5	
	KPI 2.6	Re-use of treated sewage effluent or sludge	H	Effluent and sludge has agricultural re-use potential	5	28
Economic	KPI 3.1	Sustainable job creation opportunities	M	Basic tasks exist for local community to be involved with	3	
	KPI 3.2	STP will help promote local economic development	M	Opportunities exist for VLOM and CBO to assist with keeping system operational. Higher LOS can also lead to a more affluent community.	3	
	KPI 3.3	Efficient use of electricity over operational life of technology	M	System requires contiuous electrical supply. Even if energy efficient components are used, electricity demand still relatively high compared to other technologies	3	
	KPI 3.4	STP construction value considerate of client's financing capacity	L	One of the more expensive technologies available due to combination of technologies used in this system	1	
	KPI 3.5	Opportunities for value adding by-products from the STP	M	System can be retrofitted for further recycling in future (eg Biogas and Aquaculture)	3	
	KPI 3.6	STP size is economic for local land value	H	Land in rural areas have low value due to large areas being available.	5	18
					TOTAL SCORE:	**60**



KPA	KPI No	KPI Description	WSPo	SSS	UASB	CW	InfNit	AS	BioFil	Biodiscs	IAPS	PETRO
Society	KPI 1.1	Sufficient land available for STP	M	H	H	M	H	H	H	H	M	M
	KPI 1.2	STP will help promote community development	H	H	H	H	M	M	M	M	H	M
	KPI 1.3	O&M activities suitable for local application	H	L	M	H	M	L	L	M	M	L
	KPI 1.4	Ability of consumer to pay for O&M of STP	M	L	M	H	M	L	L	M	M	L
	KPI 1.5	Community's ability to provide scientific analysis and support to the operational staff	M	L	M	L	L	L	L	M	M	L
	KPI 1.6	Safe distance between community and STP	H	L	H	H	H	H	H	H	H	H
Environmental	KPI 2.1	Safety measures in place to protect health of local ecosystems.	H	L	M	M	H	L	M	L	H	H
	KPI 2.2	Safe processing and disposal of sludge	H	L	M	M	M	M	H	M	H	H
	KPI 2.3	Technology's ability to comply with water quality requirements	M	L	H	L	H	H	H	M	M	H
	KPI 2.4	Consideration of local resources in design and construction of STP	M	M	M	H	M	L	M	L	L	M
	KPI 2.5	Degree of Public Participation in Technology Selection	H	H	M	H	M	M	M	M	H	H
	KPI 2.6	Re-use of treated sewage effluent or sludge	M	L	H	M	H	H	H	M	M	H
Economic	KPI 3.1	Sustainable job creation opportunities	H	M	M	H	L	L	M	M	M	M
	KPI 3.2	STP will help promote local economic development	H	M	M	H	M	M	M	M	H	M
	KPI 3.3	Efficient use of electricity over operational life of technology	H	H	M	H	M	L	M	M	H	M
	KPI 3.4	STP construction value considerate of client's financing capacity	H	M	L	H	L	L	L	M	L	L
	KPI 3.5	Opportunities for value adding by-products from the STP	H	L	H	M	H	H	M	L	M	M
	KPI 3.6	STP size is economic for local land value	H	H	H	H	H	H	H	H	H	H
		TOTAL SCORE:	**78**	**46**	**66**	**72**	**62**	**50**	**58**	**54**	**66**	**60**

Annexure 16: Stakeholder Preferences

TECHNOLOGY PREFERENCE: TECHNICAL STAKEHOLDERS												
TECHNOLOGY DESCRIPTION	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Waste Stabilisation Ponds	2	1	1	1	1	1	1				0.89	1
Settled Sewerage Systems	1	2	2	4	8	2	7				0.63	2
Upflow Anaerobic Sludge Blankets (UASB)	6	3	6	5	7	7	8				0.40	7
Constructed Wetlands	7	4	4	2	5	6	2				0.57	3
Infiltration Percolation System with Nitrification Basin	8	9	6	10	6	7	3				0.30	9
Activated Sludge Treatment	9	10	6	9	10	4	9				0.19	10
Biofiltration (Percolating filters)	3	8	6	8	9	3	10				0.33	8
Rotating Biological Contactors (Biodiscs)	10	5	5	7	3	5	6				0.41	6
Integrated Algal Pond System	5	7	3	2	4	7	5				0.53	5
PETRO System	4	6	6	3	2	7	4				0.54	4

TECHNOLOGY PREFERENCE: INSTITUTIONAL STAKEHOLDERS												
TECHNOLOGY DESCRIPTION	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Waste Stabilisation Ponds	1	10	1								0.60	1
Settled Sewerage Systems	2	10	9								0.30	9
Upflow Anaerobic Sludge Blankets (UASB)	2	7	3								0.60	1
Constructed Wetlands	2	9	5								0.47	6
Infiltration Percolation System with Nitrification Basin	2	7	6								0.50	5
Activated Sludge Treatment	2	10	10								0.27	10
Biofiltration (Percolating filters)	2	7	4								0.57	4
Rotating Biological Contactors (Biodiscs)	2	8	7								0.43	7
Integrated Algal Pond System	2	8	8								0.40	8
PETRO System	2	8	2								0.60	1

TECHNOLOGY PREFERENCE: SOCIAL STAKEHOLDERS												
TECHNOLOGY DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Waste Stabilisation Ponds	X		x								2	2
Settled Sewerage Systems				X							1.00	5
Upflow Anaerobic Sludge Blankets (UASB)			x	X							2.00	2
Constructed Wetlands	X		x								2.00	2
Infiltration Percolation System with Nitrification Basin											0.00	8
Activated Sludge Treatment	X	x		X							3.00	1
Biofiltration (Percolating filters)		x									1.00	5
Rotating Biological Contactors (Biodiscs)											0.00	8
Integrated Algal Pond System											0.00	8
PETRO System		x									1.00	5

TECHNOLOGY PREFERENCE SUMMARY					
TECHNOLOGY DECRIPTION	**Technical Ranking**	**Institutional Ranking**	**Social Ranking**	**Total Score**	**RANK**
Activated Sludge Treatment	10	10	1	9	7
Biofiltration (Percolating filters)	8	4	5	13	6
Constructed Wetlands	3	6	2	19	4
Infiltration Percolation System with Nitrification Basin	9	5	8	8	10
Integrated Algal Pond System	5	8	8	9	7
PETRO System	4	1	5	20	2
Rotating Biological Contactors (Biodiscs)	6	7	8	9	7
Settled Sewerage Systems	2	9	5	14	5
Upflow Anaerobic Sludge Blankets (UASB)	7	1	2	20	2
Waste Stabilisation Ponds	1	1	2	26	1
REALISTIC TECHNOLOGIES	**Tech. Rank**	**Inst. Rank**	**Social Rank**	**Total Score**	**RANK**
Waste Stabilisation Ponds	1	1	2	26	1
Constructed Wetlands	3	6	2	19	4
Upflow Anaerobic Sludge Blankets (UASB)	7	1	2	20	2
Integrated Algal Pond System	5	8	8	9	7
Infiltration Percolation System with Nitrification Basin	9	5	8	8	10

Recommended O&M Activities: Technical Stakeholders												
O&M DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Cutting of grass on embankments	x	X	X	X	x	x	x	X	X		9	1
Removal and burying of screenings	x	X	X	X	x			X			6	2
Routine maintenance of Mechanical and Electrical Equipment							x				1	6
Routine removal of sludge from Wastewater Treatment Works	x	X			x			X	X		5	3
Effluent sampling and compliance monitoring						x			X		2	5
Repairs to concrete structures			X	X			x				3	4

Recommended O&M Activities: Institutional Stakeholders												
O&M DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Cutting of grass on embankments	x	X	X	x							4	1
Removal and burying of screenings		X	X	x							3	2
Routine maintenance of Mechanical and Electrical Equipment	x										1	4
Routine removal of sludge from Wastewater Treatment Works	x	X	X								3	2
Effluent sampling and compliance monitoring											0	6
Repairs to concrete structures				x							1	4

O&M DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Repair of damage to embankments, external fences and gates	5	6	4	2							0.58	5
Inspection of pipes for and removal of blockages.	6	5	4	4							0.53	6
Weed and insect control.	1	1	4	3							0.78	1
Routine removal of settled algae.	3	2	1	6							0.70	3
Tilling of Sand Filter media.	2	4	2	5							0.68	4
Trimming/replacement of reeds	4	3	3	1							0.73	2

Recommended O&M Activities: Social Stakeholders												
O&M DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Cutting of grass on embankments	X	x	X								3	1
Removal and burying of screenings			X								1	4
Routine maintenance of Mechanical and Electrical Equipment				X							1	4
Routine removal of sludge from Wastewater Treatment Works	X		X	X							3	1
Effluent sampling and compliance monitoring											0	6
Repairs to concrete structures	X			X							2	3
O&M DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Repair of damage to embankments, external fences and gates	1	1	1	1							0.90	1
Inspection of pipes for and removal of blockages.	2	6	3	2							0.68	3
Weed and insect control.	1	2	2	3							0.80	2
Routine removal of settled algae.	1	5	4	5							0.63	4
Tilling of Sand Filter media.	2	4	5	6							0.58	6
Trimming/replacement of reeds	2	3	6	4							0.63	4

Identified Critical Issues: Technical Stakeholders												
ISSUE DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Compliance monitoring not being performed	x										1	5
Effluent quality does not comply with discharge standards	x	X	X		x	x					5	4
Operators are not adequately trained	x			X	x	x	X	X	X		7	2
Wastewater Treatment Works is overloaded							X				1	5
Operation and Maintenance is not being performed	x	X	X	X	x	x		X	X		8	1
Failed components are not being replaced/repaired	x	X	X	X			X	X	X		7	2

Identified Critical Issues: Institutional Stakeholders												
ISSUE DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Compliance monitoring not being performed											0	6
Effluent quality does not comply with discharge standards	x	x	X	X							4	1
Operators are not adequately trained	x	x		X							3	2
Wastewater Treatment Works is overloaded		x	X	X							3	2
Operation and Maintenance is not being performed	x										1	4
Failed components are not being replaced/repaired			X								1	4

Identified Critical Issues: Social Stakeholders - Part 1												
ISSUE DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Insufficient knowledge to perform tasks		x									1	3
Lack of tools & materials to perform repairs with	X	x	X								3	1
Cannot contribute financially	X	x	X								3	1
Lack of commitment to continue with tasks											0	6
Political interference	X										1	3
Lack of management capability to control tasks			X								1	3

Identified Critical Issues: Social Stakeholders - Part 2												
ISSUE DESCRIPTION:	**SH1**	**SH2**	**SH3**	**SH4**	**SH5**	**SH6**	**SH7**	**SH8**	**SH9**	**SH10**	**TOTAL**	**RANK**
Re-use of effluent for agricultural purposes	X		X	X							3	2
Political control of community members											0	5
Economic development		x	X								2	4
Job creation and skills development	X	x	X	X							4	1
Social status											0	5
Better control of the community's health	X	x		X							3	2

Annexure 17: STP Design Calculations

Calculations are only provided for Scenario 01. Calculations for Scenario 02 and 03 can be provided by the author on request.

BASE DATA:	WASTE STABILISATION POND STP - Scenario 01		
Q	498.5	m3/d	Annual Average daily dry weather flow (DWF).
DWFp	86.25	l/p/d	Daily wastewater flow per person
Li	580	mg/l	Waste Water BOD5.
Le	37.5	mg/l	Filtered BOD in Final Pond Effluent to be discharged into a water course. Taken as 50% of COD
T	23	deg C	Mean air temp of coldest month.
Population	5780	people (future)	Information provided
Sludge removal cycles	3	years	Mara(2003:105)
Sludge accumulation rates: Anaerobic Ponds	0.03	m3/p/a	Smith(2011:6.5)
Rta (min)	1	days	Minimum Retention Time. Smith(2011:6.6)
Rta (max)	5	days	Maximum Retention Time. Smith(2011:6.6)
TTCi	4.00E+07	TTC/100ml	Thermotelerant coliforms in raw waste water
TTCe	1000	TTC/100ml	Thermotelerant coliforms in Final Pond Effluent to be discharged into a water course
HE (Helminth Eggs)	1000	eggs/litre	Assumed number of eggs in raw waste. Based on Smith(2011:6.13)
N	87	mg/l	Total Nitrogen in raw waste water. Assumed
Ammoniacal Nitrogen	174	mg/l	Ammoniacal Nitrogen in raw waste water
Suspended Solids	348	mg/l	Suspended Solids in raw waste water
Alkalinity	80	mg/l	Alkalinity as CaCO3. Asumed
Pp	4	g/person	Phosphur contributed per person per day (www.lenntech.com)
Pi	46	mg/l	Inflow phosphorous into WSP
e	3.5	mm/d	Evaporation Rate
No of ponds in parallel			
Anaerobic	2		
Facultative	2		
Maturation	2		
No of ponds in serie			
Anaerobic	1		
Facultative	1		
Maturation	4		

Waste Stabilisation Pond STP - Scenario 01					Anaerobic Pond Calculations
ID:	**Parameter:**	**Value**	**Unit**	**Description**	**Reference**
PART A: Calculate minimum volume and retention requirements					
A1	Qin	249.3	m3/d	Sewage inflow into Anaerobic Pond Series, subdivided as required	
A2	Lambda	330	g/m3/d	Volumetric loading of BOD5	Table 10.1 Mara(2003:109)
				Check: This is less than 400 g/m3/d and more than 100 g/m3/d thus OK	Mara(1998:46)
A3	Li	580	mg/l or g/m3	BOD5 inflow into Anaerobic Pond (unfiltered)	Base Data
A4	Vol (min)	438	m3	Minimum storage volume required = Li x Qin / Lambda	Equation 6.2 Mara(1998:45)
A5	Rta (est)	1.8	days	Vol/Qin. Estimated retention time based on Mara(1998:45). Longer than 1 Day thus OK.	Equation 6.3 Mara(1998:45)
A6	BODr (design)	66	%	%BOD Removed - to be used as design criteria	Table 10.1 Mara(2003:109)
PART B: Compare retention times and adjust to realise effective removal of maximum BOD					
A7	Rta (check)	4.0	days	Actual retention time required to achieve desired BOD removal %. This assumes that the relationship between retention time and BOD removal provided by Smith(2011:6.6) holds true for temperatures just below 25 degrees Celcius and that the % BOD removal provided by Mara(2003:109) in Table 10.1 must be seen as a removal % which can be reached if Smith's retention periods is adhered to. Based on the studies performed by the World Health Organisation, summarised in "Wastewater Treatment Ponds: Principles of Planning and Design", Chapter XIX and specifically tables III to V suggests that Smith(2011:6.6) can be applied to this situation.	Smith (2011:6.6), WHO(1987:87-90)
	Rta (adj)	3.5	days	Manual adjustment of Retention Time to limit Odours and reduce BOD removal rate and to reduce required land area.	Reduced based on ID A36
A8	Vol (adj)	872.4	m3	Adjusted Volume to achieve desired BOD reduction. Rta (adj) x Qin	Equation 6.3 Mara(1998:45)
A9	Lambda (check)	165.6	g/m3/d	Check: This is less than 400 g/m3/d and more than 100 g/m3/d thus OK	Eq 10.1 in Mara(2003:108) and Mara(1998:46)
A10	Da	1.85	m	Working depth of pond, exlc sludge	
A11	Aa	472	m2	Vol(adj)/Da = Pond area at mid depth	
A12	L:W	2		Desired Length to Width Ratio	Mara(2003:163)
A13	W	15.4	m	Width of one pond at mid depth	
A14	L	30.7	m	Length of one pond at mid depth	
A15	W(bot)	9.805	m	Bottom Width - above sludge	
A16	L(bot)	25.161	m	Bottom Length - above sludge	
A17	Aa(bot)	246.712	m2	Bottom area - above sludge	
PART C: Calculate required sludge volume to add to anaerobic pond volumes					
A18	Vols	260.1	m3	Sludge storage volume required at base of pond, ie dead storage that needs to be omitted from calculations. Population x Sludge Accumulation per person per year x 3 years	
A19	Ds	1.054	m	Approx. depth of sludge accumulated: Ds = Aa(bot)/Vols	
A20	Ds (Say)	1.1	m	Fix sludge storage depth	
PART D: Adjust dimensions for practicality, check final pond volumes and check dimensions.					
A21	W (base)	3.205	m	Pond base width for excavation purposes (incl sludge depth)	
A22	L (base)	18.561	m	Pond base length for excavation purposes (incl sludge depth)	
A23	Wb (say)	3	m	Standardised base width for ease of construction	
A24	Lb (say)	22	m	Standardised base length for ease of construction	
A25	Vols (check)	302.016	m3	Sludge Storage Volume check. This must be larger than ID A18: Vols	ID A18
				CHECK: ACCEPTABLE - The calculated volume is just above Vols, thus max sludge accumulation will only occur after 3 years	
A26	Wa	15.15	m	Final width of one pond at mid depth of anaerobic component	
A27	La	34.15	m	Final length of one pond at mid depth of anaerobic component	
A28	L:Wa (check)	2.254		L:W ratio check at mid depth. It is desired that this is between 2 and 3, Mara(2003:163), but it is most important at Top Water Level (TWL), in order to control/check that sludge banks wont form at the inlet to the pond.	Mara(2003:163)
A29	Vol (final)	957.139	m3	Final Storage Volume for anearobic pond. This is more than the calculated Vol(adj) - ID:8, and Vol (min) ID: A4. By changing Wb or Lb slightly, the storage volume for sludge will increase too much and be uneconomical. Thus this reduced anaerobic volume is proposed, and the calculations will accordingly be adapted.	
A30	Wtwl	20.7		Width at TWL	
A31	Ltwl	39.7		Length at TWL	
A32	L:W	1.918		L:W ratio at TWL to avoid sludge banks forming at inlet	Mara(2003:163)
				Check: OK (between 2 and 3).	
A33	Ltwl or Wtwl (min)	17.7	m	Minimum distance the pond's length or width at TWL must be to ensure the desired depth can be actually be provided. 2 x Dtotal x 3/1 (where 3/1 = H/V slope ratio)	
				Check: OK - Both Ltwl and Wtwl is longer the minimum dimension	

Waste Stabilisation Pond STP - Scenario 01					Anaerobic Pond Calculations
PART E: Check and evaluate BOD removal rates due to volume fluctations					
A34	Rta (year 3)	3.8399	days	Retention time at end of 3-year sludge build-up and just prior to sludge removal. Vol (final)/Qin	
A35	BODr3	65.360	%	%BOD removal at end of 3 year cycle, it is assumed that BOD removal will have a ceiling amount of Table 10.1 in Mara(2003:109) for safety.	Smith (2011:6.6) and Mara(2003:109)
A36	Rta (year 1)	5.052	days	Retention time at start of 3-year sludge build-up and just after sludge removal has occurred. (Vol (final) + Vols (check))/Qin	
				Increased anaerobic storage is available. This check is important to ensure the maximum retention period of 5 days is not exceeded.	
				Check: OK - Maximum period of 5 days is not exceeded.	
A37	BODr1	66.000	%	%BOD removal at start of 3 year cycle	Smith (2011:6.6) and Mara(2003:109)
A38	Le (year 3)	200.814	mg/l gm3	BOD leaving Anaerobic pond, at year 3 of sludge build-up cycle. It is assumed that due to the anaerobic processes minimal to no algal activity is present in the Anaerobic Pond, thus the BOD in the effluent has got no algal content. Thus filtered and unfiltered BOD is the same.	ID A3
PART F: Overall Dimensions					
	Freeboard:				
A39	Atwl	821.790	m2	Dam surface area (at twl)	
A40	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
A41	Lta	42.700	m	Anaerobic Pond Internal Length along top of pond embankment. Lta = Ltwl + 2*3*F	ID A31
A42	Wta	23.700	m	Anaerobic Pond Internal Width along along top of pond embankment. Wta = Wtwl + 2*3*F	ID A30
A43	Dat	3.450	m	Total Pond Depth per pond	
A44	Lw	144.800	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
A45	Aat	1446.390	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
A46	Qty	2.000	No	Number of Anaerobic Ponds	
A47	AaT	2892.780	m2	Total area required for all anaerobic ponds	
PART G: Thermotolerant coliform removal (Von Sperling)					
A48	kbt	2.450		First-order rate removal for Ecoli removal in Anaerobic Ponds	Eq 12.8 in Mara(2003:147)
A49	Ni	4.0.E+07	TTC/100ml	TTC in raw waste water	Data provided
A50	Ne	3.843E+06	TTC/100ml	TTC in Anaerobic pond effluent	Eq 12.1 in Mara(2003:141)
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
A51	HEi	1000.000	eggs/litre	Number of Helminth Eggs in raw waste water flowing into Anaerobic Pond	Assumed: Smith(2011:6.13)
A52	R	92.92	%	% Removed	Eq 11.12 in Mara(2003:124)
A53	HEe	70.806	eggs/litre	Number of Helminth Eggs in effluent flowing out of Anaerobic Pond. This is more than 1 egg/litre (Mara(2003:238)) and further removal will be required.	Mara(2003:238)
PART I: Total Nitrogen removal					
A54	Ce	86.957	mg/l	Nitrogen concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
A55	Ce	173.913	mg/l	Ammonia concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
PART K: Phosphorus removal					
A56	Pe	46.377	mg/l	Phosphorous concentration in raw waste water. Removal calculated for entire system combined. Refer to end of Maturation Pond System	Mara(2003:151)

Waste Stabilisation Pond STP - Scenario 01					Facultative Pond Calculations
ID:	Parameter:	Value	Unit	Description	Reference
PART A: Calculate Pond Surface Area Based on First Order Kinetics					
F1	Qin	249	m3/d	Sewage outflow from Anaerobic Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
F2	Le (min)	60	mg/l or g/m2	Unfiltered BOD5 effluent desired for quality purposes and to ensure Aerobic conditions are met (60mg/l should be seen as upper limit)	Smith(2011:6.8)
F3	Li	201	mg/l or g/m3	BOD5 inflow from Anaerobic Pond, taken as third year quality, just before sludge removal. Ie worst case	
F4	Df1	1.8	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for.	Mara(2003:118 & 120)
F5	K20	0.1	day-1	First Order rate constant for BOD removal at 20 deg C	Mara(2003:121)
F6	teta	1.07		Arrhenius constant	Mara(2003:59)
F7	KT	0.123	day-1	First Order rate constant for BOD removal at T deg C, where T = 23 deg C (provided). It is assumed that T must be the temperature in the coldest month for safety purposes.	Equation 5.8 in Mara(2003:59)
F8	Rt1	19.158	days	Calculated retention period of facultative pond based on First Order Kinetics	Equation 5.7 in Mara(2003:59)
F9	Rt (min)	4.000	days	Min retention period based on temperatures above 20 degC	Mara(1998:48)
F10	Rt (check)	OK		Rt1 is longer than Rt (min) thus no algal washout will occur	Mara(1998:48)
F11	Af	2652.947	m2	Facultative pond area at mid depth. Af = Qin x Rt1 / D	Eq 11.4 in Mara(2003:119)
PART B: Calculate Pond Surface Area Based on Surface Loading					
F12	Qin	249	m3/d	Sewage outflow from Anaerobic Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
F13	Lambda	311	kg/ha/d	Surface loading of BOD5	Eq 11.3 in Mara(2003:119)
F14	Li	200.8	mg/l or g/m3	BOD5 inflow from Anaerobic Pond, taken as third year quality, just before sludge removal. Ie worst case	
F15	Af	1610.0	m2	Facultative pond area at mid depth	Eq 11.1 in Mara(2003:117)
F16	Df2	1.8	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for. The depth is iterratively adjusted to ensure a BOD unfiltered effluent of 60mg/l is ensured.	Mara(2003:118 & 120) ID F4 & F2
F17	Vf	2897.9	m3	Facultative pond volume	
F18	e	3.5	mm/d	Net evaporation rate per day/ Average rate for area	
F19	Qe	244	m3/d	Effluent flow rate. Infiltration and seepage is assumed negligible, thus effluent flow rate is only a function of net evaporation rate.	Equation 11.6 in Mara(2003:120)
F20	Qm	246	m3/d	Mean flow rate of influent and effluent	
F21	Rt2	12	days	Calculated retention period of facultative pond based on surface loading	Equation 11.4 in Mara(2003:120)
F22	Rt (min)	4.0	days	Min retention period based on temperatures above 4 degC	Mara(1998:48)
F23	Rt (check)	OK		Rt2 is longer than Rt (min) thus no algal washout will occur	Mara(1998:48)
F24	BOD removed	59.025	%	% BOD removed from incoming BOD (from Anaerobic pond).	Eq 5.7 in Mara(2003:120)
F25	BOD (remain)	82.284	mg/l or g/m3	Unfiltered BOD effluent leaving Facultative Pond. This is more than the upper limit of 60mg/l (Smith(2011:6.8)) and more than 60 + 20 = 80 mg/l, which Smith(2003:6.8) refers to as being maximum acceptable.	Smith(2011:6.8), Mara(1998:48) AND WHO(1987:98)
PART C: Calculate Final Pond Dimensions					
F26	Af (final)	1610.0	m2	It is proposed to use the surface laoding approach for designing the Facultative Pond. This is because the assumption of full mixing in secondary facultative ponds, and related application of first order kinetics, is too overly conservative. WHO(1987:98)	Mara(2003:118)
F27	Df	1.80	m	Working depth of pond. #See Part B	ID F4 & F16
F28	L:W	5		Desired Length to Width Ratio	Mara(2003:163)
F29	W	17.944	m	Width of one pond at mid depth	
F30	L	89.721	m	Length of one pond at mid depth	
F31	Wb (calc)	12.5	m	Pond base width for excavation purposes	
F32	Lb (b)	84.3	m	Pond base length for excavation purposes	
F33	Wb (say)	20	m	Standardised base width for ease of construction and to match available geometry	
F34	Lb (say)	100	m	Standardised base length for ease of construction and to match available geometry	
F35	W (final)	25.4	m	Final width of one pond at mid depth of facultative pond	
F36	L (final)	105.4	m	Final length of one pond at mid depth of facultative pond	
F37	L:W (check)	4.150		L:W ratio at mid depth. It is desired that this is approximately 10, Mara(2003:163), but it is most important at Top Water Level (TWL), in order to approximate plug flow conditions.	
F38	Wtwl	30.8		Width at TWL	
F39	Ltwl	110.8		Length at TWL	
F40	L:W	3.597		L:W ratio at TWL to approximate plug flow conditions.	Mara(2003:163)
				Check: Not close to 10, but shape is necessary to fit into proposed site.	
F41	Ltwl or Wtwl (min)	10.8	m	Minimum distance length or width at TWL must be to ensure the desired depth can be actually be provided. 2 x Dtotal x 3/1 (where 3/1 = H/V slope proportions)	
				Check: OK - Both Ltwl and Wtwl is longer the minimum dimension	

Waste Stabilisation Pond STP - Scenario 01					Facultative Pond Calculations
PART D: Check retention time and effluent quality (using first order kinetics)					
F42	Af (final)	2677.2	m2	Pond area at mid depth	ID F35 & F36
F43	V (final)	4818.9	m3	Pond volume	ID F27 & F42
F44	Rt (final)	19.3	days	Retention time is more than 4 days, thus OK.	Equation 11.4 in Mara(2003:120)
F45	Le (unfiltered)	59.618	mg/l or g/m2	This is less than the upper limit of 60mg/l (Smith(2011:6.8)). Thus the facultative pond will be appreciably aerobic and since the BOD influent quality is taken as the third year worst case scenario, the risk for the facultative pond ever becoming anaerobic is extremely low.	Equation 6.2 Mara(1998:45)
PART E: Calculate effluent quality					
F46	Le (unfiltered)	59.6	mg/l or g/m2	unfiltered BOD in effluent flowing out of Facultative Pond	ID F45
F47	Fna	0.3		Non algal fraction of BOD	Mara(2003:121)
F48	Le (filtered)	17.9	mg/l or g/m2	Filtered BOD (non-algal) flowing out of Facultative pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as the WHO organisation's requirements Mara(1998:42) of 25mg/l). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	Equation 11.8 in Mara(2003:121)
PART F: Overall Dimensions					
	Freeboard:				
F49	Atwl	3412.640	m2	Dam surface area (at twl)	ID F38 & 39
F50	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
F51	Ltf	113.800	m	Facultative Pond Length along top of pond embankment. Ltf = Ltwl + 2*3*F	
F52	Wtf	33.800	m	Facultative Pond Width along along top of pond embankment. Wtf = Wtwl + 2*3*F	
F53	Dat	2.300	m	Total Pond Depth per pond	
F54	Lw	307.200	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
F55	Aat	4768.040	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
F56	Qty	2.000	No	Number of Facultative Ponds	
F57	AaT	9536.080	m2	Total area required for all Facultative ponds	
PART G: Thermotolerant coliform removal (Von Sperling)					
F58	kb20	0.206		First-order removal rate for Ecoli removal in Facultative Ponds at 20 deg C	Eq 5.15 in Mara(2003:146)
F59	kbt	0.253		First-order removal rate for Ecoli removal in Facultative Ponds at T deg C	Eq 5.8 in Mara(2003:146)
F60	delta	0.278	m/m	Inverted L:W ratio. Due to Ecoli removal being a function of area exposed to solar radiation, this is assumed to be the L:W ratio at TWL.	Eq 5.14 in Mara(2003:146)
F61	a	2.537			Paragraph below Eq 5.13 in Mara(2003:145)
F62	Ni	3.8.E+06	TTC/100ml	TTC in Anaerobic pond effluent, flowing into facultative pond	Previously calculated
F63	Ne	1.965E+05	TTC/100ml	TTC in Facultative pond effluent	Eq 5.13 in Mara(2003:145)
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
F64	HEi	70.806	eggs/litre	Number of Helminth Eggs in effluent from Anaerobic Pond flowing into Facultative pond	
F65	R	99.92	%	% Removed	Eq 11.12 in Mara(2003:124)
F66	HEe	0.054	eggs/litre	Number of Helminth Eggs in effluent flowing out of Facultative Pond. This is less than 1 egg/litre (Mara(2003:238)) thus acceptable for unrestricted and restricted irrigation, but not for use where children younger than 15 years will be exposed and further removal will be required.	Mara(2003:238)
PART I: Total Nitrogen removal					
F67	Ci	86.9565217	mg/l	Nitrogen concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
F68	Alkalinity	80	mg/l		Assumed
F69	pH	7.60		pH for pond. This is a bit higher than the pH provided for the raw sewage, but this should be expected due to the algal content within the pond raising the pH.	Eq 12.13 in Mara(2003:149)
F70	Ce	49.035	mg/l	Nitrogen concentration in Facultative Pond's effluent. This is more than 15mg/l and thus requires further treatment.	Eq 12.12 in Mara(2003:149) and Mara(1998:43)

Waste Stabilisation Pond STP - Scenario 01					Facultative Pond Calculations
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
F71	Ci	173.913	mg/l	Ammonia concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
F72	A	2677.160	m2	Pond area at mid depth	ID F42
F73	Q	246.445	m3/d	Mean flow rate through pond	
F74	pH	7.598		Same as for Nitrogen removal	
F75	Ce	138.652	mg/l	Ammonia concentration in Facultative Pond's effluent.	Eq 12.15 in Mara(2003:150)
PART K: Phosphorus removal					
F76	Pi	46.377	mg/l	Phosphorous concentration in raw waste water. Removal calculated for entire system combined. Refer to end of Maturation Pond System	Mara(2003:151)

Waste Stabilisation Pond STP - Scenario 01					Maturation Pond Calculations
ID:	Parameter:	Value	Unit	Description	Reference
PART A: Quantify design parameters					
M1	Qin	243.628	m3/d	Sewage outflow from Facultative System and subdivided as required	Assume total flow from Facultative system will be redistributed to new Maturation Pond system.
M2	Le (min)	37.5	mg/l or g/m2	Filtered BOD5 effluent desired for quality purposes	Provided
M3	Li (filtered)	17.886	mg/l or g/m3	filtered BOD5 inflow from Facultative Pond, taken as third year quality, just before sludge removal in Anaerobic Pond has been done. Ie worst case	Previously calculated. ID F48
M4	Li (unfiltered)	59.618	mg/l or g/m3	unfiltered BOD5 inflow from Facultative Pond, taken as third year quality, just before sludge removal in Anaerobic Pond has been done. Ie worst case	Previously calculated. ID F46
M5	Fna	0.1		Non algal fraction of BOD	Mara(2003:149)
M6	k1	0.05	day -1	BOD removal rate constant	Mara(2003:149)
M7	Rt(f)	19.333	days	Retention time of upstream facultative pond. This is maximum retention time in any maturation pond. First Matuation pond usually being larger than the subsequant ponds.	Previously calculated and Mara(2003:142). ID F44
M8	Rt (m min)	3.000	days	Retention time any single maturation pond to prevent algal wash out	Smith(2011:6.9) and Mara(2003:142)
M9	Lamda (m1)	233.184	kg/ha/d	First maturation pond must have a surface loading of maximum 75% of facultative pond's surface loading	Mara(2003:142)
M10	D	1.5	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for. Shallower depths are not proposed as this could lead to Mosquito breeding which is not desired so close to the town.	Mara(2003:118 & 136)
M11	Ni	1.965E+05	TTC/100ml	TTC in Facultative pond effluent, flowing into first maturation pond	Previously calculated. ID F63
M12	Ne (min)	1.000E+03	TTC/100ml	Acceptable TTC in Maturation pond effluent, flowing into an open water source	Information provided
PART B: Calculate Pond Geometry and Quantity					
M13	Rt (m1 calc)	3.835	days	Retention time for first pond	Eq 12.5 in Mara(2003:143)
M14	Rt (m1 des)	4	days	Proposed retention time to reach TTC removal. This is also less than Rt (f) - so OK	ID M8
M15	kb20	0.408		First-order removal rate for Ecoli removal in Maturation Pond 1 at 20 deg C	Eq 5.15 in Mara(2003:146)
M16	kbt	0.499		First-order removal rate for Ecoli removal in Maturation Pond 1 at T deg C	Eq 5.8 in Mara(2003:146)
M17	L:Wm (TWL)	8.0	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164)
M18	delta	0.125	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M19	a	1.414			Paragraph below Eq 5.13 in Mara(2003:145)
M20	Ne (m1)	3.646E+04	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M21	Ne (m1 check)	TOO HIGH	TTC/100ml	Ne (m1) > Ne (min) thus an extra maturation pond is required	ID M12
M22	Ne (m2)	6765.30682	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M23	Ne (m2 check)	TOO HIGH	TTC/100ml	Ne (m2) > Ne (min) thus an extra maturation pond is required	ID M12
M24	Ne (m3)	1255.2364	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M25	Ne (m3 check)	OK	TTC/100ml	Ne (m3) < Ne (min) thus an extra maturation pond is not required	ID M12
	Ne (m4)	232.896818	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
	Ne (m4 check)	OK	TTC/100ml	Ne (m4) < Ne (min) thus an extra maturation pond is not required.	ID M12
	A_m1 des	162.4	m2	Mid depth area for indicative evaporation	
M26	Q mean	242.5	m3/d	Mean flow across pond system, allowing for evaporation	ID M1
M27	Am# (mid calc)	646.641924	m2	Since each of the ponds have the same depth and retention time, each shall have the same pond area at mid depth: Am1 = Am2 = Am3 = Am#	Eq 11.4 in Mara(2003:119)
M28	Wm# (mid calc)	8.99056397	m	Width of one maturation pond at mid depth	
M29	Lm# (mid calc)	71.9245118	m	Length of one maturation pond at mid depth	
M30	Wm# (base - calc)	4.49056397	m	Calculated base width for one pond	
M31	Lm# (base calc)	67.4245118	m	Calculated base length for one pond	
M32	Wm# (base - say)	25	m	Proposed dimensions for ease of construction and to fit into site footprint	
M33	Lm# (base - say)	300	m	Proposed dimensions for ease of construction and to fit into site footprint	
M34	Wm# (mid final)	29.5	m	Construction Width of one maturation pond at mid depth	
M35	Lm# (mid final)	304.5	m	Construction Length of one maturation pond at mid depth	
M36	Am# (mid final)	8982.75	m2	Final Area of one maturation pond at mid depth	
M37	Wm# (TWL final)	34	m	Construction Width of one maturation pond at TWL	
M38	Lm# (TWL final)	309	m	Construction Length of one maturation pond at TWL	
M39	W:L (TWL final)	9.088		Final L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	

Waste Stabilisation Pond STP - Scenario 01					Maturation Pond Calculations
PART C: Check retention time and TTC reduction					
M40	Am#	8982.75	m2	Each pond's area at mid depth	ID M36
M41	V#	13474.125	m3	Each pond's volume	ID M10 and M40
	Amtwl#	10506	m2	Effluent area at TWL per pond	
	Qmean	170.1	m3/d	Average flow over maturation pond system, assuming final dimensions and evaporation	
M42	Rt#	79.220	days	Retention time for each pond is more than 3 days, thus OK.	Equation 11.4 in Mara(2003:120)
M43	L:Wm (TWL)	9.1	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164). ID M39
M44	delta	0.110	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M45	a	4.290			Paragraph below Eq 5.13 in Mara(2003:145)
M46	Ne (m1)	3.870E-02	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M47	Ne (m1 check)	OK	TTC/100ml	Ne (m1) < Ne (min) thus an extra maturation pond is required	ID M12
M48	Ne (m2)	7.6196E-09	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M49	Ne (m2 check)	OK	TTC/100ml	Ne (m2) < Ne (min) thus an extra maturation pond is required	ID M12
M50	Ne (m3)	1.5004E-15	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m3 check)	OK	TTC/100ml	Ne (m3) < Ne (min) thus sufficient ponds have been allowed for	ID M12
M50	Ne (m4)	2.9543E-22	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m4 check)	OK	TTC/100ml	Ne (m4) < Ne (min) thus sufficient ponds have been allowed for	ID M12
PART E: Calculate BOD removal (first order kinetics)					
M52	Li (unfiltered)	59.6	mg/l or g/m2	unfiltered BOD in effluent flowing out of Facultative Pond	ID M4
M53	Le (m4 unfiltered)	0.1	mg/l or g/m2	unfiltered BOD in effluent flowing out of last Maturation Pond	Eq 5.7 in Mara(2003:50)
M54	Le (m4 filtered)	0.0	mg/l or g/m2	Filtered BOD (non-algal) flowing out of Maturation pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as the WHO organisation's requirements Mara(1998:42)). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	Equation 11.8 in Mara(2003:121)
PART F: Overall Dimensions					
	Freeboard:				
M55	Atwl#	10506.000	m2	Each Pond's surface area (at twl)	ID M37 & M38
M56	F	0.513	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
M57	Ltf	312.000	m	Maturation Pond Length along top of pond embankment. Ltf = Ltwl + 2*3*F	
M58	Wtf	37.000	m	Maturation Pond Width along along top of pond embankment. Wtf = Wtwl + 2*3*F	
M59	Dat	2.000	m	Total Pond Depth per pond	
M60	Lw	710.000	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
M61	Aat	13674.000	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
M62	Qty	8.000	No	Number of Maturation Ponds	
M63	AaT	109392.000	m2	Total area required for all Maturation ponds	
PART G: Helminth egg removal					
M64	HEi	0.054	eggs/litre	Number of Helminth Eggs in efluent from Facultative Pond flowing into Maturation pond	ID F66
M65	R	100	%	% Removed	Eq 11.12 in Mara(2003:124)
M66	HEe (m1)	0.000	eggs/litre	Number of Helminth Eggs in effluent flowing out of First Maturation Pond. This is less than 0.1 egg/litre (Mara(2003:238)) thus acceptable for all irrigation and where children younger than 15 years will be exposed. No further treatment/removal required - but for purposes of completeness, calculated below:	Mara(2003:238)
M67	HEe (m2)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	
M68	HEe (m3)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	
	HEe (m4)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	

Waste Stabilisation Pond STP - Scenario 01					**Maturation Pond Calculations**
PART H: Total Nitrogen removal					
M69	Ci	49.035	mg/l	Nitrogen concentration in Facultative Pond's effluent. This is more than 15mg/l and thus requires further treatment	ID F71
M70	Alkalinity	80	mg/l		Assumed, ID F68
M71	pH	7.60		pH calculated for ponds. The pH for each pond would actually change due to the presence and activity of alga, but for the purposes of this exercise it is assumed that the pH and alkalinity for the Facultative Ponds can also be used for the Maturation Ponds	Eq 12.13 in Mara(2003:149) and ID F69
M72	Ce (m1)	17.989	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M73	Ce (m2)	6.599	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M74	Ce (m3)	2.421	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
	Ce (m4)	0.888	mg/l	Nitrogen concentration in Fourth Maturation Pond's effluent. This is less than 15mg/l and thus requires no further treatment	Mara(2003:149) and Mara(1998:43)
PART I: Ammoniacal nitrogen removal (NH3 + NH4+)					
M75	Ci	138.652	mg/l	Ammonia concentration in Facultative Pond effluent.	ID F75
M76	A (m1)	8982.750	m2	Pond area at mid depth	ID M40
M77	Q mean (m1)	170.086	m3/d	Mean flow rate through pond	ID M26
M78	pH	7.598		Same as for Nitrogen removal	ID M71
M79	Ce (m1)	61.997	mg/l	Ammonia concentration in First Maturation Pond's effluent.	Eq 12.15 in Mara(2003:150)
M80	Ce (m2)	27.722	mg/l	Ammonia concentration in Second Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
M81	Ce (m3)	12.396	mg/l	Ammonia concentration in Third Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
	Ce (m4)	5.543	mg/l	Ammonia concentration in Fourth Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
PART J: Phosphorus removal					
M82	Li (unfiltered)	579.71	mg/l or g/m3	BOD5 inflow into Anaerobic Pond. Ie Raw Waste Water	Base Data
M83	Le (m4 - filtered)	0.0	mg/l or g/m4	Filtered BOD leaving last Maturation Pond	Calculated above. ID M54
M84	BODr	99.998	%	Percentage BOD removal	
M85	Pr	49.999	%	Percentage Phosphorus removal	Mara(2003:151) and Mara(1998:53)
M86	Pi	46.377	mg/l	Phosporus content of raw sewage	Base data
M87	Pe	23.189	mg/l	Phosporus content of treated effluent flowing out of final maturation pond	

Waste Stabilisation Pond STP - Scenario 01				
Summary of Results				
Basic data				
Q-full (m^3/day)	498.53			
Q-half (for parallel flow) (m^3/day)	249.26			
BOD full load (kg BOD/day)	289.00			
BOD falf load (kg BOD/day)	144.50			
L_i (BOD of pond influent) (mg/l)	579.71			
T (Min mean monthly temperature)	23.00			
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07			
Net evaporation, evap - rainfall (mm/day)	3.50			
Effluent standards required				
BOD_R (filtered BOD at effluent)	37.5			
Ne (Number of FC: CFU/100 ml of effluent)	1000			
Nitrogen (mg/l)	15			
Suspended Solids (mg/l)	25			
Ammoniacal Nitrogen (mg/l)	6			
Phosphorus (mg/l)	10			
Effluent standards desired				
Helminth eggs (eggs/litre)	0.1			
Design with Anaerobic pond	Anaerobic Pond	Facultative Pond	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:				
Number of ponds in series	1	1	1	3
Number of ponds in parallel	2	2	2	2
Sludge Storage Depth (m)	1.10	0.00	0.00	0.00
Active Depth (m)	1.85	1.80	1.50	1.50
Freeboard (m)	0.50	0.50	0.51	0.51
Total Pond Depth (m)	3.45	2.30	2.01	2.01
Length/Breadth at mid depth	2.25	4.15	10.32	10.32
Length at mid-depth (m)	34.15	105.40	304.50	304.50
Breadth at mid-depth (m)	15.15	25.40	29.50	29.50
Length/Breadth at TWL	1.92	3.60	9.09	9.09
Length at TWL (m)	39.70	110.80	309.00	309.00
Breadth at TWL (m)	20.70	30.80	34.00	34.00
Length at top of embankment (m)	42.70	113.80	312.00	312.00
Breadth at top of embakment (m)	23.70	33.80	37.00	37.00
Single Pond Plan area at mid-depth (m^2)	517.37	2677.16	8982.75	8982.75
Single Pond Plan area at top of embankment, incl crest (m^2)	1446.39	4768.04	13674.00	13674.00
Total Pond Area for all similar ponds (m^2)	2892.78	9536.08	27348.00	82044.00
Cumulative Pond Area (ha)	0.29	1.24	3.98	12.18
POND HYDRAULICS:				
Flow into pond (m^3/day)	249.26	249.26	170.09	170.09
Flow out of pond (m^3/day)	249.26	243.63	170.09	170.09
Retention time per pond (days)	3.84	19.33	79.22	79.22
Combined retention time of similar ponds in serie (days)	3.84	19.33	79.22	237.66
Combined Volume of similar ponds (m3)	1914.28	9528.84	26948.25	80844.75
EFFLUENT QUALITY CHECKS:				
BOD at pond inlet (mg/l) (unfiltered)	579.71	200.81	59.62	49.68
BOD at pond outlet (mg/l) (unfiltered)	200.81	59.62	49.68	0.10
BOD at pond outlet (mg/l) (filtered)	200.81	17.89	4.97	0.01
No. of TTC/100 ml at pond inlet	4.00E+07	3.84E+06	1.97E+05	3.87E-02
No. of TTC/100 ml at pond outlet	3.84E+06	1.97E+05	3.87E-02	2.95E-22
No. of Helminth Eggs/litre at pond inlet	1000.000	70.806	0.054	0.00E+00
No. of Helminth Eggs/litre at pond outlet	70.806	0.054	0.000	0.00E+00
Nitrogen Concentration (mg/l) at pond inlet	86.957	86.957	49.035	17.989
Nitrogen Concentration (mg/l) at pond outlet	86.957	49.035	17.989	0.888
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	173.913	138.652	61.997
Ammoniacal Nitrogen (mg/l) at pond outlet	173.913	138.652	61.997	5.543
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	46.377	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	n/a	23.189

BASE DATA:	Constructed Wetland STP - Scenario 01		
Q	498.5	m3/d	Annual Average daily dry weather flow (DWF).
DWFp	86.25	l/p/d	Daily wastewater flow per person
Li	580	mg/l	Waste Water BOD5.
Le	37.5	mg/l	Filtered BOD in Final Pond Effluent to be discharged into a water course. Taken as 50% of COD
T	23	deg C	Mean air temp of coldest month.
Population	5780	people (future)	Information provided
Sludge removal cycles	3	years	Mara(2003:105)
Sludge accumulation rates: Anaerobic Ponds	0.03	m3/p/a	Smith(2011:6.5)
Rta (min)	1	days	Minimum Retention Time. Smith(2011:6.6)
Rta (max)	5	days	Maximum Retention Time. Smith(2011:6.6)
TTCi	4.00E+07	TTC/100ml	Thermotelerant coliforms in raw waste water
TTCe	1000	TTC/100ml	Thermotelerant coliforms in Final Pond Effluent to be discharged into a water course
HE (Helminth Eggs)	1000	eggs/litre	Assumed number of eggs in raw waste. Based on Smith(2011:6.13)
N	87	mg/l	Total Nitrogen in raw waste water. Assumed
Ammoniacal Nitrogen	174	mg/l	Ammoniacal Nitrogen in raw waste water
Suspended Solids	348	mg/l	Suspended Solids in raw waste water
Alkalinity	80	mg/l	Alkalinity as CaCO3. Asumed
Pp	4	g/person	Phosphur contributed per person per day (www.lenntech.com)
Pi	46	mg/l	Inflow phosphorous into WSP
e	3.5	mm/d	Evaporation Rate
No of ponds in parallel			
Anaerobic	2		
Facultative	2		
Maturation	2		
No of ponds in serie			
Anaerobic	1		
Facultative	1		
Maturation	4		

Constructed Wetland STP - Scenario 01					Anaerobic Pond Calculations
ID:	**Parameter:**	**Value**	**Unit**	**Description**	**Reference**
PART A: Calculate minimum volume and retention requirements					
A1	Qin	249.3	m3/d	Sewage inflow into Anaerobic Pond Series, subdivided as required	
A2	Lambda	330	g/m3/d	Volumetric loading of BOD5	Table 10.1 Mara(2003:109)
				Check: This is less than 400 g/m3/d and more than 100 g/m3/d thus OK	Mara(1998:46)
A3	Li	580	mg/l or g/m3	BOD5 inflow into Anaerobic Pond (unfiltered)	Base Data
A4	Vol (min)	438	m3	Minimum storage volume required = Li x Qin / Lambda	Equation 6.2 Mara(1998:45)
A5	Rta (est)	1.8	days	Vol/Qin. Estimated retention time based on Mara(1998:45). Longer than 1 Day thus OK.	Equation 6.3 Mara(1998:45)
A6	BODr (design)	66	%	%BOD Removed - to be used as design criteria	Table 10.1 Mara(2003:109)
PART B: Compare retention times and adjust to realise effective removal of maximum BOD					
A7	Rta (check)	4.0	days	Actual retention time required to achieve desired BOD removal %. This assumes that the relationship between retention time and BOD removal provided by Smith(2011:6.6) holds true for temperatures just below 25 degrees Celcius and that the % BOD removal provided by Mara(2003:109) in Table 10.1 must be seen as a removal % which can be reached if Smith's retention periods is adhered to. Based on the studies performed by the World Health Organisation, summarised in "Wastewater Treatment Ponds: Principles of Planning and Design", Chapter XIX and specifically tables III to V suggests that Smith(2011:6.6) can be applied to this situation.	Smith (2011:6.6), WHO(1987:87-90)
	Rta (adj)	3.5	days	Manual adjustment of Retention Time to limit Odours and reduce BOD removal rate and to reduce required land area.	Reduced based on ID A36
A8	Vol (adj)	872.4	m3	Adjusted Volume to achieve desired BOD reduction. Rta (adj) x Qin	Equation 6.3 Mara(1998:45)
A9	Lambda (check)	165.6	g/m3/d	Check: This is less than 400 g/m3/d and more than 100 g/m3/d thus OK	Eq 10.1 in Mara(2003:108) and Mara(1998:46)
A10	Da	1.85	m	Working depth of pond, exlc sludge	
A11	Aa	472	m2	Vol(adj)/Da = Pond area at mid depth	
A12	L:W	2		Desired Length to Width Ratio	Mara(2003:163)
A13	W	15.4	m	Width of one pond at mid depth	
A14	L	30.7	m	Length of one pond at mid depth	
A15	W(bot)	9.805	m	Bottom Width - above sludge	
A16	L(bot)	25.161	m	Bottom Length - above sludge	
A17	Aa(bot)	246.712	m2	Bottom area - above sludge	
PART C: Calculate required sludge volume to add to anaerobic pond volumes					
A18	Vols	260.1	m3	Sludge storage volume required at base of pond, ie dead storage that needs to be omitted from calculations. Population x Sludge Accumulation per person per year x 3 years	
A19	Ds	1.054	m	Approx. depth of sludge accumulated: Ds = Aa(bot)/Vols	
A20	Ds (Say)	1.1	m	Fix sludge storage depth	
PART D: Adjust dimensions for practicality, check final pond volumes and check dimensions.					
A21	W (base)	3.205	m	Pond base width for excavation purposes (incl sludge depth)	
A22	L (base)	18.561	m	Pond base length for excavation purposes (incl sludge depth)	
A23	Wb (say)	3	m	Standardised base width for ease of construction	
A24	Lb (say)	22	m	Standardised base length for ease of construction	
A25	Vols (check)	302.016	m3	Sludge Storage Volume check. This must be larger than ID A18: Vols	ID A18
				CHECK: ACCEPTABLE - The calculated volume is just above Vols, thus max sludge accumulation will only occur after 3 years	
A26	Wa	15.15	m	Final width of one pond at mid depth of anaerobic component	
A27	La	34.15	m	Final length of one pond at mid depth of anaerobic component	
A28	L:Wa (check)	2.254		L:W ratio check at mid depth. It is desired that this is between 2 and 3, Mara(2003:163), but it is most important at Top Water Level (TWL), in order to control/check that sludge banks wont form at the inlet to the pond.	Mara(2003:163)
A29	Vol (final)	957.139	m3	Final Storage Volume for anaerobic pond. This is more than the calculated Vol(adj) - ID:8, and Vol (min) ID: A4. By changing Wb or Lb slightly, the storage volume for sludge will increase too much and be uneconomical. Thus this reduced anaerobic volume is proposed, and the calculations will accordingly be adapted.	
A30	Wtwl	20.7		Width at TWL	
A31	Ltwl	39.7		Length at TWL	
A32	L:W	1.918		L:W ratio at TWL to avoid sludge banks forming at inlet	Mara(2003:163)
				Check: OK (between 2 and 3).	
A33	Ltwl or Wtwl (min)	17.7	m	Minimum distance the pond's length or width at TWL must be to ensure the desired depth can be actually be provided. 2 x Dtotal x 3/1 (where 3/1 = H/V slope ratio)	
				Check: OK - Both Ltwl and Wtwl is longer the minimum dimension	

Constructed Wetland STP - Scenario 01					Anaerobic Pond Calculations
PART E: Check and evaluate BOD removal rates due to volume fluctations					
A34	Rta (year 3)	3.8399	days	Retention time at end of 3-year sludge build-up and just prior to sludge removal. Vol (final)/Qin	
A35	BODr3	65.360	%	%BOD removal at end of 3 year cycle, it is assumed that BOD removal will have a ceiling amount of Table 10.1 in Mara(2003:109) for safety.	Smith (2011:6.6) and Mara(2003:109)
A36	Rta (year 1)	5.052	days	Retention time at start of 3-year sludge build-up and just after sludge removal has occurred. (Vol (final) + Vols (check))/Qin	
				Increased anaerobic storage is available. This check is important to ensure the maximum retention period of 5 days is not exceeded.	
				Check: OK - Maximum period of 5 days is not exceeded.	
A37	BODr1	66.000	%	%BOD removal at start of 3 year cycle	Smith (2011:6.6) and Mara(2003:109)
A38	Le (year 3)	200.814	mg/l gm3	BOD leaving Anaerobic pond, at year 3 of sludge build-up cycle. It is assumed that due to the anaerobic processes minimal to no algal activity is present in the Anaerobic Pond, thus the BOD in the effluent has got no algal content. Thus filtered and unfiltered BOD is the same.	ID A3
PART F: Overall Dimensions					
	Freeboard:				
A39	Atwl	821.790	m2	Dam surface area (at twl)	
A40	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
A41	Lta	42.700	m	Anaerobic Pond Internal Length along top of pond embankment. Lta = Ltwl + 2*3*F	ID A31
A42	Wta	23.700	m	Anaerobic Pond Internal Width along along top of pond embankment. Wta = Wtwl + 2*3*F	ID A30
A43	Dat	3.450	m	Total Pond Depth per pond	
A44	Lw	144.800	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
A45	Aat	1446.390	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
A46	Qty	2.000	No	Number of Anaerobic Ponds	
A47	AaT	2892.780	m2	Total area required for all anaerobic ponds	
PART G: Thermotolerant coliform removal (Von Sperling)					
A48	kbt	2.450		First-order rate removal for Ecoli removal in Anaerobic Ponds	Eq 12.8 in Mara(2003:147)
A49	Ni	4.0.E+07	TTC/100ml	TTC in raw waste water	Data provided
A50	Ne	3.843E+06	TTC/100ml	TTC in Anaerobic pond effluent	Eq 12.1 in Mara(2003:141)
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
A51	HEi	1000.000	eggs/litre	Number of Helminth Eggs in raw waste water flowing into Anaerobic Pond	Assumed: Smith(2011:6.13)
A52	R	92.92	%	% Removed	Eq 11.12 in Mara(2003:124)
A53	HEe	70.806	eggs/litre	Number of Helminth Eggs in effluent flowing out of Anaerobic Pond. This is more than 1 egg/litre (Mara(2003:238)) and further removal will be required.	Mara(2003:238)
PART I: Total Nitrogen removal					
A54	Ce	86.957	mg/l	Nitrogen concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
A55	Ce	173.913	mg/l	Ammonia concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
PART K: Phosphorus removal					
A56	Pe	46.377	mg/l	Phosphorous concentration in raw waste water. Removal calculated for entire system combined. Refer to end of Maturation Pond System	Mara(2003:151)

Constructed Wetland STP - Scenario 01					Constructed Wetland
ID:	**Parameter:**	**Value**	**Unit**	**Description**	**Reference**
PART F: Overall Dimensions					
CW1	Qi	249.263	m3/d	Flow into Constructed Wetland = Flow out of Anaerobic Pond, Subdivided	ID A1
CW2	Le	37.500	mg/l or g/m2	Targettted filtered BOD loading of CW Effluent = WSPo Facultative Pond Effluent, or Discharge Standard, whichever is more.	Assumed and Mara(2003:198)
CW3	Li	200.814	mg/l or g/m2	BOD Loading of influent = Anaerobioc Pond effluent	ID A38
CW4	Ɛ	0.400	mm	Gravel Porosity	Assumed and Mara(2003:196)
CW5	T	23.000	deg C	Temperature	Base Data
CW6	k1	1.787	day -1	BOD removal rate constant	Eq 17.3 in Mara(2003:196)
CW7	Dcw	0.700	m	Average Depth of CW	Assumed, based on Smith(2011:8.27)
CW8	e	3.500	mm/d	Net evaporation = evapotranspiration	Assumed
CW9	Acw	831.2	m2	Surface Area of CW	Mara(2003:199)
CW10	S	0.010	m/m	Proposed Slope	Smith(2011:8.29)
CW11	L_calc	70.000	m		
CW12	L_min	25.0	m	Minimum length to remove most helminth eggs.	Mara(2003:198)
CW13		OK		Calculated min length is more than minimum permissible.	
CW14	Dmin	0.300	m2	Minimum gravel depth	Smith(2011:8.29)
CW15	Dmax	1.000	m	Maximum gravel depth, assuming a flat topography. Limited to 1m to ensure Local Labour can easily perform maintenance if required.	Assumed
CW16	Dmax_calc	1.000	m		
CW17		OK		Calculated max depth is less than maximum permissible	
CW18	W_calc	11.9	m	Calculated Width of CW	
CW19	Lf	70.0	m	Designed length of CW	
CW20	Wf	20.0	m	Designed width of CW	
CW21	Df_avg	0.7	m	Average depth of CW	
CW22	Af_cw	1400.0	m2	Surface area of CW	
CW23	Volf_cw	980.0	m3	Volume of gravel required for CW	
CW24	FB	0.5	m	Freeboard required for CW	
PART E: Calculate effluent quality					
CW25	Le	11.8	mg/l or g/m2	filtered BOD in effluent flowing out of CW	Eq 17.2 Mara(2003:196)
PART G: Thermotolerant coliform removal					
CW26	delta_f	91%		% removal in Facultative Pond, as part of WSPo	
CW27	eff.	50%		Relative efficiency of CW, compared to Facultative Ponds. According to Smith(2011:8.28) the removal is mediocre	Smith(2011:8.28)
CW28	Ni	3.8.E+06	TTC/100ml	TTC in Anaerobic pond effluent, flowing into facultative pond	Previously calculated
CW29	Ne	2.087E+06	TTC/100ml	TTC in Facultative pond effluent	Eq 5.13 in Mara(2003:145)
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
CW30	HEi	70.806	eggs/litre	Number of Helminth Eggs in efluent from Anaerobic Pond flowing into Facultative pond	
CW31	R_25m	90.0	%	Assumed, based on Mara(2003:196)	
CW32	R_100m	100.0	%	Assumed, based on Mara(2003:196)	
CW33	R_L	97.0	%	% Removed	Eq 11.12 in Mara(2003:124)
CW34	HEe	2.124	eggs/litre	Number of Helminth Eggs in effluent flowing out of CW	
PART I: Total Nitrogen removal					
CW35	Ci	86.9565217	mg/l	Nitrogen concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
CW36	R_amm	40%	%	Removal efficiency of Ammoniac	Assumed
CW37	eff	150%	%	Efficiency for Nitrogen Removal, based on performance of Ammoniam. According to Smith(2011), Ammoniac removal is poor, while nitrogen removal is good	Assumed and based on Smith(2011:8.29)
CW38	Ce	35.054	mg/l	Nitrogen concentration in Facultative Pond's effluent. This is more than 15mg/l and thus requires further treatment.	Eq 12.12 in Mara(2003:149) and Mara(1998:43)
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
CW39	Ci	173.913	mg/l	Ammonia concentration in raw waste water. No removal occurs within the Anaerobic Pond	
CW40	teta	3.9	days	Retention Time	Eq 17.1 in Mara(2003:196)
CW41	Ce	104.709	mg/l	Ammonia concentration in Facultative Pond's effluent.	Eq 17.5 in Mara(2003:198)

Constructed Wetland STP - Scenario 01					Constructed Wetland
PART J: Suspended Solids Removal					
CW42	SSi	347.826	mg/l	Suspended Solids in raw waste water. Assume no removal occurs within the Anaerobic Pond	
CW43	AHLR	0.2	m/d	Aerial Hydraulic Loading Rate	Mara(2003:197)
CW44	SSe	43.682	mg/l	Suspended Solids in CW Effluent	Eq 17.4 in Mara(2003:196)
PART K: Phosphorus removal					
CW45	Pi	46.377	mg/l	Phosphorous concentration in raw waste water. Removal calculated for entire system combined. Refer to end of Maturation Pond System	Mara(2003:151)

Constructed Wetland STP - Scenario 01					Maturation Pond Calculations
ID:	Parameter:	Value	Unit	Description	Reference
PART A: Quantify design parameters					
M1	Qin	249.263	m3/d	Sewage outflow from CW and subdivided as required	Assume total flow from CW system will be redistributed to new Maturation Pond system.
M2	Le (min)	37.5	mg/l or g/m2	Filtered BOD5 effluent desired for quality purposes	Provided
M3	Li (filtered)	11.761	mg/l or g/m3	filtered BOD5 inflow from CW, taken as third year quality, just before sludge removal in Anaerobic Pond has been done. Ie worst case	Previously calculated. ID CW25
M4	Li (unfiltered)	11.761	mg/l or g/m3	unfiltered BOD5 inflow from CW, taken as third year quality, just before sludge removal in Anaerobic Pond has been done. Ie worst case. Filtered = unfiltered	Previously calculated. ID CW26
M5	Fna	1.0		Non algal fraction of BOD	Mara(2003:149)
M6	k1	0.05	day -1	BOD removal rate constant	Mara(2003:149)
M7	Rt(f)	3.932	days	Retention time of upstream CW. This is maximum retention time in any maturation pond. First Matuation pond usually being larger than the subsequant ponds.	Previously calculated and Mara(2003:142). ID CW40
M8	Rt (m min)	3.000	days	Retention time any single maturation pond to prevent algal wash out	Smith(2011:6.9) and Mara(2003:142)
M9	Lamda (m1)	233.184	kg/ha/d	First maturation pond must have a surface loading of maximum 75% of CW pond's surface loading	Mara(2003:142)
M10	D	1.5	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for. Shallower depths are not proposed as this could lead to Mosquito breeding which is not desired so close to the town.	Mara(2003:118 & 136)
M11	Ni	2.087E+06	TTC/100ml	TTC in CW pond effluent, flowing into first maturation pond	Previously calculated. ID CW29
M12	Ne (min)	1.000E+03	TTC/100ml	Acceptable TTC in Maturation pond effluent, flowing into an open water source	Information provided
PART B: Calculate Pond Geometry and Quantity					
M13	Rt (m1 calc)	0.757	days	Retention time for first pond	Eq 12.5 in Mara(2003:143)
M14	Rt (m1 des)	4	days	Proposed retention time to reach TTC removal. This is also less than Rt (f) - so OK	ID M8
M15	kb20	0.408		First-order removal rate for Ecoli removal in Maturation Pond 1 at 20 deg C	Eq 5.15 in Mara(2003:146)
M16	kbt	0.499		First-order removal rate for Ecoli removal in Maturation Pond 1 at T deg C	Eq 5.8 in Mara(2003:146)
M17	L:Wm (TWL)	8.0	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164)
M18	delta	0.125	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M19	a	1.414			Paragraph below Eq 5.13 in Mara(2003:145)
M20	Ne (m1)	3.872E+05	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M21	Ne (m1 check)	TOO HIGH	TTC/100ml	Ne (m1) > Ne (min) thus an extra maturation pond is required	ID M12
M22	Ne (m2)	71849.0091	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M23	Ne (m2 check)	TOO HIGH	TTC/100ml	Ne (m2) > Ne (min) thus an extra maturation pond is required	ID M12
M24	Ne (m3)	13330.8798	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M25	Ne (m3 check)	TOO HIGH	TTC/100ml	Ne (m3) > Ne (min) thus an extra maturation pond is required	ID M12
	Ne (m4)	2473.41415	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
	Ne (m4 check)	TOO HIGH	TTC/100ml	Ne (m4) > Ne (min) thus an extra maturation pond is required	ID M12
	A_m1 des	166.2	m2	Mid depth area for indicative evaporation	
M26	Q mean	248.1	m3/d	Mean flow across pond system, allowing for evaporation	ID M1
M27	Am# (mid calc)	661.598067	m2	Since each of the ponds have the same depth and retention time, each shall have the same pond area at mid depth: Am1 = Am2 = Am3 = Am#	Eq 11.4 in Mara(2003:119)
M28	Wm# (mid calc)	9.09394075	m	Width of one maturation pond at mid depth	
M29	Lm# (mid calc)	72.751526	m	Length of one maturation pond at mid depth	
M30	Wm# (base - calc)	4.59394075	m	Calculated base width for one pond	
M31	Lm# (base calc)	68.251526	m	Calculated base length for one pond	
M32	Wm# (base - say)	25	m	Proposed dimensions for ease of construction and to fit into site footprint	
M33	Lm# (base - say)	275	m	Proposed dimensions for ease of construction and to fit into site footprint	
M34	Wm# (mid final)	29.5	m	Construction Width of one maturation pond at mid depth	
M35	Lm# (mid final)	279.5	m	Construction Length of one maturation pond at mid depth	
M36	Am# (mid final)	8245.25	m2	Final Area of one maturation pond at mid depth	
M37	Wm# (TWL final)	34	m	Construction Width of one maturation pond at TWL	
M38	Lm# (TWL final)	284	m	Construction Length of one maturation pond at TWL	
M39	W:L (TWL final)	8.353		Final L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	

Constructed Wetland STP - Scenario 01					**Maturation Pond Calculations**
PART C: Check retention time and TTC reduction					
M40	Am#	8245.25	m2	Each pond's area at mid depth	ID M36
M41	V#	12367.875	m3	Each pond's volume	ID M10 and M40
	Amtwl#	9656	m2	Effluent area at TWL per pond	
	Qmean	181.7	m3/d	Average flow over maturation pond system, assuming final dimensions and evaporation	
M42	Rt#	68.079	days	Retention time for each pond is more than 3 days, thus OK.	Equation 11.4 in Mara(2003:120)
M43	L:Wm (TWL)	8.4	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164). ID M39
M44	delta	0.120	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M45	a	4.156			Paragraph below Eq 5.13 in Mara(2003:145)
M46	Ne (m1)	2.458E+00	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M47	Ne (m1 check)	OK	TTC/100ml	Ne (m1) < Ne (min) thus an extra maturation pond is not required	ID M12
M48	Ne (m2)	2.8946E-06	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M49	Ne (m2 check)	OK	TTC/100ml	Ne (m2) < Ne (min) thus an extra maturation pond is not required	ID M12
M50	Ne (m3)	3.4088E-12	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m3 check)	OK	TTC/100ml	Ne (m3) < Ne (min) thus no extra maturation pond is required	ID M12
M50	Ne (m4)	4.0144E-18	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m4 check)	OK	TTC/100ml	Ne (m4) < Ne (min) thus sufficient ponds have been allowed for	ID M12
PART E: Calculate BOD removal (first order kinetics)					
M52	Li (unfiltered)	11.8	mg/l or g/m2	unfiltered BOD in effluent flowing out of CW Pond	ID M4
M53	Le (m4 unfiltered)	0.0	mg/l or g/m2	unfiltered BOD in effluent flowing out of last Maturation Pond	Eq 5.7 in Mara(2003:59)
M54	Le (m4 filtered)	0.0	mg/l or g/m2	Filtered BOD (non-algal) flowing out of Maturation pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as the WHO organisation's requirements Mara(1998:42)). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	Equation 11.8 in Mara(2003:121)
PART F: Overall Dimensions					
	Freeboard:				
M55	Atwl#	9656.000	m2	Each Pond's surface area (at twl)	ID M37 & M38
M56	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
M57	Ltf	287.000	m	Maturation Pond Length along top of pond embankment. Ltf = Ltwl + 2*3*F	
M58	Wtf	37.000	m	Maturation Pond Width along along top of pond embankment. Wtf = Wtwl + 2*3*F	
M59	Dat	2.000	m	Total Pond Depth per pond	
M60	Lw	660.000	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
M61	Aat	12599.000	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
M62	Qty	8.000	No	Number of Maturation Ponds	
M63	AaT	100792.000	m2	Total area required for all Maturation ponds	
PART G: Helminth egg removal					
M64	HEi	2.124	eggs/litre	Number of Helminth Eggs in effluent from CW Pond flowing into Maturation pond	ID CW34
M65	R	100.00	%	% Removed	Eq 11.12 in Mara(2003:124)
M66	HEe (m1)	0.000	eggs/litre	Number of Helminth Eggs in effluent flowing out of First Maturation Pond. This is less than 0.1 egg/litre (Mara(2003:238)) thus acceptable for all irrigation and where children younger than 15 years will be exposed. No further treatment/removal required - but for purposes of completeness, calculated below:	Mara(2003:238)
M67	HEe (m2)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	
M68	HEe (m3)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	
	HEe (m4)	0.000E+00	eggs/litre	All ponds are same, thus same Removal percentage	

Constructed Wetland STP - Scenario 01					Maturation Pond Calculations
PART H: Total Nitrogen removal					
M69	Ci	35.054	mg/l	Nitrogen concentration in CW Pond's effluent. This is more than 15mg/l and thus requires further treatment	ID CW38
M70	Alkalinity	80	mg/l		Assumed, ID F68
M71	pH	7.60		pH calculated for ponds. The pH for each pond would actually change due to the presence and activity of alga, but for the purposes of this exercise it is assumed that the pH and alkalinity for the CW Ponds can also be used for the Maturation Ponds	Eq 12.13 in Mara(2003:149) and ID F69
M72	Ce (m1)	13.931	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M73	Ce (m2)	5.536	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M74	Ce (m3)	2.200	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
	Ce (m4)	0.874	mg/l	Nitrogen concentration in Fourth Maturation Pond's effluent. This is less than 15mg/l and thus requires no further treatment	Mara(2003:149) and Mara(1998:43)
PART I: Ammoniacal nitrogen removal (NH3 + NH4+)					
M75	Ci	104.709	mg/l	Ammonia concentration in CW Pond effluent.	ID CW41
M76	A (m1)	8245.250	m2	Pond area at mid depth	ID M40
M77	Q mean (m1)	181.671	m3/d	Mean flow rate through pond	ID M26
M78	pH	7.598		Same as for Nitrogen removal	ID M71
M79	Ce (m1)	50.768	mg/l	Ammonia concentration in First Maturation Pond's effluent.	Eq 12.15 in Mara(2003:150)
M80	Ce (m2)	24.614	mg/l	Ammonia concentration in Second Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
M81	Ce (m3)	11.934	mg/l	Ammonia concentration in Third Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
	Ce (m4)	5.786	mg/l	Ammonia concentration in Fourth Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
PART J: Phosphorus removal					
M82	Li (unfiltered)	579.710145	mg/l or g/m3	BOD5 inflow into Anaerobic Pond. Ie Raw Waste Water	Base Data
M83	Le (m4 - filtered)	0.0	mg/l or g/m4	Filtered BOD leaving last Maturation Pond	Calculated above. ID M54
M84	BODr	99.995	%	Percentage BOD removal	
M85	Pr	49.997	%	Percentage Phosphorus removal	Mara(2003:151) and Mara(1998:53)
M86	Pi	46.377	mg/l	Phosporus content of raw sewage	Base data
M87	Pe	23.190	mg/l	Phosporus content of treated effluent flowing out of final maturation pond	

Constructed Wetland STP - Scenario 01				
Summary of Results				
Basic data				
Q-full (m^3/day)	498.53			
Q-half (for parallel flow) (m^3/day)	249.26			
BOD full load (kg BOD/day)	289.00			
BOD falf load (kg BOD/day)	144.50			
L_i (BOD of pond influent) (mg/l)	579.71			
T (Min mean monthly temperature)	23.00			
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07			
Net evaporation, evap - rainfall (mm/day)	3.50			
Effluent standards required				
BOD_R (filtered BOD at effluent)	37.5			
Ne (Number of FC: CFU/100 ml of effluent)	1000			
Nitrogen (mg/l)	15			
Suspended Solids (mg/l)	25			
Ammoniacal Nitrogen (mg/l)	6			
Phosphorus (mg/l)	10			
Effluent standards desired				
Helminth eggs (eggs/litre)	0.1			
Design with Anaerobic pond	Anaerobic Pond	Constructed Wetland	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:				
Number of ponds in series	1	1	1	3
Number of ponds in parallel	2	2	2	2
Sludge Storage Depth (m)	1.10	0.00	0.00	0.00
Active Depth (m)	1.85	0.70	1.50	1.50
Freeboard (m)	0.50	0.50	0.50	0.50
Total Pond Depth (m)	3.45	1.20	2.00	2.00
Length/Breadth at mid depth	2.25	3.50	9.47	9.47
Length at mid-depth (m)	34.15	70.00	279.50	279.50
Breadth at mid-depth (m)	15.15	20.00	29.50	29.50
Length/Breadth at TWL	1.92	3.50	8.35	8.35
Length at TWL (m)	39.70	70.00	284.00	284.00
Breadth at TWL (m)	20.70	20.00	34.00	34.00
Length at top of embankment (m)	42.70	77.20	287.00	287.00
Breadth at top of embakment (m)	23.70	27.20	37.00	37.00
Single Pond Plan area at mid-depth (m^2)	517.37	1400.00	8245.25	8245.25
Single Pond Plan area at top of embankment, incl crest (m^2)	1446.39	2099.84	12599.00	12599.00
Total Pond Area for all similar ponds (m^2)	2892.78	4199.68	25198.00	75594.00
Cumulative Pond Area (ha)	0.29	0.71	3.23	10.79
POND HYDRAULICS:				
Flow into pond (m^3/day)	249.26	249.26	181.67	181.67
Flow out of pond (m^3/day)	249.26	249.26	181.67	181.67
Retention time per pond (days)	3.84	3.93	68.08	68.08
Combined retention time of similar ponds in serie (days)	3.84	3.93	68.08	204.24
Combined Volume of similar ponds (m3)	1914.28	1960.00	24735.75	74207.25
EFFLUENT QUALITY CHECKS:				
BOD at pond inlet (mg/l) (unfiltered)	579.71	200.81	11.76	9.80
BOD at pond outlet (mg/l) (unfiltered)	200.81	11.76	9.80	0.03
BOD at pond outlet (mg/l) (filtered)	200.81	11.76	9.80	0.03
No. of TTC/100 ml at pond inlet	4.00E+07	3.84E+06	2.09E+06	2.46E+00
No. of TTC/100 ml at pond outlet	3.84E+06	2.09E+06	2.46E+00	4.01E-18
No. of Helminth Eggs/litre at pond inlet	1000.000	70.806	2.124	0.00E+00
No. of Helminth Eggs/litre at pond outlet	70.806	2.124	0.000	0.00E+00
Nitrogen Concentration (mg/l) at pond inlet	86.957	86.957	35.054	13.931
Nitrogen Concentration (mg/l) at pond outlet	86.957	35.054	13.931	0.874
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	173.913	104.709	50.768
Ammoniacal Nitrogen (mg/l) at pond outlet	173.913	104.709	50.768	5.786
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	46.377	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	n/a	23.190

BASE DATA:	Integrated Algal Pond System STP - Scenario 01			
Q	498.5	m3/d	Annual Average daily dry weather flow (DWF).	
DWFp	86.25	l/p/d	Daily wastewater flow per person	
Li	580	mg/l	Waste Water BOD5.	
Le	37.5	mg/l	Filtered BOD in Final Pond Effluent to be discharged into a water course. Taken as 50% of COD	
T	23	deg C	Mean air temp of coldest month.	
Population	5780	people (future)	Information provided	
Sludge removal cycles	3	years	Mara(2003:105)	
Sludge accumulation rates: Anaerobic Ponds	0.03	m3/p/a	Smith(2011:6.5)	
Rta (min)	1	days	Minimum Retention Time. Smith(2011:6.6)	
Rta (max)	5	days	Maximum Retention Time. Smith(2011:6.6)	
TTCi	4.00E+07	TTC/100ml	Thermotelerant coliforms in raw waste water	
TTCe	1000	TTC/100ml	Thermotelerant coliforms in Final Pond Effluent to be discharged into a water course	
HE (Helminth Eggs)	1000	eggs/litre	Assumed number of eggs in raw waste. Based on Smith(2011:6.13)	
N	87	mg/l	Total Nitrogen in raw waste water. Assumed	
Ammoniacal Nitrogen	174	mg/l	Ammoniacal Nitrogen in raw waste water	
Suspended Solids	348	mg/l	Suspended Solids in raw waste water	
Alkalinity	80	mg/l	Alkalinity as CaCO3. Asumed	
Pp	4	g/person	Phosphur contributed per person per day (www.lenntech.com)	
Pi	46	mg/l	Inflow phosphorous into WSP	
e	3.5	mm/d	Evaporation Rate	
No of ponds in parallel				
Anaerobic	2			
Facultative	2			
Maturation	2			
No of ponds in serie				
Anaerobic	1			
Facultative	1			
Maturation	4			

Integrated Algal Pond System STP - Scenario 01					**Facultative Pond Calculations**
ID:	**Parameter:**	**Value**	**Unit**	**Description**	**Reference**
PART A: Calculate Pond Surface Area Based on First Order Kinetics					
F1	Qin	249	m3/d	Sewage outflow from Anaerobic Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
F2	Le (min)	60	mg/l or g/m2	Unfiltered BOD5 effluent desired for quality purposes and to ensure Aerobic conditions are met (60mg/l should be seen as upper limit)	Smith(2011:6.8)
F3	Li	580	mg/l or g/m3	BOD5 from RAW Sewage	
F4	Df1	1.8	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for.	Mara(2003:118 & 120)
F5	K20	0.3	day-1	First Order rate constant for BOD removal at 20 deg C	Mara(2003:121)
F6	teta	1.07		Arrhenius constant	Mara(2003:59)
F7	KT	0.368	day-1	First Order rate constant for BOD removal at T deg C, where T = 23 deg C (provided). It is assumed that T must be the temperature in the coldest month for safety purposes.	Equation 5.8 in Mara(2003:59)
F8	Rt1	23.569	days	Calculated retention period of facultative pond based on First Order Kinetics	Equation 5.7 in Mara(2003:59)
F9	Rt (min)	4.000	days	Min retention period based on temperatures above 20 degC	Mara(1998:48)
F10	Rt (check)	OK		Rt1 is longer than Rt (min) thus no algal washout will occur	Mara(1998:48)
F11	Af	3263.787	m2	Facultative pond area at mid depth. Af = Qin x Rt1 / D	Eq 11.4 in Mara(2003:119)
PART B: Calculate Pond Surface Area Based on Surface Loading					
F12	Qin	249	m3/d	Sewage outflow from Anaerobic Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
F13	Lambda	311	kg/ha/d	Surface loading of BOD5	Eq 11.3 in Mara(2003:119)
F14	Li	579.7	mg/l or g/m3	BOD5 from RAW Sewage	
F15	Af	4647.6	m2	Facultative pond area at mid depth	Eq 11.1 in Mara(2003:117)
F16	Df2	1.8	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for. The depth is iterratively adjusted to ensure a BOD unfiltered effluent of 60mg/l is ensured.	Mara(2003:118 & 120) ID F4 & F2
F17	Vf	8365.7	m3	Facultative pond volume	
F18	e	3.5	mm/d	Net evaporation rate per day/ Average rate for area	
F19	Qe	233	m3/d	Effluent flow rate. Infiltration and seepage is assumed negligible, thus effluent flow rate is only a function of net evaporation rate.	Equation 11.6 in Mara(2003:120)
F20	Qm	241	m3/d	Mean flow rate of influent and effluent	
F21	Rt2	35	days	Calculated retention period of facultative pond based on surface loading	Equation 11.4 in Mara(2003:120)
F22	Rt (min)	4.0	days	Min retention period based on temperatures above 4 degC	Mara(1998:48)
F23	Rt (check)	OK		Rt2 is longer than Rt (min) thus no algal washout will occur	Mara(1998:48)
F24	BOD removed	92.728	%	% BOD removed from incoming BOD (from Anaerobic pond).	Eq 5.7 in Mara(2003:120)
F25	BOD (remain)	42.159	mg/l or g/m3	Unfiltered BOD effluent leaving Facultative Pond. This is more than the upper limit of 60mg/l (Smith(2011:6.8)) and more than 60 + 20 = 80 mg/l, which Smith(2003:6.8) refers to as being maximum acceptable.	Smith(2011:6.8), Mara(1998:48) AND WHO(1987:98)
PART C: Calculate Final Pond Dimensions					
F26	Af (final)	4647.6	m2	It is proposed to use the surface laoding approach for designing the Facultative Pond. This is because the assumption of full mixing in secondary facultative ponds, and related application of first order kinetics, is too overly conservative. WHO(1987:98)	Mara(2003:118)
F27	Df	1.80	m	Working depth of pond. #See Part B	ID F4 & F16
F28	L:W	5		Desired Length to Width Ratio	Mara(2003:163)
F29	W	30.488	m	Width of one pond at mid depth	
F30	L	152.440	m	Length of one pond at mid depth	
F31	Wb (calc)	25.1	m	Pond base width for excavation purposes	
F32	Lb (b)	147.0	m	Pond base length for excavation purposes	
F33	Wb (say)	20	m	Standardised base width for ease of construction and to match available geometry	
F34	Lb (say)	120	m	Standardised base length for ease of construction and to match available geometry	
F35	W (final)	25.4	m	Final width of one pond at mid depth of facultative pond	
F36	L (final)	125.4	m	Final length of one pond at mid depth of facultative pond	
F37	L:W (check)	4.937		L:W ratio at mid depth. It is desired that this is approximately 10, Mara(2003:163), but it is most important at Top Water Level (TWL), in order to approximate plug flow conditions.	
F38	Wtwl	30.8		Width at TWL	
F39	Ltwl	130.8		Length at TWL	
F40	L:W	4.247		L:W ratio at TWL to approximate plug flow conditions. Check: Not close to 10, but shape is necessary to fit into proposed site.	Mara(2003:163)
F41	Ltwl or Wtwl (min)	10.8	m	Minimum distance length or width at TWL must be to ensure the desired depth can be actually be provided. 2 x Dtotal x 3/1 (where 3/1 = H/V slope proportions) Check: OK - Both Ltwl and Wtwl is longer the minimum dimension	
PART D: Check retention time and effluent quality (using first order kinetics)					
F42	Af (final)	3185.2	m2	Pond area at mid depth	ID F35 & F36
F43	V (final)	5733.3	m3	Pond volume	ID F27 & F42
F44	Rt (final)	23.0	days	Retention time is more than 4 days, thus OK.	Equation 11.4 in Mara(2003:120)
F45	Le (unfiltered)	61.324	mg/l or g/m2	This is less than the upper limit of 60mg/l (Smith(2011:6.8)). Thus the facultative pond will be appreciably aerobic and since the BOD influent quality is taken as the third year worst case scenario, the risk for the facultative pond ever becoming anaerobic is extremely low.	Equation 6.2 Mara(1998:45)

Integrated Algal Pond System STP - Scenario 01					Facultative Pond Calculations
PART E: Calculate effluent quality					
F46	Le (unfiltered)	61.3	mg/l or g/m2	unfiltered BOD in effluent flowing out of Facultative Pond	ID F45
F47	Fna	0.3		Non algal fraction of BOD	Mara(2003:121)
F48	Le (filtered)	18.4	mg/l or g/m2	Filtered BOD (non-algal) flowing out of Facultative pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as the WHO organisation's requirements Mara(1998:42) of 25mg/l). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	Equation 11.8 in Mara(2003:121)
PART F: Overall Dimensions					
	Freeboard:				
F49	Atwl	4028.640	m2	Dam surface area (at twl)	ID F38 & 39
F50	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
F51	Ltf	133.800	m	Facultative Pond Length along top of pond embankment. Ltf = Ltwl + 2*3*F	
F52	Wtf	33.800	m	Facultative Pond Width along along top of pond embankment. Wtf = Wtwl + 2*3*F	
F53	Dat	2.300	m	Total Pond Depth per pond	
F54	Lw	347.200	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
F55	Aat	5564.040	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
F56	Qty	2.000	No	Number of Facultative Ponds	
F57	AaT	11128.080	m2	Total area required for all Facultative ponds	
PART G: Thermotolerant coliform removal (Von Sperling)					
F58	kb20	0.195		First-order removal rate for Ecoli removal in Facultative Ponds at 20 deg C	Eq 5.15 in Mara(2003:146)
F59	kbt	0.239		First-order removal rate for Ecoli removal in Facultative Ponds at T deg C	Eq 5.8 in Mara(2003:146)
F60	delta	0.235	m/m	Inverted L:W ratio. Due to Ecoli removal being a function of area exposed to solar radiation, this is assumed to be the L:W ratio at TWL.	Eq 5.14 in Mara(2003:146)
F61	a	2.484			Paragraph below Eq 5.13 in Mara(2003:145)
F62	Ni	4.0.E+07	TTC/100ml	TTC in raw sewage, flowing into facultative pond	Previously calculated
F63	Ne	1.400E+06	TTC/100ml	TTC in Facultative pond effluent	Eq 5.13 in Mara(2003:145)
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
F64	HEi	1000.000	eggs/litre	Number of Helminth Eggs in efluent from Anaerobic Pond flowing into Facultative pond	
F65	R	99.95	%	% Removed	Eq 11.12 in Mara(2003:124)
F66	HEe	0.469	eggs/litre	Number of Helminth Eggs in effluent flowing out of Facultative Pond. This is less than 1 egg/litre (Mara(2003:238)) thus acceptable for unrestricted and restricted irrigation, but not for use where children younger than 15 years will be exposed and further removal will be required.	Mara(2003:238)
PART I: Total Nitrogen removal					
F67	Ci	87	mg/l	Nitrogen concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
F68	Alkalinity	80	mg/l		Assumed
F69	pH	7.60		pH for pond. This is a bit higher than the pH provided for the raw sewage, but this should be expected due to the algal content within the pond raising the pH.	Eq 12.13 in Mara(2003:149)
F70	Ce	47.760	mg/l	Nitrogen concentration in Facultative Pond's effluent. This is more than 15mg/l and thus requires further treatment.	Eq 12.12 in Mara(2003:149) and Mara(1998:43)
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
F71	Ci	173.913	mg/l	Ammonia concentration in raw waste water. No removal occurs within the Anaerobic Pond	Mara(2003:149)
F72	A	3185.160	m2	Pond area at mid depth	ID F42
F73	Q	241.129	m3/d	Mean flow rate through pond	
F74	pH	7.598		Same as for Nitrogen removal	
F75	Ce	132.835	mg/l	Ammonia concentration in Facultative Pond's effluent.	Eq 12.15 in Mara(2003:150)
PART K: Phosphorus removal					
F76	Pi	46.377	mg/l	Phosphorous concentration in raw waste water. Removal calculated for entire system combined. Refer to end of Maturation Pond System	Mara(2003:151)

Integrated Algal Pond System STP - Scenario 01					INTEGRATED ALGAL POND SYSTEM
ID:	**Parameter:**	**Value**	**Unit**	**Description**	**Reference**
PART A: HRAP Dimensions					
H1	Qin	233	m3/d	Sewage outflow from Primary Facultative Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
H2	HRT	3	days	Hydraulic Retention Time	Mambo et al.(2014:389)
H3	Vol	699	m3	Volume of HRAOP	
H4	Dp	0.3	m	Depth of HRAOP	Mambo et al.(2014:389)
H5	L/W Ratio	10	m/m	Based on Belmont Valley STP	Measured from Aerial Photographs
H6	Length	153	m		
H7	Width	15	m		
PART B: ASP Dimensions					
H8	Qin	233	m3/d	Sewage outflow from Primary Facultative Pond Series, subdivided as required.	Assume total flow from Anaerobic system will be redistributed to new Facultative system.
H9	HRT	0.5	days	Hydraulic Retention Time	Mambo et al.(2014:389)
H10	Vol	116	m3	Volume of ASP	
H11	Dp	1	m	Depth of ASP. Assumed	
H12	L/W Ratio	1	m/m		Assumed
H13	Length	3	m		
H14	Width	3	m		
PART E: Calculate effluent quality					
H15	Li (unfiltered)	61.3	mg/l or g/m2	unfiltered BOD in effluent flowing out of Facultative Pond	ID F46
H16	R1	43%	%	COD reduction in first pass of Pilot Plant at Belmont Valley	Wells et al.(nd:5)
H17	R2	15%	%	COD reduction in second pass of Pilot Plant at Belmont Valley	Wells et al.(nd:5)
H18	Le (unfiltered)	29.7	mg/l or g/m2	Unfiltered BOD flowing out of Facultative pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as just above the WHO organisation's requirements Mara(1998:42) of 25mg/l). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	
PART G: Thermotolerant coliform removal					
H19	Ni	1.4.E+06	TTC/100ml	TTC in Facultative Pond Effluent	ID F63
H20	R1	97%	%	TTC reduction in first pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H21	R2	97%	%	TTC reduction in second pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H22	Ne	1555.92	TTC/100ml	TTC in IAPS effluent	
				Check: This is more than minimum TTC for effluent discharge into open waters, thus further treatment is required	
PART H: Helminth egg removal					
H23	HEi	0.469	eggs/litre	Number of Helminth Eggs in efluent from Facultative pond flowing into IAPS	ID F66
H24	R	97.99	%	% Removed	Eq 11.12 in Mara(2003:124)
H25	HEe	0.009	eggs/litre	Number of Helminth Eggs in effluent flowing out of IAPS. This is less than 1 egg/litre (Mara(2003:238)) thus acceptable for unrestricted and restricted irrigation, but not for use where children younger than 15 years will be exposed and further removal will be required.	Mara(2003:238)
PART I: Total Nitrogen removal					
H26	Ci	48	mg/l	Nitrogen concentration in Facultative Pond Effluent	ID F70
H27	R1	-56%	%	Nitrogen reduction in first pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H28	R2	11%	%	Nitrogen reduction in second pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H29	Ce	66.26	mg/l	Nitrogen concentration in Facultative Pond's effluent. This is more than 15mg/l and thus requires further treatment.	
PART J: Ammoniacal nitrogen removal (NH3 + NH4+)					
H30	Ci	132.835	mg/l	Ammonia concentration in Facultative Pond Effluent	ID F75
H31	R1	52%	%	Ammoniacal nitrogen reduction in first pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H32	R2	71%	%	Ammoniacal nitrogen reduction in second pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H33	Ce	18.49	mg/l	Ammonia concentration in Facultative Pond's effluent.	
PART K: Phosphorus removal					
H34	Pi	46.377	mg/l	Phosphorous concentration in raw waste water.	
H35	R1	18%	%	Phosphorous reduction in Facultative Pond, based on findings at Belmont Valley	Wells et al.(nd:8)
H36	R2	15%	%	Ammoniacal nitrogen reduction in first pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H37	R3	54%	%	Ammoniacal nitrogen reduction in second pass of Pilot Plant at Belmont Valley	Wells et al.(nd:8)
H38	Ce	14.87	mg/l	Ammonia concentration in IAPS's effluent.	

Integrated Algal Pond System STP - Scenario 01					Maturation Pond Calculations
ID:	Parameter:	Value	Unit	Description	Reference
PART A: Quantify design parameters					
M1	Qin	232.996	m3/d	Sewage outflow from IAPS and subdivided as required	ID H1
M2	Le (min)	37.5	mg/l or g/m2	Filtered BOD5 effluent desired for quality purposes	Provided
M3	Li (filtered)	9.904	mg/l or g/m3	filtered BOD5 inflow from IAPS. Assumed	
M4	Li (unfiltered)	29.712	mg/l or g/m3	unfiltered BOD5 inflow from IAPS	Previously calculated. ID H18
M5	Fna	0.1		Non algal fraction of BOD	Mara(2003:149)
M6	k1	0.05	day -1	BOD removal rate constant	Mara(2003:149)
M7	Rt(f)	7.000	days	Retention time of upstream IAPS pond. This is maximum retention time in any maturation pond. First Matuation pond usually being larger than the subsequant ponds.	Previously calculated and Mara(2003:142). ID H2 & H9
M8	Rt (m min)	3.000	days	Retention time any single maturation pond to prevent algal wash out	Smith(2011:6.9) and Mara(2003:142)
M9	Lamda (m1)	233.184	kg/ha/d	First maturation pond must have a surface loading of maximum 75% of facultative pond's surface loading. Assumed	Mara(2003:142)
M10	D	1.5	m	Working pond depth. This depth is proposed based on industry standards. Based on Mara(2003:118) no storage for sludge removal needs to be allowed for. Shallower depths are not proposed as this could lead to Mosquito breeding which is not desired so close to the town.	Mara(2003:118 & 136)
M11	Ni	1.556E+03	TTC/100ml	TTC in IAPS effluent, flowing into first maturation pond.	Previously calculated. ID H22
M12	Ne (min)	1.000E+03	TTC/100ml	Acceptable TTC in Maturation pond effluent, flowing into an open water source	Information provided
PART B: Calculate Pond Geometry and Quantity					
M13	Rt (m1 calc)	1.911	days	Retention time for first pond	Eq 12.5 in Mara(2003:143)
M14	Rt (m1 des)	4	days	Proposed retention time to reach TTC removal. This is also less than Rt (f) - so OK	ID M8
M15	kb20	0.408		First-order removal rate for Ecoli removal in Maturation Pond 1 at 20 deg C	Eq 5.15 in Mara(2003:146)
M16	kbt	0.499		First-order removal rate for Ecoli removal in Maturation Pond 1 at T deg C	Eq 5.8 in Mara(2003:146)
M17	L:Wm (TWL)	8.0	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164)
M18	delta	0.125	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M19	a	1.414			Paragraph below Eq 5.13 in Mara(2003:145)
M20	Ne (m1)	2.887E+02	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M21	Ne (m1 check)	OK	TTC/100ml	Ne (m1) < Ne (min) thus an extra maturation pond is not required	ID M12
M22	Ne (m2)	53.562859	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M23	Ne (m2 check)	OK	TTC/100ml	Ne (m2) < Ne (min) thus an extra maturation pond is not required	ID M12
M24	Ne (m3)	9.93806375	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M25	Ne (m3 check)	OK	TTC/100ml	Ne (m3) < Ne (min) thus an extra maturation pond is not required	ID M12
	Ne (m4)	1.84391037	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
	Ne (m4 check)	OK	TTC/100ml	Ne (m4) < Ne (min) thus an extra maturation pond is not required.	ID M12
	A_m1 des	155.3	m2	Mid depth area for indicative evaporation	
M26	Q mean	231.9	m3/d	Mean flow across pond system, allowing for evaporation	ID M1
M27	Am# (mid calc)	618.422714	m2	Since each of the ponds have the same depth and retention time, each shall have the same pond area at mid depth: Am1 = Am2 = Am3 = Am#	Eq 11.4 in Mara(2003:119)
M28	Wm# (mid calc)	8.79220332	m	Width of one maturation pond at mid depth	
M29	Lm# (mid calc)	70.3376266	m	Length of one maturation pond at mid depth	
M30	Wm# (base - calc)	4.29220332	m	Calculated base width for one pond	
M31	Lm# (base calc)	65.8376266	m	Calculated base length for one pond	
M32	Wm# (base - say)	15	m	Proposed dimensions for ease of construction and to fit into site footprint	
M33	Lm# (base - say)	150	m	Proposed dimensions for ease of construction and to fit into site footprint	
M34	Wm# (mid final)	19.5	m	Construction Width of one maturation pond at mid depth	
M35	Lm# (mid final)	154.5	m	Construction Length of one maturation pond at mid depth	
M36	Am# (mid final)	3012.75	m2	Final Area of one maturation pond at mid depth	
M37	Wm# (TWL final)	24	m	Construction Width of one maturation pond at TWL	
M38	Lm# (TWL final)	159	m	Construction Length of one maturation pond at TWL	
M39	W:L (TWL final)	6.625		Final L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	

Integrated Algal Pond System STP - Scenario 01					**Maturation Pond Calculations**
PART C: Check retention time and TTC reduction					
M40	Am#	3012.75	m2	Each pond's area at mid depth	ID M36
M41	V#	4519.125	m3	Each pond's volume	ID M10 and M40
	Amtwl#	3816	m2	Effluent area at TWL per pond	
	Qmean	206.3	m3/d	Average flow over maturation pond system, assuming final dimensions and evaporation	
M42	Rt#	21.907	days	Retention time for each pond is more than 3 days, thus OK.	Equation 11.4 in Mara(2003:120)
M43	L:Wm (TWL)	6.6	m/m	L:W ratio at TWL. Due to Ecoli removal being a function of area exposed to solar radiation, it is assumed that the L:W ratio at TWL is more important than the ratio at mid depth.	Ratios obtained from Mara(2003:164). ID M39
M44	delta	0.151	m/m	Inverted L:W ratio.	Eq 5.14 in Mara(2003:146)
M45	a	2.757			Paragraph below Eq 5.13 in Mara(2003:145)
M46	Ne (m1)	3.602E+00	TTC/100ml	TTC in first maturation pond effluent	Eq 5.13 in Mara(2003:145)
M47	Ne (m1 check)	OK	TTC/100ml	Ne (m1) < Ne (min) thus an extra maturation pond is not required	ID M12
M48	Ne (m2)	0.00833929	TTC/100ml	TTC in second maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M49	Ne (m2 check)	OK	TTC/100ml	Ne (m2) < Ne (min) thus an extra maturation pond is not required	ID M12
M50	Ne (m3)	1.9306E-05	TTC/100ml	TTC in third maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m3 check)	OK	TTC/100ml	Ne (m3) < Ne (min) thus sufficient ponds have been allowed for	ID M12
M50	Ne (m4)	4.4696E-08	TTC/100ml	TTC in fouth maturation pond effluent. For ease of construction all ponds are assumed same in size and function	Eq 5.13 in Mara(2003:145)
M51	Ne (m4 check)	OK	TTC/100ml	Ne (m4) < Ne (min) thus sufficient ponds have been allowed for	ID M12
PART E: Calculate BOD removal (first order kinetics)					
M52	Li (unfiltered)	29.7	mg/l or g/m2	unfiltered BOD in effluent flowing out of IAPS	ID M4
M53	Le (m4 unfiltered)	1.5	mg/l or g/m2	unfiltered BOD in effluent flowing out of last Maturation Pond	Eq 5.7 in Mara(2003:59)
M54	Le (m4 filtered)	0.2	mg/l or g/m2	Filtered BOD (non-algal) flowing out of Maturation pond. This is less than the required BOD (filtered) value (37.5Mg/l) required in the effluent standards to discharge into an open watercourse. (as well as the WHO organisation's requirements Mara(1998:42)). Thus ito BOD removal no further treatment, other than rock filters to remove algal BOD, will be required.	Equation 11.8 in Mara(2003:121)
PART F: Overall Dimensions					
	Freeboard:				
M55	Atwl#	3816.000	m2	Each Pond's surface area (at twl)	ID M37 & M38
M56	F	0.500	m	Freeboard required above TWL	Mara(2003:165)
	F (say)	0.500	m	Proposed Freeboard based on ease of construction.	
	Top Dimensions:				
M57	Ltf	162.000	m	Maturation Pond Length along top of pond embankment. Ltf = Ltwl + 2*3*F	
M58	Wtf	27.000	m	Maturation Pond Width along along top of pond embankment. Wtf = Wtwl + 2*3*F	
M59	Dat	2.000	m	Total Pond Depth per pond	
M60	Lw	390.000	m	Pond wall crest centre line distance, per pond. (Lta+3)*2 + (Wta+3)*2	
M61	Aat	5544.000	m2	Total pond area, per pond, at pond wall crest level plus pond wall area	
M62	Qty	8.000	No	Number of Maturation Ponds	
M63	AaT	44352.000	m2	Total area required for all Maturation ponds	
PART G: Helminth egg removal					
M64	HEi	0.009	eggs/litre	Number of Helminth Eggs in efluent from IAPS flowing into Maturation pond.	ID H25
M65	R	99.95	%	% Removed	Eq 11.12 in Mara(2003:124)
M66	HEe (m1)	0.000	eggs/litre	Number of Helminth Eggs in effluent flowing out of First Maturation Pond. This is less than 0.1 egg/litre (Mara(2003:238)) thus acceptable for all irrigation and where children younger than 15 years will be exposed. No further treatment/removal required - but for purposes of completeness, calculated below:	Mara(2003:238)
M67	HEe (m2)	2.631E-09	eggs/litre	All ponds are same, thus same Removal percentage	
M68	HEe (m3)	1.388E-12	eggs/litre	All ponds are same, thus same Removal percentage	
	HEe (m4)	7.328E-16	eggs/litre	All ponds are same, thus same Removal percentage	

Integrated Algal Pond System STP - Scenario 01					**Maturation Pond Calculations**
PART H: Total Nitrogen removal					
M69	Ci	66.260	mg/l	Nitrogen concentration in IAPS's effluent.	ID H29
M70	Alkalinity	80	mg/l		Assumed
M71	pH	7.60		pH calculated for ponds. The pH for each pond would actually change due to the presence and activity of alga, but for the purposes of this exercise it is assumed that the pH and alkalinity for the Facultative Ponds can also be used for the Maturation Ponds	Eq 12.13 in Mara(2003:149) and ID F69
M72	Ce (m1)	36.680	mg/l	Nitrogen concentration in First Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M73	Ce (m2)	20.305	mg/l	Nitrogen concentration in Second Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
M74	Ce (m3)	11.240	mg/l	Nitrogen concentration in Third Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
	Ce (m4)	6.222	mg/l	Nitrogen concentration in Fourth Maturation Pond's effluent. This is more than 15mg/l and thus requires further treatment	Mara(2003:149) and Mara(1998:43)
PART I: Ammoniacal nitrogen removal (NH3 + NH4+)					
M75	Ci	18.491	mg/l	Ammonia concentration in IAPS Pond effluent.	ID H33
M76	A (m1)	3012.750	m2	Pond area at mid depth	ID M40
M77	Q mean (m1)	206.284	m3/d	Mean flow rate through pond	ID M26
M78	pH	7.598		Same as for Nitrogen removal	ID M71
M79	Ce (m1)	13.779	mg/l	Ammonia concentration in First Maturation Pond's effluent.	Eq 12.15 in Mara(2003:150)
M80	Ce (m2)	10.268	mg/l	Ammonia concentration in Second Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
M81	Ce (m3)	7.652	mg/l	Ammonia concentration in Third Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
	Ce (m4)	5.702	mg/l	Ammonia concentration in Fourth Maturation Pond's effluent. Since each maturation Pond's characteristics will remain the same, the same input data as for the previous maturation pond can be used.	Eq 12.15 in Mara(2003:150)
PART J: Phosphorus removal					
M82	Li (unfiltered)	30	mg/l or g/m3	BOD5 inflow into Maturation Pond. Ie From ASP	ID M4
M83	Le (m1 - filtered)	0.2	mg/l or g/m4	Filtered BOD leaving last Maturation Pond	Calculated above. ID M54
M84	BODr	99.481	%	Percentage BOD removal	
M85	Pr	49.741	%	Percentage Phosphorus removal	Mara(2003:151) and Mara(1998:53)
M86	Pi	14.869	mg/l	Phosporus content leaving ASP	ID H38
M87	Pe	7.473	mg/l	Phosporus content of treated effluent flowing out of final maturation pond	

Integrated Algal Pond System STP - Scenario 01
Summary of Results

Basic data	
Q-full (m^3/day)	498.53
Q-half (for parallel flow) (m^3/day)	249.26
BOD full load (kg BOD/day)	289.00
BOD falf load (kg BOD/day)	144.50
L_i (BOD of pond influent) (mg/l)	579.71
T (Min mean monthly temperature)	23.00
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07
Net evaporation, evap - rainfall (mm/day)	3.50
Effluent standards required	
BOD_R (filtered BOD at effluent)	37.5
Ne (Number of FC: CFU/100 ml of effluent)	1000
Nitrogen (mg/l)	15
Suspended Solids (mg/l)	25
Ammoniacal Nitrogen (mg/l)	6
Phosphorus (mg/l)	10
Effluent standards desired	
Helminth eggs (eggs/litre)	0.1

Design with Anaerobic pond	Facultative Pond	High Rate Algal Pond	Algal Settling Pond	Algal Drying Beds	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:						
Number of ponds in series	1	2	2	n/a	1	3
Number of ponds in parallel	2	2	2	n/a	2	2
Sludge Storage Depth (m)	1.20	0.00	0.00	n/a	0.00	0.00
Active Depth (m)	1.80	0.30	1.00	n/a	1.50	1.50
Freeboard (m)	0.50	0.50	0.50	n/a	0.50	0.50
Total Pond Depth (m)	3.50	0.80	1.50	n/a	2.00	2.00
Length/Breadth at mid depth	4.94	10.00	1.00	n/a	7.92	7.92
Length at mid-depth (m)	125.40	152.64	3.41	n/a	154.50	154.50
Breadth at mid-depth (m)	25.40	15.26	3.41	n/a	19.50	19.50
Length/Breadth at TWL	4.25	10.00	1.00	n/a	6.63	6.63
Length at TWL (m)	130.80	152.64	4.91	n/a	159.00	159.00
Breadth at TWL (m)	30.80	15.26	4.91	n/a	24.00	24.00
Length at top of embankment (m)	133.80	152.64	5.66	n/a	162.00	162.00
Breadth at top of embakment (m)	33.80	15.26	5.66	n/a	27.00	27.00
Single Pond Plan area at mid-depth (m^2)	3185.16	2329.96	11.65	n/a	3012.75	3012.75
Single Pond Plan area at top of embankment, incl crest (m^2)	5564.04	2329.96	32.07	n/a	5544.00	5544.00
Total Pond Area for all similar ponds (m^2)	11128.08	9319.83	128.29	500.00	11088.00	33264.00
Cumulative Pond Area (ha)	1.11	2.04	2.06	2.11	3.22	6.54
POND HYDRAULICS:						
Flow into pond (m^3/day)	249.26	233.00	233.00	n/a	206.28	206.28
Flow out of pond (m^3/day)	233.00	233.00	233.00	n/a	206.28	206.28
Retention time per pond (days)	23.00	3.00	0.50	n/a	21.91	21.91
Combined retention time of similar ponds in serie (days)	23.00	6.00	1.00	n/a	21.91	65.72
Combined Volume of similar ponds (days)	11092.43	2795.95	465.99		9038.25	27114.75
EFFLUENT QUALITY CHECKS:						
BOD at pond inlet (mg/l) (unfiltered)	579.71		61.32	n/a	29.71	24.76
BOD at pond outlet (mg/l) (unfiltered)	61.32		29.71	n/a	24.76	1.54
BOD at pond outlet (mg/l) (filtered)	18.40		9.90	n/a	2.48	0.15
No. of TTC/100 ml at pond inlet	4.00E+07		1.40E+06	n/a	1.56E+03	3.60E+00
No. of TTC/100 ml at pond outlet	1.40E+06		1.56E+03	n/a	3.60E+00	4.47E-08
No. of Helminth Eggs/litre at pond inlet	1000.000		0.469	n/a	0.009	4.98E-06
No. of Helminth Eggs/litre at pond outlet	0.469		0.009	n/a	0.000	7.33E-16
Nitrogen Concentration (mg/l) at pond inlet	86.957		47.760	n/a	66.260	36.680
Nitrogen Concentration (mg/l) at pond outlet	47.760		66.260	n/a	36.680	6.222
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913		132.835	n/a	18.491	13.779
Ammoniacal Nitrogen (mg/l) at pond outlet	132.835		18.491	n/a	13.779	5.702
Phosphorus concentration (mg/l) at pond inlet	46.377		46.377	n/a	14.869	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a		14.869	n/a	n/a	7.473

Waste Stabilisation Pond STP - Scenario 02				
Summary of Results				
Basic data				
Q-full (m^3/day)	498.53			
Q-half (for parallel flow) (m^3/day)	249.26			
BOD full load (kg BOD/day)	289.00			
BOD falf load (kg BOD/day)	144.50			
L_i (BOD of pond influent) (mg/l)	579.71			
T (Min mean monthly temperature)	23.00			
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07			
Net evaporation, evap - rainfall (mm/day)	3.50			
Effluent standards required				
BOD_R (filtered BOD at effluent)	37.5			
Ne (Number of FC: CFU/100 ml of effluent)	1000			
Effluent standards desired				
Helminth eggs (eggs/litre)	0.1			
Nitrogen (mg/l)	15			
Suspended Solids (mg/l)	25			
Ammoniacal Nitrogen (mg/l)	6			
Phosphorus (mg/l)	10			
Design with Anaerobic pond	Anaerobic Pond	Facultative Pond	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:				
Number of ponds in series	1	1	1	2
Number of ponds in parallel	2	2	2	2
Sludge Storage Depth (m)	1.10	0.00	0.00	0.00
Active Depth (m)	1.85	1.80	1.20	1.20
Freeboard (m)	0.50	0.50	0.50	0.50
Total Pond Depth (m)	3.45	2.30	1.70	1.70
Length/Breadth at mid depth	2.25	4.15	7.42	7.42
Length at mid-depth (m)	34.15	105.40	78.60	78.60
Breadth at mid-depth (m)	15.15	25.40	10.60	10.60
Length/Breadth at TWL	1.92	3.60	5.79	5.79
Length at TWL (m)	39.70	110.80	82.20	82.20
Breadth at TWL (m)	20.70	30.80	14.20	14.20
Length at top of embankment (m)	42.70	113.80	85.20	85.20
Breadth at top of embakment (m)	23.70	33.80	17.20	17.20
Single Pond Plan area at mid-depth (m^2)	517.37	2677.16	833.16	833.16
Single Pond Plan area at top of embankment, incl crest (m^2)	1446.39	4768.04	2115.84	2115.84
Total Pond Area for all similar ponds (m^2)	2892.78	9536.08	4231.68	8463.36
Cumulative Pond Area (ha)	0.29	1.24	1.67	2.51
POND HYDRAULICS:				
Flow into pond (m^3/day)	249.26	249.26	237.50	237.50
Flow out of pond (m^3/day)	249.26	243.63	237.50	237.50
Retention time per pond (days)	3.84	19.33	4.21	4.21
Combined retention time of similar ponds in serie (days)	3.84	19.33	4.21	8.42
Combined Volume of similar ponds (days)	1914.28	9528.84	1999.58	3999.17
EFFLUENT QUALITY CHECKS:				
BOD at pond inlet (mg/l) (unfiltered)	579.71	200.81	59.62	49.68
BOD at pond outlet (mg/l) (unfiltered)	200.81	59.62	49.68	33.61
BOD at pond outlet (mg/l) (filtered)	200.81	17.89	4.97	3.36
No. of TTC/100 ml at pond inlet	4.00E+07	3.84E+06	1.97E+05	2.70E+04
No. of TTC/100 ml at pond outlet	3.84E+06	1.97E+05	2.70E+04	5.10E+02
No. of Helminth Eggs/litre at pond inlet	1000.000	70.806	0.054	3.24E-03
No. of Helminth Eggs/litre at pond outlet	70.806	0.054	0.003	1.19E-05
Nitrogen Concentration (mg/l) at pond inlet	86.957	86.957	49.035	30.821
Nitrogen Concentration (mg/l) at pond outlet	86.957	49.035	30.821	12.177
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	173.913	138.652	128.129
Ammoniacal Nitrogen (mg/l) at pond outlet	173.913	138.652	128.129	109.418
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	46.377	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	n/a	23.323

Constructed Wetland STP - Scenario 02				
Summary of Results				
Basic data				
Q-full (m^3/day)	498.53			
Q-half (for parallel flow) (m^3/day)	249.26			
BOD full load (kg BOD/day)	289.00			
BOD falf load (kg BOD/day)	144.50			
L_i (BOD of pond influent) (mg/l)	579.71			
T (Min mean monthly temperature)	23.00			
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07			
Net evaporation, evap - rainfall (mm/day)	3.50			
Effluent standards required				
BOD_R (filtered BOD at effluent)	37.5			
Ne (Number of FC: CFU/100 ml of effluent)	1000			
Effluent standards desired				
Helminth eggs (eggs/litre)	0.1			
Nitrogen (mg/l)	15			
Suspended Solids (mg/l)	25			
Ammoniacal Nitrogen (mg/l)	6			
Phosphorus (mg/l)	10			
Design with Anaerobic pond	Anaerobic Pond	Constructed Wetland	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:				
Number of ponds in series	1	1	1	2
Number of ponds in parallel	2	2	2	2
Sludge Storage Depth (m)	1.10	0.00	0.00	0.00
Active Depth (m)	1.85	0.60	1.20	1.20
Freeboard (m)	0.50	0.50	0.50	0.50
Total Pond Depth (m)	3.45	1.10	1.70	1.70
Length/Breadth at mid depth	2.25	3.64	8.35	8.35
Length at mid-depth (m)	34.15	60.00	113.60	113.60
Breadth at mid-depth (m)	15.15	16.50	13.60	13.60
Length/Breadth at TWL	1.92	3.64	6.81	6.81
Length at TWL (m)	39.70	60.00	117.20	117.20
Breadth at TWL (m)	20.70	16.50	17.20	17.20
Length at top of embankment (m)	42.70	66.60	120.20	120.20
Breadth at top of embakment (m)	23.70	23.10	20.20	20.20
Single Pond Plan area at mid-depth (m^2)	517.37	990.00	1544.96	1544.96
Single Pond Plan area at top of embankment, incl crest (m^2)	1446.39	1538.46	3306.44	3306.44
Total Pond Area for all similar ponds (m^2)	2892.78	3076.92	6612.88	13225.76
Cumulative Pond Area (ha)	0.29	0.60	1.26	2.58
POND HYDRAULICS:				
Flow into pond (m^3/day)	249.26	249.26	238.68	238.68
Flow out of pond (m^3/day)	249.26	249.26	238.68	238.68
Retention time per pond (days)	3.84	2.38	7.77	7.77
Combined retention time of similar ponds in serie (days)	3.84	2.38	7.77	15.54
Combined Volume of similar ponds (m3)	1914.28	1188.00	3707.90	7415.81
EFFLUENT QUALITY CHECKS:				
BOD at pond inlet (mg/l) (unfiltered)	579.71	200.81	36.14	30.12
BOD at pond outlet (mg/l) (unfiltered)	200.81	36.14	30.12	13.50
BOD at pond outlet (mg/l) (filtered)	200.81	36.14	30.12	13.50
No. of TTC/100 ml at pond inlet	4.00E+07	3.84E+06	2.09E+06	7.57E+04
No. of TTC/100 ml at pond outlet	3.84E+06	2.09E+06	7.57E+04	9.96E+01
No. of Helminth Eggs/litre at pond inlet	1000.000	70.806	2.832	4.31E-02
No. of Helminth Eggs/litre at pond outlet	70.806	2.832	0.043	9.99E-06
Nitrogen Concentration (mg/l) at pond inlet	86.957	86.957	52.426	32.122
Nitrogen Concentration (mg/l) at pond outlet	86.957	52.426	32.122	12.059
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	173.913	127.872	111.044
Ammoniacal Nitrogen (mg/l) at pond outlet	173.913	127.872	111.044	83.741
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	46.377	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	n/a	23.729

Integrated Algal Pond System STP - Scenario 02
Summary of Results

Basic data	
Q-full (m^3/day)	498.53
Q-half (for parallel flow) (m^3/day)	249.26
BOD full load (kg BOD/day)	289.00
BOD falf load (kg BOD/day)	144.50
L_i (BOD of pond influent) (mg/l)	579.71
T (Min mean monthly temperature)	23.00
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07
Net evaporation, evap - rainfall (mm/day)	3.50

Effluent standards required	
BOD_R (filtered BOD at effluent)	37.5
Ne (Number of FC: CFU/100 ml of effluent)	1000

Effluent standards desired	
Helminth eggs (eggs/litre)	0.1
Nitrogen (mg/l)	15
Suspended Solids (mg/l)	25
Ammoniacal Nitrogen (mg/l)	6
Phosphorus (mg/l)	10

Design with Anaerobic pond	Facultative Pond	High Rate Algal Pond	Algal Settling Pond	Algal Drying Beds	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:						
Number of ponds in series	1	1	1	n/a	1	1
Number of ponds in parallel	2	2	2	n/a	2	2
Sludge Storage Depth (m)	1.20	0.00	0.00	n/a	0.00	0.00
Active Depth (m)	1.80	0.30	1.00	n/a	1.20	1.20
Freeboard (m)	0.50	0.50	0.50	n/a	0.50	0.50
Total Pond Depth (m)	3.50	0.80	1.50	n/a	1.70	1.70
Length/Breadth at mid depth	4.94	10.00	1.00	n/a	7.42	7.42
Length at mid-depth (m)	125.40	152.64	3.41	n/a	78.60	78.60
Breadth at mid-depth (m)	25.40	15.26	3.41	n/a	10.60	10.60
Length/Breadth at TWL	4.25	10.00	1.00	n/a	5.79	5.79
Length at TWL (m)	130.80	152.64	4.91	n/a	82.20	82.20
Breadth at TWL (m)	30.80	15.26	4.91	n/a	14.20	14.20
Length at top of embankment (m)	133.80	152.64	5.66	n/a	85.20	85.20
Breadth at top of embakment (m)	33.80	15.26	5.66	n/a	17.20	17.20
Single Pond Plan area at mid-depth (m^2)	3185.16	2329.96	11.65	n/a	833.16	833.16
Single Pond Plan area at top of embankment, incl crest (m^2)	5564.04	2329.96	32.07	n/a	2115.84	2115.84
Total Pond Area for all similar ponds (m^2)	11128.08	4659.92	64.14	500.00	4231.68	4231.68
Cumulative Pond Area (ha)	1.11	1.58	1.59	1.64	2.06	2.48
POND HYDRAULICS:						
Flow into pond (m^3/day)	249.26	233.00	233.00	n/a	228.91	228.91
Flow out of pond (m^3/day)	233.00	233.00	233.00	n/a	228.91	228.91
Retention time per pond (days)	23.00	3.00	0.50	n/a	4.37	4.37
Combined retention time of similar ponds in serie (days)	23.00	3.00	0.50	n/a	4.37	4.37
Combined Volume of similar ponds (days)	11092.43	1397.97	233.00		1999.58	1999.58
EFFLUENT QUALITY CHECKS:						
BOD at pond inlet (mg/l) (unfiltered)	579.71		61.32	n/a	34.95	29.13
BOD at pond outlet (mg/l) (unfiltered)	61.32		34.95	n/a	29.13	23.55
BOD at pond outlet (mg/l) (filtered)	18.40		11.65	n/a	2.91	2.35
No. of TTC/100 ml at pond inlet	4.00E+07		1.40E+06	n/a	4.67E+04	6.04E+03
No. of TTC/100 ml at pond outlet	1.40E+06		4.67E+04	n/a	6.04E+03	7.82E+02
No. of Helminth Eggs/litre at pond inlet	1000.000		0.469	n/a	0.009	5.36E-04
No. of Helminth Eggs/litre at pond outlet	0.469		0.009	n/a	0.001	3.04E-05
Nitrogen Concentration (mg/l) at pond inlet	86.957		47.760	n/a	74.450	46.743
Nitrogen Concentration (mg/l) at pond outlet	47.760		74.450	n/a	46.743	29.348
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913		132.835	n/a	63.761	58.754
Ammoniacal Nitrogen (mg/l) at pond outlet	132.835		63.761	n/a	58.754	54.141
Phosphorus concentration (mg/l) at pond inlet	46.377		46.377	n/a	32.325	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a		32.325	n/a	n/a	17.251

Waste Stabilisation Pond STP - Scenario 03			
Summary of Results			
Basic data			
Q-full (m^3/day)	498.53		
Q-half (for parallel flow) (m^3/day)	249.26		
BOD full load (kg BOD/day)	289.00		
BOD falf load (kg BOD/day)	144.50		
L_i (BOD of pond influent) (mg/l)	579.71		
T (Min mean monthly temperature)	23.00		
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07		
Net evaporation, evap - rainfall (mm/day)	3.50		
Effluent standards required			
BOD_R (filtered BOD at effluent)	200		
Ne (Number of FC: CFU/100 ml of effluent)	1.00E+05		
Effluent standards desired			
Helminth eggs (eggs/litre)	0.1		
Nitrogen (mg/l)	15		
Suspended Solids (mg/l)	25		
Ammoniacal Nitrogen (mg/l)	6		
Phosphorus (mg/l)	10		
Design with Anaerobic pond	Facultative Pond	First Maturation Pond	Additional Maturation Ponds
PHYSICAL POND CHARACTERISTICS:			
Number of ponds in series	1	1	1
Number of ponds in parallel	2	2	2
Sludge Storage Depth (m)	0.00	0.00	0.00
Active Depth (m)	1.80	1.20	1.20
Freeboard (m)	0.50	0.50	0.50
Total Pond Depth (m)	2.30	1.70	1.70
Length/Breadth at mid depth	4.15	7.42	7.42
Length at mid-depth (m)	105.40	78.60	78.60
Breadth at mid-depth (m)	25.40	10.60	10.60
Length/Breadth at TWL	3.60	5.79	5.79
Length at TWL (m)	110.80	82.20	82.20
Breadth at TWL (m)	30.80	14.20	14.20
Length at top of embankment (m)	113.80	85.20	85.20
Breadth at top of embakment (m)	33.80	17.20	17.20
Single Pond Plan area at mid-depth (m^2)	2677.16	833.16	833.16
Single Pond Plan area at top of embankment, incl crest (m^2)	4768.04	2115.84	2115.84
Total Pond Area for all similar ponds (m^2)	9536.08	4231.68	4231.68
Cumulative Pond Area (ha)	0.95	1.38	1.80
POND HYDRAULICS:			
Flow into pond (m^3/day)	249.26	228.91	228.91
Flow out of pond (m^3/day)	233.00	228.91	228.91
Retention time per pond (days)	19.33	4.50	4.50
Combined retention time of similar ponds in serie (days)	19.33	4.50	4.50
Combined Volume of similar ponds (days)	9323.30	2060.19	2060.19
EFFLUENT QUALITY CHECKS:			
BOD at pond inlet (mg/l) (unfiltered)	579.71	71.53	58.39
BOD at pond outlet (mg/l) (unfiltered)	71.53	58.39	48.18
BOD at pond outlet (mg/l) (filtered)	21.46	5.84	4.82
No. of TTC/100 ml at pond inlet	4.00E+07	2.05E+06	2.82E+05
No. of TTC/100 ml at pond outlet	2.05E+06	2.82E+05	3.89E+04
No. of Helminth Eggs/litre at pond inlet	1000.000	0.756	4.29E-02
No. of Helminth Eggs/litre at pond outlet	0.756	0.043	2.43E-03
Nitrogen Concentration (mg/l) at pond inlet	86.957	49.035	30.786
Nitrogen Concentration (mg/l) at pond outlet	49.035	30.786	19.329
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	138.035	127.196
Ammoniacal Nitrogen (mg/l) at pond outlet	138.035	127.196	117.209
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	n/a
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	23.381

Constructed Wetland STP - Scenario 03			
Summary of Results			
Basic data			
Q-full (m^3/day)	498.53		
Q-half (for parallel flow) (m^3/day)	249.26		
BOD full load (kg BOD/day)	289.00		
BOD falf load (kg BOD/day)	144.50		
L_i (BOD of pond influent) (mg/l)	579.71		
T (Min mean monthly temperature)	23.00		
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07		
Net evaporation, evap - rainfall (mm/day)	3.50		
Effluent standards required			
BOD_R (filtered BOD at effluent)	200		
Ne (Number of FC: CFU/100 ml of effluent)	100000		
Effluent standards desired			
Helminth eggs (eggs/litre)	0.1		
Nitrogen (mg/l)	15		
Suspended Solids (mg/l)	25		
Ammoniacal Nitrogen (mg/l)	6		
Phosphorus (mg/l)	10		
Design with Anaerobic pond	Anaerobic Pond	Constructed Wetland	First Maturation Pond
PHYSICAL POND CHARACTERISTICS:			
Number of ponds in series	1	1	1
Number of ponds in parallel	2	2	2
Sludge Storage Depth (m)	1.10	0.00	0.00
Active Depth (m)	1.85	0.30	1.20
Freeboard (m)	0.50	0.50	0.50
Total Pond Depth (m)	3.45	0.80	1.70
Length/Breadth at mid depth	2.25	3.64	8.35
Length at mid-depth (m)	34.15	60.00	113.60
Breadth at mid-depth (m)	15.15	16.50	13.60
Length/Breadth at TWL	1.92	3.64	6.81
Length at TWL (m)	39.70	60.00	117.20
Breadth at TWL (m)	20.70	16.50	17.20
Length at top of embankment (m)	42.70	64.80	120.20
Breadth at top of embakment (m)	23.70	21.30	20.20
Single Pond Plan area at mid-depth (m^2)	517.37	990.00	1544.96
Single Pond Plan area at top of embankment, incl crest (m^2)	1446.39	1380.24	3306.44
Total Pond Area for all similar ponds (m^2)	2892.78	2760.48	6612.88
Cumulative Pond Area (ha)	0.29	0.57	1.23
POND HYDRAULICS:			
Flow into pond (m^3/day)	249.26	249.26	245.73
Flow out of pond (m^3/day)	249.26	249.26	245.73
Retention time per pond (days)	3.84	1.19	4.00
Combined retention time of similar ponds in serie (days)	3.84	1.19	4.00
Combined Volume of similar ponds (m3)	1914.28	594.00	1965.88
EFFLUENT QUALITY CHECKS:			
BOD at pond inlet (mg/l) (unfiltered)	579.71	200.81	85.19
BOD at pond outlet (mg/l) (unfiltered)	200.81	85.19	70.99
BOD at pond outlet (mg/l) (filtered)	200.81	85.19	70.99
No. of TTC/100 ml at pond inlet	4.00E+07	3.84E+06	2.09E+06
No. of TTC/100 ml at pond outlet	3.84E+06	2.09E+06	8.15E+04
No. of Helminth Eggs/litre at pond inlet	1000.000	70.806	2.832
No. of Helminth Eggs/litre at pond outlet	70.806	2.832	0.047
Nitrogen Concentration (mg/l) at pond inlet	86.957	86.957	68.366
Nitrogen Concentration (mg/l) at pond outlet	86.957	68.366	41.956
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913	173.913	149.126
Ammoniacal Nitrogen (mg/l) at pond outlet	173.913	149.126	129.993
Phosphorus concentration (mg/l) at pond inlet	46.377	46.377	46.377
Phosphorus concentration (mg/l) at pond outlet	n/a	n/a	25.663

Integrated Algal Pond System STP - Scenario 03					
Summary of Results					
Basic data					
Q-full (m^3/day)	498.53				
Q-half (for parallel flow) (m^3/day)	249.26				
BOD full load (kg BOD/day)	289.00				
BOD falf load (kg BOD/day)	144.50				
L_i (BOD of pond influent) (mg/l)	579.71				
T (Min mean monthly temperature)	23.00				
Ni (Number of FC: CFU/100 ml of influent)	4.00E+07				
Net evaporation, evap - rainfall (mm/day)	3.50				
Effluent standards required					
BOD_R (filtered BOD at effluent)	200				
Ne (Number of FC: CFU/100 ml of effluent)	100000				
Effluent standards desired					
Helminth eggs (eggs/litre)	0.1				
Nitrogen (mg/l)	15				
Suspended Solids (mg/l)	25				
Ammoniacal Nitrogen (mg/l)	6				
Phosphorus (mg/l)	10				
Design with Anaerobic pond	Facultative Pond	High Rate Algal Pond	Algal Settling Pond	Algal Drying Beds	First Maturation Pond
PHYSICAL POND CHARACTERISTICS:					
Number of ponds in series	1	1	1	n/a	1
Number of ponds in parallel	2	2	2	n/a	2
Sludge Storage Depth (m)	1.20	0.00	0.00	n/a	0.00
Active Depth (m)	1.80	0.30	1.00	n/a	1.20
Freeboard (m)	0.50	0.50	0.50	n/a	0.50
Total Pond Depth (m)	3.50	0.80	1.50	n/a	1.70
Length/Breadth at mid depth	4.94	10.00	1.00	n/a	7.42
Length at mid-depth (m)	125.40	152.64	3.41	n/a	78.60
Breadth at mid-depth (m)	25.40	15.26	3.41	n/a	10.60
Length/Breadth at TWL	4.25	10.00	1.00	n/a	5.79
Length at TWL (m)	130.80	152.64	4.91	n/a	82.20
Breadth at TWL (m)	30.80	15.26	4.91	n/a	14.20
Length at top of embankment (m)	133.80	152.64	5.66	n/a	85.20
Breadth at top of embakment (m)	33.80	15.26	5.66	n/a	17.20
Single Pond Plan area at mid-depth (m^2)	3185.16	2329.96	11.65	n/a	833.16
Single Pond Plan area at top of embankment, incl crest (m^2)	5564.04	2329.96	32.07	n/a	2115.84
Total Pond Area for all similar ponds (m^2)	11128.08	4659.92	64.14	500.00	4231.68
Cumulative Pond Area (ha)	1.11	1.58	1.59	1.64	2.06
POND HYDRAULICS:					
Flow into pond (m^3/day)	249.26	233.00	233.00	n/a	230.95
Flow out of pond (m^3/day)	233.00	233.00	233.00	n/a	230.95
Retention time per pond (days)	23.00	3.00	0.50	n/a	4.33
Combined retention time of similar ponds in serie (days)	23.00	3.00	0.50	n/a	4.33
Combined Volume of similar ponds (days)	11092.43	1397.97	233.00		1999.58
EFFLUENT QUALITY CHECKS:					
BOD at pond inlet (mg/l) (unfiltered)	579.71		61.32	n/a	34.95
BOD at pond outlet (mg/l) (unfiltered)	61.32		34.95	n/a	29.13
BOD at pond outlet (mg/l) (filtered)	18.40		11.65	n/a	2.91
No. of TTC/100 ml at pond inlet	4.00E+07		1.40E+06	n/a	4.67E+04
No. of TTC/100 ml at pond outlet	1.40E+06		4.67E+04	n/a	6.13E+03
No. of Helminth Eggs/litre at pond inlet	1000.000		0.469	n/a	0.009
No. of Helminth Eggs/litre at pond outlet	0.469		0.009	n/a	0.001
Nitrogen Concentration (mg/l) at pond inlet	86.957		47.760	n/a	74.450
Nitrogen Concentration (mg/l) at pond outlet	47.760		74.450	n/a	46.756
Ammoniacal Nitrogen (mg/l) at pond inlet	173.913		132.835	n/a	63.761
Ammoniacal Nitrogen (mg/l) at pond outlet	132.835		63.761	n/a	58.795
Phosphorus concentration (mg/l) at pond inlet	46.377		46.377	n/a	32.325
Phosphorus concentration (mg/l) at pond outlet	n/a		32.325	n/a	17.255

Annexure 18: O&M Staff Requirements and Activities

Employment Requirements: WSPo

WSA	Tot No of Villages	No of STPs req	Central Staff Required				Local Village Staff					
			Supervisor	Laboratory Staff	Central Maint. Staff	Sub-Total 1	Process Controllers - Senior	Process Controllers - Trainee	Gen. Main. Staff	Security	Sub-Total 2	Total
ADM	1218	122	18	6	9	33	244	-	122	-	365	**398**
ANDM	781	78	12	4	6	22	156	-	78	-	234	**256**
CHDM	804	80	12	4	6	22	161	-	80	-	241	**263**
ORTDM	1697	170	25	8	12	45	339	-	170	-	509	**554**
TOTAL	**4500**	**450**	**67**	**22**	**33**	**122**	**900**	**-**	**450**	**-**	**1 350**	**1 472**

Employment Requirements: CW

WSA	Tot No of Villages	No of STPs req	Central Staff Required				Local Village Staff					
			Supervisor	Laboratory Staff	Central Maint. Staff	Sub-Total 1	Process Controllers - Senior	Process Controllers - Trainee	Gen. Main. Staff	Security	Sub-Total 2	Total
ADM	1218	122	18	6	9	33	244	-	122	-	365	**398**
ANDM	781	78	12	4	6	22	156	-	78	-	234	**256**
CHDM	804	80	12	4	6	22	161	-	80	-	241	**263**
ORTDM	1697	170	25	8	12	45	339	-	170	-	509	**554**
TOTAL	**4500**	**450**	**67**	**22**	**33**	**122**	**900**	**-**	**450**	**-**	**1 350**	**1 472**

Employment Requirements: IAPS

WSA	Tot No of Villages	No of STPs req	Central Staff Required				Local Village Staff					
			Supervisor	Laboratory Staff	Central Maint. Staff	Sub-Total 1	Process Controllers - Senior	Process Controllers - Trainee	Gen. Main. Staff	Security	Sub-Total 2	Total
ADM	1218	122	18	6	9	33	365	244	244	365	1 218	**1 251**
ANDM	781	78	12	4	6	22	234	156	156	234	781	**803**
CHDM	804	80	12	4	6	22	241	161	161	241	804	**826**
ORTDM	1697	170	25	8	12	45	509	339	339	509	1 697	**1 742**
TOTAL	**4500**	**450**	**67**	**22**	**33**	**122**	**1 350**	**900**	**900**	**1 350**	**4 500**	**4 622**

ACTIVITIES	WSPo				CW				IAPS			
	PC	GM	SM	S	PC	GM	SM	S	PC	GM	SM	S
Daily:												
Bird Scaring.		X				X				X		
Flow meter reading and recording	X				X				X			
Routine removal of settled algae.										X		
STP Activity Diary	X				X				X			
Temperature and Rainfall recording	X				X				X			
Total Daily Events:	**3**	**1**	**0**	**0**	**3**	**1**	**0**	**0**	**3**	**2**	**0**	**0**
Weekly:												
Inspect monitoring equipment	X				X				X			
Maintenance record keeping	X				X				X			
Monitor discharge into wetland to prevent sludge carry over.					X							
Removal and burial of Screenings.		X				X				X		
Stock taking	X				X				X			
Total Weekly Events:	**3**	**1**	**0**	**0**	**4**	**1**	**0**	**0**	**3**	**1**	**0**	**0**
Monthly:												
Analyses of effluent				X				X				X
Calculate dosing and generate reports				X				X				X
Cut grass on embankments and general site maintenance	X		X		X		X		X		X	
Erosion control and growth media repairs due to wash-out or erosion					X	X		X				
General structural inspections of buildings	X				X				X			
Inspect and adjust effluent distribution through CW media					X	X		X				
Adjustments to paddlewheel speed									X		X	X
Inspect performance of ponds for any odour problems, short circuiting or nuisances	X			X	X			X	X			X
Inspection and lubrication of valves	X		X		X		X		X		X	
Inspection and reinstatement of safety signage and measures	X		X		X		X		X		X	
Maintain STP access.	X	X			X	X			X	X		
Monitor condition of plants, minimise need for replanting of wetland plants;							X	X				
Recording of data on electronic database				X				X				X
Removal and burial of Grit		X				X				X		
Removal of roots intruding into pipes.					X	X						
Removal of solids from pipes, inlets, outlets and weirs		X				X				X		
Remove weeds and tree saplings;						X						
Routine maintenance to all mechanical and electrical equipment.									X		X	X
Sampling of effluent	X				X				X			
Scum and macrophytes such as duckweed needs to be routinely removed.	X	X			X	X			X	X		
Weed and insect control.		X				X				X		
Total Monthly Events:	**8**	**5**	**3**	**4**	**11**	**9**	**4**	**7**	**10**	**5**	**5**	**6**

ACTIVITIES	WSPo				CW				IAPS			
	PC	GM	SM	S	PC	GM	SM	S	PC	GM	SM	S
Semi-Annual:												
Desludging of algal settling pond									X	X	X	X
Inspect ponds for any burrowing animals		X				X				X		
Inspection of HRAP structure of any cracks and repairs to it.									X		X	
Record sludge depth in ponds	X	X		X	X	X		X	X	X		X
Remove sediment and organic debris build up in wetland pond.						X						
Repair of damage to embankments, external fences and gates.	X		X		X		X		X		X	
Repairs to manholes.			X				X				X	
Trimming/replacement of reeds					X	X	X	X				
Total Semi-Annual Events:	**2**	**2**	**2**	**1**	**3**	**4**	**3**	**2**	**4**	**3**	**4**	**2**
Annual:												
Calibrate monitoring equipment			X	X			X	X			X	X
Inspection of and repair to bedding liner.					X		X	X				
Inspection of and repair to pond liner.	X		X	X	X		X	X	X		X	X
Replacement of gravel bed media.					X		X					
Total Annual Events:	**1**	**0**	**2**	**2**	**3**	**0**	**4**	**3**	**1**	**0**	**2**	**2**
Other:												
Desludging of ponds	X	X	X	X	X	X	X	X	X	X	X	X
Total Other Events:	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
TOTAL EVENTS:	**18**	**10**	**8**	**8**	**25**	**16**	**12**	**13**	**22**	**12**	**12**	**11**

Annexure 19: STP Life Cycle Costing

STP Type: **Waste Stabilisation Ponds (WSPo) - Scenario 01**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components				CAPITAL COST Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 13 350 444**	**N/A**	**R 13 350 443.86**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*14 814*	*R 120.00*	*R 1 777 680*	*N/A*	*R 1 777 680.00*
1.3	Pond Excavation to Spoil	m3	*94 669*	*R 60.00*	*R 5 680 166*	*N/A*	*R 5 680 165.83*
1.4	Pond Lining	m2	*15 141*	*R 145.00*	*R 2 195 425*	*N/A*	*R 2 195 424.70*
1.5	Pond Rip Rap	m2	*5 584*	*R 75.00*	*R 418 800*	*N/A*	*R 418 800.00*
1.6	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.7	Interconnection Pipes and Chambers	Sum	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.8	Site Clearance and Access	Ha	*15*	*R 50 000.00*	*R 761 380*	*N/A*	*R 761 380.38*
1.9	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.10	Security Fencing and Gates	m	*1 561*	*R 1 100.00*	*R 1 716 993*	*N/A*	*R 1 716 992.96*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 75 000.00***	**R 75 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*0*	*R 20 000.00*	*N/A*	*R -*	*R -*
2.3	Electrical Ancillaries	Sum	*0*	*R 150 000.00*	*N/A*	*R -*	*R -*
	Total of schedule of quantities				R 13 350 443.86	R 75 000.00	R 13 425 443.86
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 3 337 610.97*	*N/A*	*R 3 337 610.97*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 9 375.00*	*R 9 375.00*
				Sub-Total 1	R 16 688 054.83	R 84 375.00	R 16 772 429.83
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 4 218.75*	*R 4 218.75*
				Sub-Total 2	R 16 688 054.83	R 88 593.75	R 16 776 648.58
	Contingencies			*10.0%*	*R 1 668 805.48*	*R 8 859.38*	*R 1 677 664.86*
				Sub-Total 3	R 18 356 860.31	R 97 453.13	R 18 454 313.44
	Professional Fees			*17.50%*	*R 3 212 450.55*	*R 17 054.30*	*R 3 229 504.85*
				Sub-Total 4	R 21 569 310.87	R 114 507.42	R 21 683 818.29
	Purchase of Land	*m^2*	*152 276*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 21 569 310.87	R 114 507.42	R 21 683 818.29
	VAT			*14.0%*	*R 3 019 703.52*	*R 16 031.04*	*R 3 035 734.56*
				TOTAL CAPITAL COSTS	R 24 589 014.39	R 130 538.46	**R 24 719 552.85**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs

STP Type: **Waste Stabilisation Ponds (WSPo) - Scenario 02**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components	UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 5 154 697**	**N/A**	**R 5 154 696.88**
1.1	Inlet Works	No	1	R 250 000.00	R 250 000	N/A	R 250 000.00
1.2	Pond Embankment Berms (From Excavations)	m3	4 961	R 120.00	R 595 296	N/A	R 595 296.00
1.3	Pond Excavation to Spoil	m3	10 167	R 60.00	R 610 049	N/A	R 610 049.30
1.4	Pond Lining	m2	15 141	R 145.00	R 2 195 425	N/A	R 2 195 424.70
1.5	Pond Rip Rap	m2	1 229	R 75.00	R 92 160	N/A	R 92 160.00
1.6	Outlet Works	No	1	R 150 000.00	R 150 000	N/A	R 150 000.00
1.7	Interconnection Pipes and Chambers	Sum	1	R 175 000.00	R 175 000	N/A	R 175 000.00
1.8	Site Clearance and Access	Ha	3	R 50 000.00	R 157 024	N/A	R 157 024.38
1.9	Ancillary Buildings	Sum	1	R 150 000.00	R 150 000	N/A	R 150 000.00
1.10	Security Fencing and Gates	m	709	R 1 100.00	R 779 743	N/A	R 779 742.51
2	***Mechanical and Electrical Infrastructure***				**N/A**	**R 75 000.00**	**R 75 000.00**
2.1	Flow Meters	No	3	R 25 000.00	N/A	R 75 000.00	R 75 000.00
2.2	High Mast Lighting	No	0	R 20 000.00	N/A	R -	R -
2.3	Electrical Ancillaries	Sum	0	R 150 000.00	N/A	R -	R -
	Total of schedule of quantities				R 5 154 696.88	R 75 000.00	R 5 229 696.88
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			25.0%	R 1 288 674.22	N/A	R 1 288 674.22
	- Electrical and Mechanical Infrastructure			12.5%	N/A	R 9 375.00	R 9 375.00
				Sub-Total 1	R 6 443 371.10	R 84 375.00	R 6 527 746.10
	Foreign Exchange Allowance (M&E Works Only)			5.0%	N/A	R 4 218.75	R 4 218.75
				Sub-Total 2	R 6 443 371.10	R 88 593.75	R 6 531 964.85
	Contingencies			10.0%	R 644 337.11	R 8 859.38	R 653 196.48
				Sub-Total 3	R 7 087 708.21	R 97 453.13	R 7 185 161.33
	Professional Fees			17.50%	R 1 240 348.94	R 17 054.30	R 1 257 403.23
				Sub-Total 4	R 8 328 057.14	R 114 507.42	R 8 442 564.57
	Purchase of Land	m^2	31 405	R -	R -	N/A	R -
				Sub-Total 5	R 8 328 057.14	R 114 507.42	R 8 442 564.57
	VAT			14.0%	R 1 165 928.00	R 16 031.04	R 1 181 959.04
	TOTAL CAPITAL COSTS				R 9 493 985.15	R 130 538.46	**R 9 624 523.61**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs

STP Type: **Waste Stabilisation Ponds (WSPo) - Scenario 03**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	**ITEM DESCRIPTION** Infrastructure Components				**CAPITAL COST** Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	**TOTAL**
1	***Civil and Structural Infrastructure***				**R 4 056 124**	**N/A**	**R 4 056 124.07**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*3 334*	*R 120.00*	*R 400 032*	*N/A*	*R 400 032.00*
1.3	Pond Excavation to Spoil	m3	*7 870*	*R 60.00*	*R 472 170*	*N/A*	*R 472 170.24*
1.4	Pond Lining	m2	*11 379*	*R 145.00*	*R 1 649 996*	*N/A*	*R 1 649 995.60*
1.5	Pond Rip Rap	m2	*819*	*R 75.00*	*R 61 440*	*N/A*	*R 61 440.00*
1.6	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.7	Interconnection Pipes and Chambers	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.8	Site Clearance and Access	Ha	*2*	*R 50 000.00*	*R 112 497*	*N/A*	*R 112 496.50*
1.9	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.10	Security Fencing and Gates	m	*600*	*R 1 100.00*	*R 659 990*	*N/A*	*R 659 989.73*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 75 000.00***	**R 75 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*0*	*R 20 000.00*	*N/A*	*R -*	*R -*
2.3	Electrical Ancillaries	Sum	*0*	*R 150 000.00*	*N/A*	*R -*	*R -*
	Total of schedule of quantities				R 4 056 124.07	R 75 000.00	R 4 131 124.07
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 1 014 031.02*	*N/A*	*R 1 014 031.02*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 9 375.00*	*R 9 375.00*
				Sub-Total 1	R 5 070 155.09	R 84 375.00	R 5 154 530.09
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 4 218.75*	*R 4 218.75*
				Sub-Total 2	R 5 070 155.09	R 88 593.75	R 5 158 748.84
	Contingencies			*10.0%*	*R 507 015.51*	*R 8 859.38*	*R 515 874.88*
				Sub-Total 3	R 5 577 170.60	R 97 453.13	R 5 674 623.73
	Professional Fees			*17.50%*	*R 976 004.86*	*R 17 054.30*	*R 993 059.15*
				Sub-Total 4	R 6 553 175.46	R 114 507.42	R 6 667 682.88
	Purchase of Land	*m²*	*22 499*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 6 553 175.46	R 114 507.42	R 6 667 682.88
	VAT			*14.0%*	*R 917 444.56*	*R 16 031.04*	*R 933 475.60*
	TOTAL CAPITAL COSTS				R 7 470 620.02	R 130 538.46	**R 7 601 158.48**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs

STP Type: **Constructed Wetland (CW) - Scenario 01**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components				CAPITAL COST Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 12 101 829**	**N/A**	**R 12 101 829.22**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*13 525*	*R 120.00*	*R 1 623 024*	*N/A*	*R 1 623 024.00*
1.3	Pond Excavation to Spoil	m3	*79 741*	*R 60.00*	*R 4 784 450*	*N/A*	*R 4 784 450.42*
1.4	Pond Lining	m2	*9 286*	*R 145.00*	*R 1 346 479*	*N/A*	*R 1 346 478.70*
1.5	Gravel for Wetland	m3	*980*	*R 750.00*	*R 735 000*	*N/A*	*R 735 000.00*
1.6	Planting of Wetland	m2	*1 400*	*R 60.00*	*R 84 000*	*N/A*	*R 84 000.00*
1.7	Pond Rip Rap	m2	*5 184*	*R 75.00*	*R 388 800*	*N/A*	*R 388 800.00*
1.8	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.9	Interconnection Pipes and Chambers	Sum	*1*	*R 300 000.00*	*R 300 000*	*N/A*	*R 300 000.00*
1.10	Site Clearance and Access	Ha	*13*	*R 50 000.00*	*R 674 278*	*N/A*	*R 674 277.88*
1.11	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.12	Security Fencing and Gates	m	*1 469*	*R 1 100.00*	*R 1 615 798*	*N/A*	*R 1 615 798.23*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 75 000.00***	**R 75 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*0*	*R 20 000.00*	*N/A*	*R -*	*R -*
2.3	Electrical Ancillaries	Sum	*0*	*R 150 000.00*	*N/A*	*R -*	*R -*
	Total of schedule of quantities				R 12 101 829.22	R 75 000.00	R 12 176 829.22
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 3 025 457.31*	*N/A*	*R 3 025 457.31*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 9 375.00*	*R 9 375.00*
				Sub-Total 1	R 15 127 286.53	R 84 375.00	R 15 211 661.53
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 4 218.75*	*R 4 218.75*
				Sub-Total 2	R 15 127 286.53	R 88 593.75	R 15 215 880.28
	Contingencies			*10.0%*	*R 1 512 728.65*	*R 8 859.38*	*R 1 521 588.03*
				Sub-Total 3	R 16 640 015.18	R 97 453.13	R 16 737 468.31
	Professional Fees			*17.50%*	*R 2 912 002.66*	*R 17 054.30*	*R 2 929 056.95*
				Sub-Total 4	R 19 552 017.84	R 114 507.42	R 19 666 525.26
	Purchase of Land	*m^2*	*134 856*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 19 552 017.84	R 114 507.42	R 19 666 525.26
	VAT			*14.0%*	*R 2 737 282.50*	*R 16 031.04*	*R 2 753 313.54*
				TOTAL CAPITAL COSTS	R 22 289 300.34	R 130 538.46	**R 22 419 838.80**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs

STP Type: **Constructed Wetland (CW) - Scenario 02**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	**ITEM DESCRIPTION** Infrastructure Components				**CAPITAL COST** Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	**TOTAL**
1	***Civil and Structural Infrastructure***				**R 4 544 210**	**N/A**	**R 4 544 210.40**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*5 466*	*R 120.00*	*R 655 884*	*N/A*	*R 655 884.00*
1.3	Pond Excavation to Spoil	m3	*6 206*	*R 60.00*	*R 372 372*	*N/A*	*R 372 371.54*
1.4	Pond Lining	m2	*7 987*	*R 145.00*	*R 1 158 101*	*N/A*	*R 1 158 100.50*
1.5	Gravel for Wetland	m3	*594*	*R 750.00*	*R 445 500*	*N/A*	*R 445 500.00*
1.6	Planting of Wetland	m2	*990*	*R 60.00*	*R 59 400*	*N/A*	*R 59 400.00*
1.7	Pond Rip Rap	m2	*1 685*	*R 75.00*	*R 126 360*	*N/A*	*R 126 360.00*
1.8	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.9	Interconnection Pipes and Chambers	Sum	*1*	*R 225 000.00*	*R 225 000*	*N/A*	*R 225 000.00*
1.10	Site Clearance and Access	Ha	*3*	*R 50 000.00*	*R 161 302*	*N/A*	*R 161 302.13*
1.11	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.12	Security Fencing and Gates	m	*718*	*R 1 100.00*	*R 790 292*	*N/A*	*R 790 292.24*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 75 000.00***	**R 75 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*0*	*R 20 000.00*	*N/A*	*R -*	*R -*
2.3	Electrical Ancillaries	Sum	*0*	*R 150 000.00*	*N/A*	*R -*	*R -*
	Total of schedule of quantities				R 4 544 210.40	R 75 000.00	R 4 619 210.40
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 1 136 052.60*	*N/A*	*R 1 136 052.60*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 9 375.00*	*R 9 375.00*
				Sub-Total 1	R 5 680 263.00	R 84 375.00	R 5 764 638.00
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 4 218.75*	*R 4 218.75*
				Sub-Total 2	R 5 680 263.00	R 88 593.75	R 5 768 856.75
	Contingencies			*10.0%*	*R 568 026.30*	*R 8 859.38*	*R 576 885.68*
				Sub-Total 3	R 6 248 289.30	R 97 453.13	R 6 345 742.43
	Professional Fees			*17.50%*	*R 1 093 450.63*	*R 17 054.30*	*R 1 110 504.92*
				Sub-Total 4	R 7 341 739.93	R 114 507.42	R 7 456 247.35
	Purchase of Land	*m^2*	*32 260*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 7 341 739.93	R 114 507.42	R 7 456 247.35
	VAT			*14.0%*	*R 1 027 843.59*	*R 16 031.04*	*R 1 043 874.63*
	TOTAL CAPITAL COSTS				R 8 369 583.52	R 130 538.46	**R 8 500 121.98**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs

STP Type: **Constructed Wetland (CW) - Scenario 03**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components	UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 3 354 041**	**N/A**	**R 3 354 040.72**
1.1	Inlet Works	No	1	R 250 000.00	R 250 000	N/A	R 250 000.00
1.2	Pond Embankment Berms (From Excavations)	m3	2 798	R 120.00	R 335 772	N/A	R 335 772.00
1.3	Pond Excavation to Spoil	m3	2 788	R 60.00	R 167 302	N/A	R 167 301.86
1.4	Pond Lining	m2	7 627	R 145.00	R 1 105 953	N/A	R 1 105 952.70
1.5	Gravel for Wetland	m3	396	R 750.00	R 297 000	N/A	R 297 000.00
1.6	Planting of Wetland	m2	990	R 60.00	R 59 400	N/A	R 59 400.00
1.7	Pond Rip Rap	m2	562	R 75.00	R 42 120	N/A	R 42 120.00
1.8	Outlet Works	No	1	R 150 000.00	R 150 000	N/A	R 150 000.00
1.9	Interconnection Pipes and Chambers	Sum	1	R 175 000.00	R 175 000	N/A	R 175 000.00
1.10	Site Clearance and Access	Ha	1.5	R 50 000.00	R 76 663	N/A	R 76 663.38
1.11	Ancillary Buildings	Sum	1	R 150 000.00	R 150 000	N/A	R 150 000.00
1.12	Security Fencing and Gates	m	495	R 1 100.00	R 544 831	N/A	R 544 830.79
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 75 000.00***	**R 75 000.00**
2.1	Flow Meters	No	3	R 25 000.00	N/A	R 75 000.00	R 75 000.00
2.2	High Mast Lighting	No	0	R 20 000.00	N/A	R -	R -
2.3	Electrical Ancillaries	Sum	0	R 150 000.00	N/A	R -	R -
	Total of schedule of quantities				R 3 354 040.72	R 75 000.00	R 3 429 040.72
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			25.0%	R 838 510.18	N/A	R 838 510.18
	- Electrical and Mechanical Infrastructure			12.5%	N/A	R 9 375.00	R 9 375.00
				Sub-Total 1	R 4 192 550.90	R 84 375.00	R 4 276 925.90
	Foreign Exchange Allowance (M&E Works Only)			5.0%	N/A	R 4 218.75	R 4 218.75
				Sub-Total 2	R 4 192 550.90	R 88 593.75	R 4 281 144.65
	Contingencies			10.0%	R 419 255.09	R 8 859.38	R 428 114.46
				Sub-Total 3	R 4 611 805.99	R 97 453.13	R 4 709 259.11
	Professional Fees			17.50%	R 807 066.05	R 17 054.30	R 824 120.34
				Sub-Total 4	R 5 418 872.04	R 114 507.42	R 5 533 379.46
	Purchase of Land	m^2	15 333	R -	R -	N/A	R -
				Sub-Total 5	R 5 418 872.04	R 114 507.42	R 5 533 379.46
	VAT			14.0%	R 758 642.08	R 16 031.04	R 774 673.12
	TOTAL CAPITAL COSTS				R 6 177 514.12	R 130 538.46	**R 6 308 052.58**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs
Labour rates for WSPo and CW are less than for IAPS since a lowet qualification is required

STP Type: **Integrated Algal Pond System (IAPS) - Scenario 01**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components				CAPITAL COST Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 16 798 507**	**N/A**	**R 16 798 506.72**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*8 894*	*R 120.00*	*R 1 067 313*	*N/A*	*R 1 067 312.93*
1.3	Pond Excavation to Spoil	m3	*42 389*	*R 60.00*	*R 2 543 347*	*N/A*	*R 2 543 346.67*
1.4	Pond Lining	m2	*13 755*	*R 145.00*	*R 1 994 533*	*N/A*	*R 1 994 532.85*
1.5	HRAP (Concrete Race Track Design)	m2	*10 721*	*R 750.00*	*R 8 040 730*	*N/A*	*R 8 040 729.70*
1.6	Sludge Drying Beds	m2	*545*	*R 750.00*	*R 408 541*	*N/A*	*R 408 541.02*
1.7	Pond Rip Rap	m2	*3 024*	*R 75.00*	*R 226 800*	*N/A*	*R 226 800.00*
1.8	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.9	Interconnection Pipes and Chambers	Sum	*1*	*R 300 000.00*	*R 300 000*	*N/A*	*R 300 000.00*
1.10	Site Clearance and Access	Ha	*8*	*R 50 000.00*	*R 408 926*	*N/A*	*R 408 926.25*
1.11	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.12	Security Fencing and Gates	m	*1 144*	*R 1 100.00*	*R 1 258 317*	*N/A*	*R 1 258 317.30*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 405 000.00***	**R 405 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*9*	*R 20 000.00*	*N/A*	*R 180 000.00*	*R 180 000.00*
2.3	Electrical Ancillaries	Sum	*1*	*R 150 000.00*	*N/A*	*R 150 000.00*	*R 150 000.00*
	Total of schedule of quantities				R 16 798 506.72	R 405 000.00	R 17 203 506.72
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 4 199 626.68*	*N/A*	*R 4 199 626.68*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 50 625.00*	*R 50 625.00*
				Sub-Total 1	R 20 998 133.40	R 455 625.00	R 21 453 758.40
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 22 781.25*	*R 22 781.25*
				Sub-Total 2	R 20 998 133.40	R 478 406.25	R 21 476 539.65
	Contingencies			*10.0%*	*R 2 099 813.34*	*R 47 840.63*	*R 2 147 653.97*
				Sub-Total 3	R 23 097 946.74	R 526 246.88	R 23 624 193.62
	Professional Fees			*17.50%*	*R 4 042 140.68*	*R 92 093.20*	*R 4 134 233.88*
				Sub-Total 4	R 27 140 087.42	R 618 340.08	R 27 758 427.50
	Purchase of Land	*m^2*	*81 785*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 27 140 087.42	R 618 340.08	R 27 758 427.50
	VAT			*14.0%*	*R 3 799 612.24*	*R 86 567.61*	*R 3 886 179.85*
				TOTAL CAPITAL COSTS	R 30 939 699.66	R 704 907.69	**R 31 644 607.35**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs
HRAP Design is a racetrack formation, with additional divider walls at bends. Constructed out of concrete and bricks.

STP Type: **Integrated Algal Pond System (IAPS) - Scenario 02**

Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	ITEM DESCRIPTION Infrastructure Components				CAPITAL COST Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	TOTAL
1	***Civil and Structural Infrastructure***				**R 9 710 190**	**N/A**	**R 9 710 189.65**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*3 670*	*R 120.00*	*R 440 344*	*N/A*	*R 440 344.47*
1.3	Pond Excavation to Spoil	m3	*18 240*	*R 60.00*	*R 1 094 376*	*N/A*	*R 1 094 376.21*
1.4	Pond Lining	m2	*13 483*	*R 145.00*	*R 1 955 084*	*N/A*	*R 1 955 084.23*
1.5	HRAP (Concrete Race Track Design)	m2	*5 360*	*R 750.00*	*R 4 020 365*	*N/A*	*R 4 020 364.85*
1.6	Sludge Drying Beds	m2	*545*	*R 750.00*	*R 408 541*	*N/A*	*R 408 541.02*
1.7	Pond Rip Rap	m2	*819*	*R 75.00*	*R 61 440*	*N/A*	*R 61 440.00*
1.8	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.9	Interconnection Pipes and Chambers	Sum	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.10	Site Clearance and Access	Ha	*3.1*	*R 50 000.00*	*R 155 097*	*N/A*	*R 155 096.87*
1.11	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.12	Security Fencing and Gates	m	*704*	*R 1 100.00*	*R 774 942*	*N/A*	*R 774 942.00*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 305 000.00***	**R 305 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*4*	*R 20 000.00*	*N/A*	*R 80 000.00*	*R 80 000.00*
2.3	Electrical Ancillaries	Sum	*1*	*R 150 000.00*	*N/A*	*R 150 000.00*	*R 150 000.00*
	Total of schedule of quantities				R 9 710 189.65	R 305 000.00	R 10 015 189.65
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 2 427 547.41*	*N/A*	*R 2 427 547.41*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 38 125.00*	*R 38 125.00*
				Sub-Total 1	R 12 137 737.06	R 343 125.00	R 12 480 862.06
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 17 156.25*	*R 17 156.25*
				Sub-Total 2	R 12 137 737.06	R 360 281.25	R 12 498 018.31
	Contingencies			*10.0%*	*R 1 213 773.71*	*R 36 028.13*	*R 1 249 801.83*
				Sub-Total 3	R 13 351 510.76	R 396 309.38	R 13 747 820.14
	Professional Fees			*17.50%*	*R 2 336 514.38*	*R 69 354.14*	*R 2 405 868.52*
				Sub-Total 4	R 15 688 025.15	R 465 663.52	R 16 153 688.66
	Purchase of Land	*m^2*	*31 019*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 15 688 025.15	R 465 663.52	R 16 153 688.66
	VAT			*14.0%*	*R 2 196 323.52*	*R 65 192.89*	*R 2 261 516.41*
				TOTAL CAPITAL COSTS	**R 17 884 348.67**	**R 530 856.41**	**R 18 415 205.07**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs
HRAP Design is a racetrack formation, with additional divider walls at bends. Constructed out of concrete and bricks.

STP Type: **Integrated Algal Pond System (IAPS) - Scenario 03**
Estimate Type: **Order of magnitude: Infrastructure Capital Costs**

ITEM No	**ITEM DESCRIPTION** Infrastructure Components				**CAPITAL COST** Amount (ZAR)		
		UNIT	QTY	RATE	CIV & STRUCT	MECH & ELEC	**TOTAL**
1	***Civil and Structural Infrastructure***				**R 9 393 288**	**N/A**	**R 9 393 287.56**
1.1	Inlet Works	No	*1*	*R 250 000.00*	*R 250 000*	*N/A*	*R 250 000.00*
1.2	Pond Embankment Berms (From Excavations)	m3	*2 694*	*R 120.00*	*R 323 272*	*N/A*	*R 323 272.47*
1.3	Pond Excavation to Spoil	m3	*17 848*	*R 60.00*	*R 1 070 874*	*N/A*	*R 1 070 873.97*
1.4	Pond Lining	m2	*13 483*	*R 145.00*	*R 1 955 084*	*N/A*	*R 1 955 084.23*
1.5	HRAP (Concrete Race Track Design)	m2	*5 360*	*R 750.00*	*R 4 020 365*	*N/A*	*R 4 020 364.85*
1.6	Sludge Drying Beds	m2	*545*	*R 750.00*	*R 408 541*	*N/A*	*R 408 541.02*
1.7	Pond Rip Rap	m2	*410*	*R 75.00*	*R 30 720*	*N/A*	*R 30 720.00*
1.8	Outlet Works	No	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.9	Interconnection Pipes and Chambers	Sum	*1*	*R 200 000.00*	*R 200 000*	*N/A*	*R 200 000.00*
1.10	Site Clearance and Access	Ha	*2.6*	*R 50 000.00*	*R 128 649*	*N/A*	*R 128 648.87*
1.11	Ancillary Buildings	Sum	*1*	*R 150 000.00*	*R 150 000*	*N/A*	*R 150 000.00*
1.12	Security Fencing and Gates	m	*642*	*R 1 100.00*	*R 705 782*	*N/A*	*R 705 782.15*
2	***Mechanical and Electrical Infrastructure***				***N/A***	***R 285 000.00***	**R 285 000.00**
2.1	Flow Meters	No	*3*	*R 25 000.00*	*N/A*	*R 75 000.00*	*R 75 000.00*
2.2	High Mast Lighting	No	*3*	*R 20 000.00*	*N/A*	*R 60 000.00*	*R 60 000.00*
2.3	Electrical Ancillaries	Sum	*1*	*R 150 000.00*	*N/A*	*R 150 000.00*	*R 150 000.00*
	Total of schedule of quantities				R 9 393 287.56	R 285 000.00	R 9 678 287.56
	Preliminary and general costs:						
	- Civil and Structural Infrastructure			*25.0%*	*R 2 348 321.89*	*N/A*	*R 2 348 321.89*
	- Electrical and Mechanical Infrastructure			*12.5%*	*N/A*	*R 35 625.00*	*R 35 625.00*
				Sub-Total 1	R 11 741 609.45	R 320 625.00	R 12 062 234.45
	Foreign Exchange Allowance (M&E Works Only)			*5.0%*	*N/A*	*R 16 031.25*	*R 16 031.25*
				Sub-Total 2	R 11 741 609.45	R 336 656.25	R 12 078 265.70
	Contingencies			*10.0%*	*R 1 174 160.94*	*R 33 665.63*	*R 1 207 826.57*
				Sub-Total 3	R 12 915 770.39	R 370 321.88	R 13 286 092.27
	Professional Fees			*17.50%*	*R 2 260 259.82*	*R 64 806.33*	*R 2 325 066.15*
				Sub-Total 4	R 15 176 030.21	R 435 128.20	R 15 611 158.41
	Purchase of Land	*m^2*	*25 730*	*R -*	*R -*	*N/A*	*R -*
				Sub-Total 5	R 15 176 030.21	R 435 128.20	R 15 611 158.41
	VAT			*14.0%*	*R 2 124 644.23*	*R 60 917.95*	*R 2 185 562.18*
				TOTAL CAPITAL COSTS	R 17 300 674.44	R 496 046.15	**R 17 796 720.59**

COST ESTIMATE ASSUMPTIONS:

Property is owned by the local municipality and no property taxes will be leveled agains the WSA
Electricity tarrif and price increases have been averaged out based on current trends
Staff salary increases will always be 2% above inflation
Pond Embankments will be formed from material excavated out of pond basins
Pond linings only required where biological treatment is to occur and not in Maturation Ponds
Maturation Ponds will be provided with Rip Rap however
High Mast Lighting and Electrical Ancillaries will only be required if STP is to be operated at night
Professional Fees are included in Initial Capital Costs, but it is assumed that the WSP will be able to provide all other technical support in-house, thereafter
Mechanical Components needs to be refurbished every 5 years
It is assumed that the off-site support staff is included in the maintenance costs
HRAP Design is a racetrack formation, with additional divider walls at bends. Constructed out of concrete and bricks.

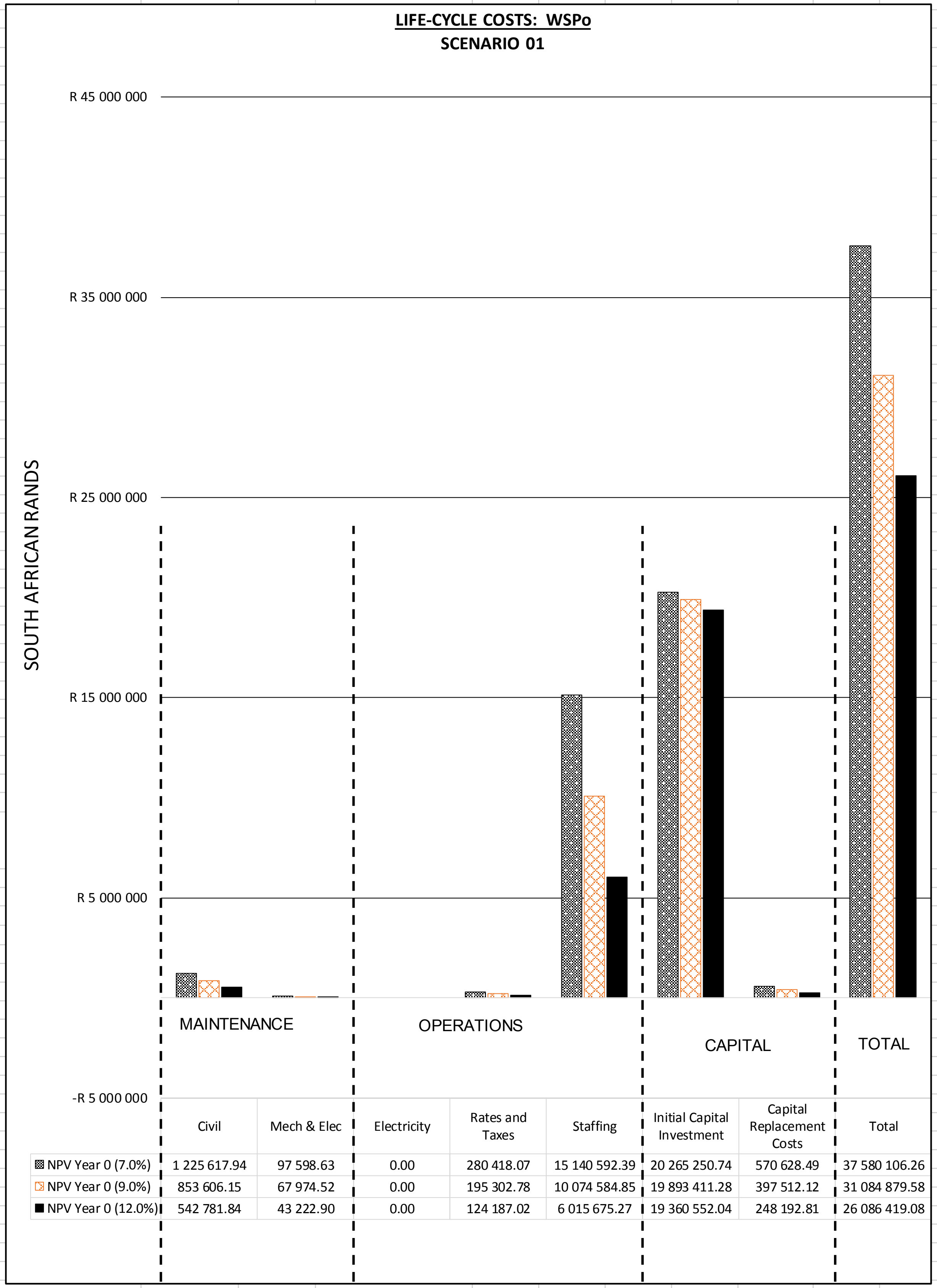
WSPo LCC Estimation: Scenario 01

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	21 683 818.29	0.00	**21 683 818.29**	
1	39 063.40	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**383 682.90**	
2	41 563.46	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**414 890.03**	
3	44 223.52	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**448 653.14**	
4	47 053.82	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**485 182.73**	
5	50 065.27	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**657 600.30**	Mech replacement
6	53 269.44	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**567 471.98**	
7	56 678.69	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**613 745.64**	
8	60 306.12	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**663 817.07**	
9	64 165.72	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**717 999.58**	
10	68 272.32	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**957 854.89**	Mech replacement
11	72 641.75	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**840 082.95**	
12	77 290.82	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**908 748.99**	
13	82 237.44	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**983 061.31**	
14	87 500.63	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 063 486.43**	
15	93 100.67	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 397 656.51**	Mech replacement
16	99 059.12	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 244 737.68**	
17	105 398.90	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 346 703.41**	
18	112 144.43	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 457 068.36**	
19	119 321.67	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 576 527.44**	
20	126 958.26	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**2 042 832.04**	Mech replacement
21	135 083.59	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 845 800.94**	
22	143 728.94	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**1 997 313.27**	
23	152 927.59	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 161 326.40**	
24	162 714.95	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 338 875.92**	
25	173 128.71	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**2 990 637.39**	Mech replacement
26	184 208.95	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 739 163.96**	
27	195 998.32	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**2 964 433.24**	
28	208 542.21	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 208 316.63**	
29	221 888.92	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 472 357.97**	
30	236 089.81	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 384 907.75**	Mech replacement
31	251 199.55	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**4 067 742.67**	
32	267 276.33	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 402 859.51**	
33	284 382.01	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 765 705.47**	
34	302 582.46	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**5 158 582.85**	
35	321 947.74	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 438 565.70**	Mech replacement
36	342 552.39	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**6 044 615.53**	
37	364 475.75	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 543 399.12**	
38	387 802.19	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**7 083 506.83**	
39	412 621.53	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 668 373.17**	
40	439 029.31	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**8 301 718.79**	

Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**
NPV Year 0 (7.0%)	1 225 617.94	97 598.63	0.00	280 418.07	15 140 592.39	20 265 250.74	570 628.49	**37 580 106.26**
NPV Year 0 (9.0%)	853 606.15	67 974.52	0.00	195 302.78	10 074 584.85	19 893 411.28	397 512.12	**31 084 879.58**
NPV Year 0 (12.0%)	542 781.84	43 222.90	0.00	124 187.02	6 015 675.27	19 360 552.04	248 192.81	**26 086 419.08**

Operational & Maintenance Inputs

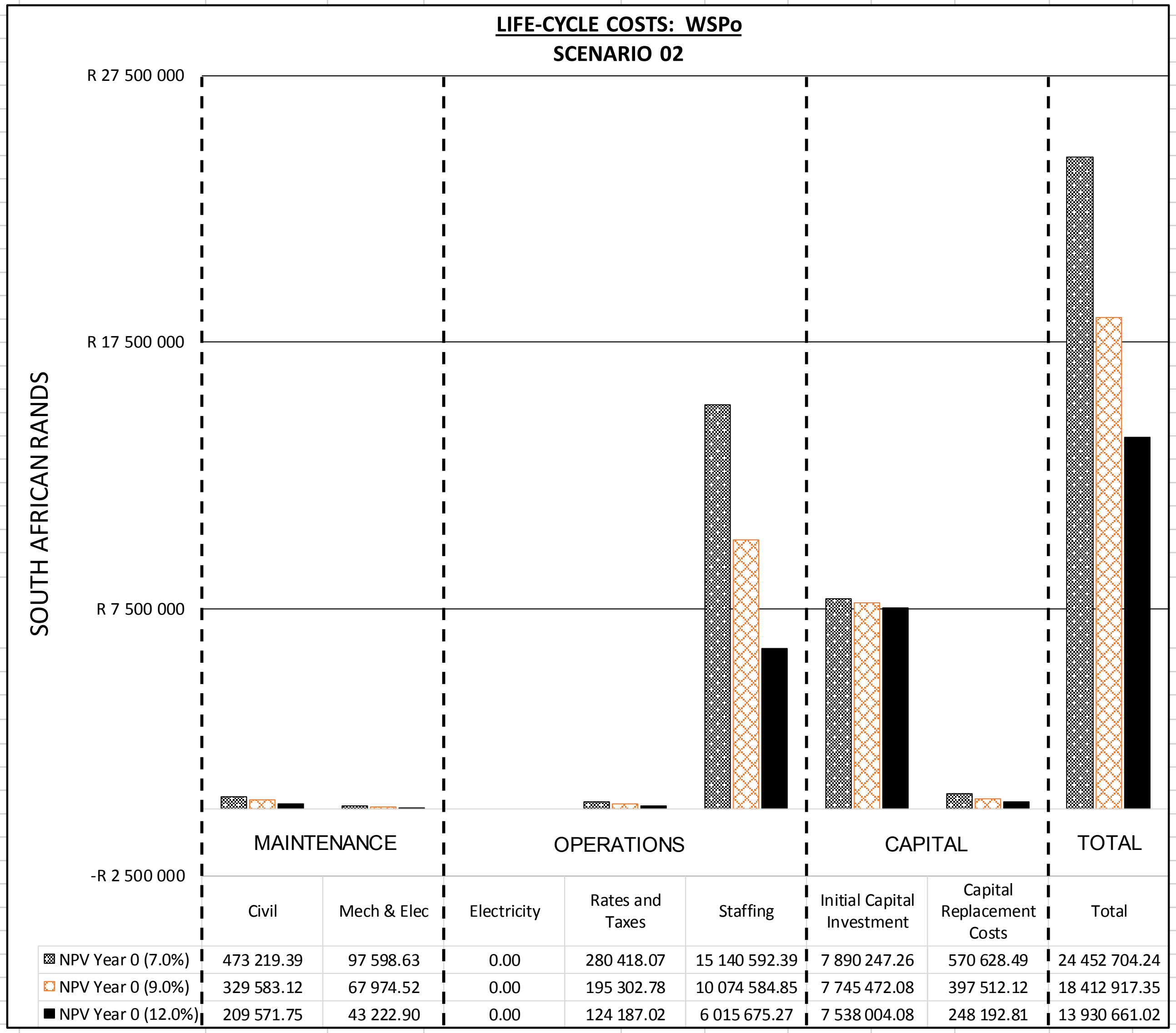
Annual Rates and Taxes				**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec, Etc)	R	8 400.00		Process Controller	30	2	85
Property Tax Rate	R	0.02	R/Prop Value	Trainee Process Controller	0	0	70
Property Tax:	R	-		General Maintenance Staff	40	1	20
Total Rates and Taxes	R	8 400.00		Security	0	0	60
Electricity Pricing				Salary (Staff) Increase	8.4 % per year		
Electricity price increase		8.5	% per year				
Eskom Averaged charge		1.65	R/kWh				
				Total Power Installed			
Inflation/Discounted rates				Flow Meters	0 kWh	24	hrs/day
				Paddle Wheel: 2No	0 kWh	24	hrs/day
Inflation Rate @		6.4	%				
Interest Rate @		7.0	%				
Interest Rate @		9.0	%				
Interest Rate @		12.0	%				
Civil Maintenance		0.2	% of capital cost				
Mech & Elec Maintenance		3	% of capital cost				



WSPo LCC Estimation: Scenario 02

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	8 442 564.57	0.00	**8 442 564.57**	
1	15 082.64	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**359 702.15**	
2	16 047.93	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**389 374.51**	
3	17 075.00	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**421 504.62**	
4	18 167.80	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**456 296.71**	
5	19 330.54	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**626 865.58**	Mech replacement
6	20 567.69	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**534 770.23**	
7	21 884.03	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**578 950.98**	
8	23 284.60	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**626 795.55**	
9	24 774.82	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**678 608.68**	
10	26 360.41	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**915 942.98**	Mech replacement
11	28 047.47	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**795 488.68**	
12	29 842.51	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**861 300.68**	
13	31 752.43	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**932 576.31**	
14	33 784.59	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 009 770.38**	
15	35 946.80	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 340 502.64**	Mech replacement
16	38 247.40	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 183 925.96**	
17	40 695.23	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 281 999.74**	
18	43 299.72	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 388 223.65**	
19	46 070.91	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 503 276.67**	
20	49 019.44	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**1 964 893.23**	Mech replacement
21	52 156.69	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 762 874.04**	
22	55 494.72	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**1 909 079.05**	
23	59 046.38	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 067 445.19**	
24	62 825.35	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 238 986.31**	
25	66 846.17	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**2 884 354.85**	Mech replacement
26	71 124.32	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 626 079.33**	
27	75 676.28	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**2 844 111.20**	
28	80 519.56	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 080 293.98**	
29	85 672.81	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 336 141.87**	
30	91 155.88	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 239 973.82**	Mech replacement
31	96 989.85	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**3 913 532.96**	
32	103 197.20	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 238 780.39**	
33	109 801.82	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 591 125.28**	
34	116 829.14	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**4 972 829.53**	
35	124 306.20	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 240 924.17**	Mech replacement
36	132 261.80	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**5 834 324.94**	
37	140 726.56	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 319 649.93**	
38	149 733.06	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**6 845 437.69**	
39	159 315.97	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 415 067.60**	
40	169 512.19	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**8 032 201.67**	Residual value

Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**
NPV Year 0 (7.0%)	473 219.39	97 598.63	0.00	280 418.07	15 140 592.39	7 890 247.26	570 628.49	**24 452 704.24**
NPV Year 0 (9.0%)	329 583.12	67 974.52	0.00	195 302.78	10 074 584.85	7 745 472.08	397 512.12	**18 412 917.35**
NPV Year 0 (12.0%)	209 571.75	43 222.90	0.00	124 187.02	6 015 675.27	7 538 004.08	248 192.81	**13 930 661.02**



Operational & Maintenance Inputs

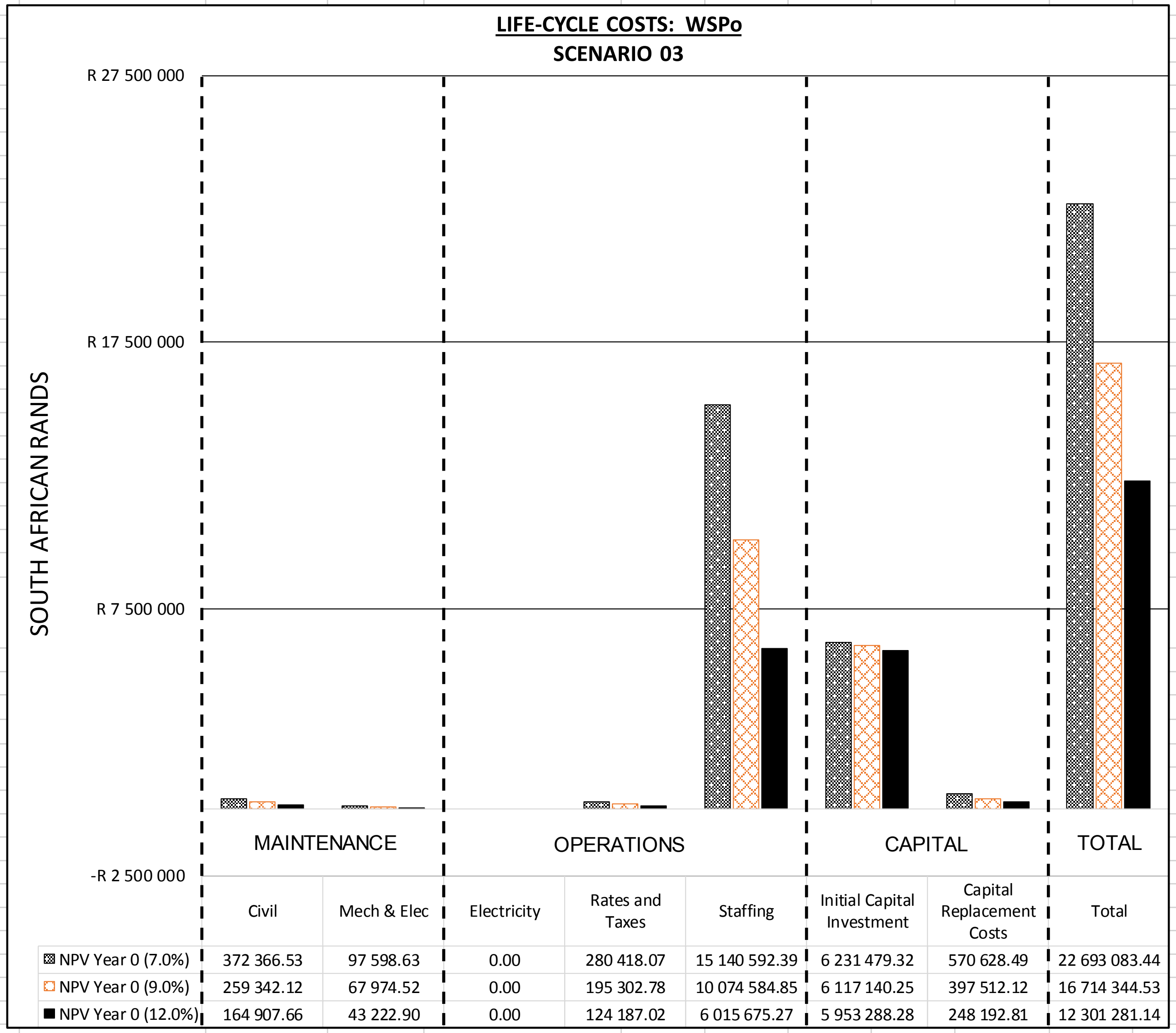
Annual Rates and Taxes				**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec	R	8 400.00		Process Controll	30	2	85
Property Tax Rate	R	0.02	R/Prop Value	Trainee Process	0	0	70
Property Tax:	R	-		General Mainter	40	1	20
Total Rates and Taxe	R	8 400.00		Security	0	0	60
Electricity Pricing				Salary (Staff) Inc	8.4 % per year		
Electricity price incre		8.5	% per year				
Eskom Averaged cha		1.65	R/kWh				
				Total Power Installed			
Inflation/Discounted rates				Flow Meters	0 kWh	24 hrs/day	
				Paddle Wheel: :	0 kWh	24 hrs/day	
Inflation Rate @		6.4	%				
Interest Rate @		7.0	%				
Interest Rate @		9.0	%				
Interest Rate @		12.0	%				
Civil Maintenance		0.2	% of capital cost				
Mech & Elec Mainter		3	% of capital cost				

WSPo LCC Estimation: Scenario 03

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	6 667 682.88	0.00	**6 667 682.88**	
1	11 868.22	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**356 487.72**	
2	12 627.79	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**385 954.36**	
3	13 435.96	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**417 865.58**	
4	14 295.86	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**452 424.78**	
5	15 210.80	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**622 745.84**	Mech replacement
6	16 184.29	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**530 386.83**	
7	17 220.09	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**574 287.04**	
8	18 322.17	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**621 833.12**	
9	19 494.79	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**673 328.66**	
10	20 742.46	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**910 325.03**	Mech replacement
11	22 069.97	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**789 511.18**	
12	23 482.45	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**854 940.62**	
13	24 985.33	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**925 809.21**	
14	26 584.39	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 002 570.19**	
15	28 285.79	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 332 841.63**	Mech replacement
16	30 096.08	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 175 774.65**	
17	32 022.23	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 273 326.75**	
18	34 071.65	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 378 995.58**	
19	36 252.24	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 493 458.01**	
20	38 572.38	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**1 954 446.17**	Mech replacement
21	41 041.02	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 751 758.37**	
22	43 667.64	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**1 897 251.98**	
23	46 462.37	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 054 861.18**	
24	49 435.96	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 225 596.93**	
25	52 599.86	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**2 870 108.54**	Mech replacement
26	55 966.26	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 610 921.26**	
27	59 548.10	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**2 827 983.01**	
28	63 359.17	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 063 133.59**	
29	67 414.16	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 317 883.22**	
30	71 728.67	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 220 546.61**	Mech replacement
31	76 319.30	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**3 892 862.41**	
32	81 203.74	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 216 786.92**	
33	86 400.78	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 567 724.23**	
34	91 930.43	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**4 947 930.82**	
35	97 813.97	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 214 431.94**	Mech replacement
36	104 074.07	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**5 806 137.20**	
37	110 734.81	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 289 658.18**	
38	117 821.84	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**6 813 526.47**	
39	125 362.43	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 381 114.07**	
40	133 385.63	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**7 996 075.11**	Residual value
Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**	
NPV Year 0 (7.0%)	372 366.53	97 598.63	0.00	280 418.07	15 140 592.39	6 231 479.32	570 628.49	**22 693 083.44**	
NPV Year 0 (9.0%)	259 342.12	67 974.52	0.00	195 302.78	10 074 584.85	6 117 140.25	397 512.12	**16 714 344.53**	
NPV Year 0 (12.0%)	164 907.66	43 222.90	0.00	124 187.02	6 015 675.27	5 953 288.28	248 192.81	**12 301 281.14**	

Operational & Maintenance Inputs

Annual Rates and Taxes			**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec	R	8 400.00	Process Controll	30	2	85
Property Tax Rate	R	0.02 R/Prop Value	Trainee Process	0	0	70
Property Tax:	R	-	General Mainter	40	1	20
Total Rates and Taxe	R	8 400.00	Security	0	0	60
Electricity Pricing			Salary (Staff) Inc	8.4 % per year		
Electricity price incre		8.5 % per year				
Eskom Averaged cha		1.65 R/kWh				
			Total Power Installed			
Inflation/Discounted rates			Flow Meters	0 kWh	24 hrs/day	
			Paddle Wheel: :	0 kWh	24 hrs/day	
Inflation Rate @		6.4 %				
Interest Rate @		7.0 %				
Interest Rate @		9.0 %				
Interest Rate @		12.0 %				
Civil Maintenance		0.2 % of capital cost				
Mech & Elec Mainter		3 % of capital cost				



CW LCC Estimation: Scenario 01

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	19 666 525.26	0.00	**19 666 525.26**	
1	53 114.93	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**397 734.43**	
2	56 514.28	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**429 840.86**	
3	60 131.20	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**464 560.82**	
4	63 979.59	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**502 108.51**	
5	68 074.29	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**675 609.33**	Mech replacement
6	72 431.04	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**586 633.58**	
7	77 066.63	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**634 133.58**	
8	81 998.89	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**685 509.84**	
9	87 246.82	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**741 080.69**	
10	92 830.62	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**982 413.19**	Mech replacement
11	98 771.78	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**866 212.98**	
12	105 093.17	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**936 551.34**	
13	111 819.14	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**1 012 643.01**	
14	118 975.56	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 094 961.36**	
15	126 590.00	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 431 145.84**	Mech replacement
16	134 691.76	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 280 370.33**	
17	143 312.03	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 384 616.54**	
18	152 484.00	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 497 407.93**	
19	162 242.98	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 619 448.74**	
20	172 626.53	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**2 088 500.31**	Mech replacement
21	183 674.62	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 894 391.98**	
22	195 429.80	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**2 049 014.13**	
23	207 937.31	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 216 336.12**	
24	221 245.30	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 397 406.26**	
25	235 404.99	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**3 052 913.67**	Mech replacement
26	250 470.91	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 805 425.92**	
27	266 501.05	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**3 034 935.97**	
28	283 557.12	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 283 331.54**	
29	301 704.78	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 552 173.83**	
30	321 013.88	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 469 831.83**	Mech replacement
31	341 558.77	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**4 158 101.88**	
32	363 418.53	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 499 001.71**	
33	386 677.32	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 868 000.77**	
34	411 424.66	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**5 267 425.05**	
35	437 755.84	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 554 373.80**	Mech replacement
36	465 772.22	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**6 167 835.35**	
37	495 581.64	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 674 505.01**	
38	527 298.86	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**7 223 003.50**	
39	561 045.99	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 816 797.62**	
40	596 952.93	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**8 459 642.41**	Residual value

Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**
NPV Year 0 (7.0%)	1 666 486.05	97 598.63	-	280 418.07	15 140 592.39	18 379 930.15	570 628.49	**36 135 653.78**
NPV Year 0 (9.0%)	1 160 657.58	67 974.52	-	195 302.78	10 074 584.85	18 042 683.73	397 512.12	**29 541 203.46**
NPV Year 0 (12.0%)	738 026.38	43 222.90	-	124 187.02	6 015 675.27	17 559 397.55	248 192.81	**24 480 509.13**

Operational & Maintenance Inputs

Annual Rates and Taxes			
Services (Water, Elec	R	8 400.00	
Property Tax Rate	R	0.02	R/Prop Value
Property Tax:	R	-	
Total Rates and Taxe	R	8 400.00	

Staff Member	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Process Controll	30	2	85
Trainee Process	0	0	70
General Mainter	40	1	20
Security	0	0	60

Salary (Staff) Inc 8.4 % per year

Electricity Pricing

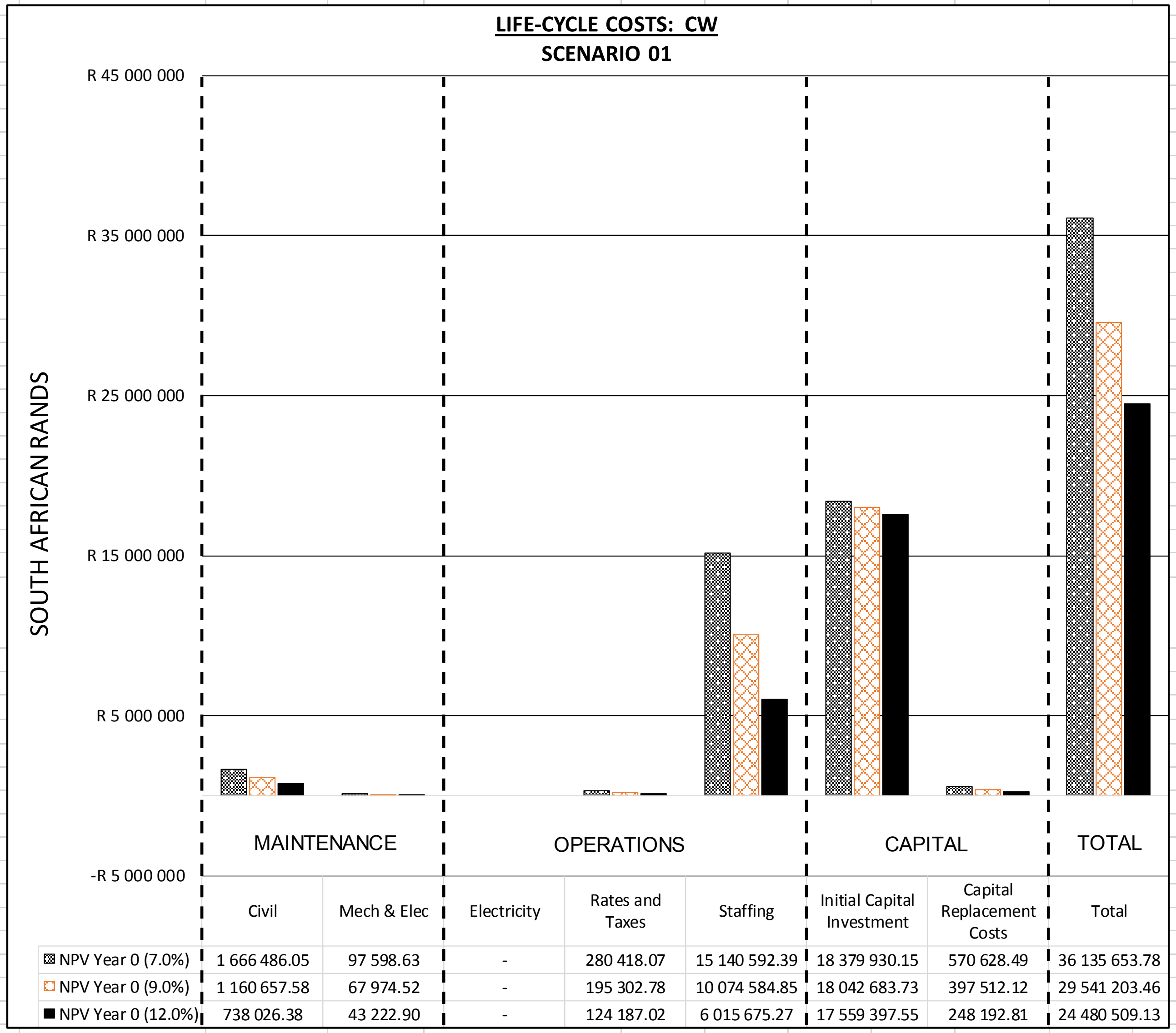
Electricity price incre	8.5	% per year
Eskom Averaged cha	1.65	R/kWh

Total Power Installed

Flow Meters	0	kWh	24	hrs/day
Paddle Wheel: :	0	kWh	24	hrs/day

Inflation/Discounted rates

Inflation Rate @	6.4	%
Interest Rate @	7.0	%
Interest Rate @	9.0	%
Interest Rate @	12.0	%
Civil Maintenance	0.3	% of capital cost
Mech & Elec Mainter	3	% of capital cost



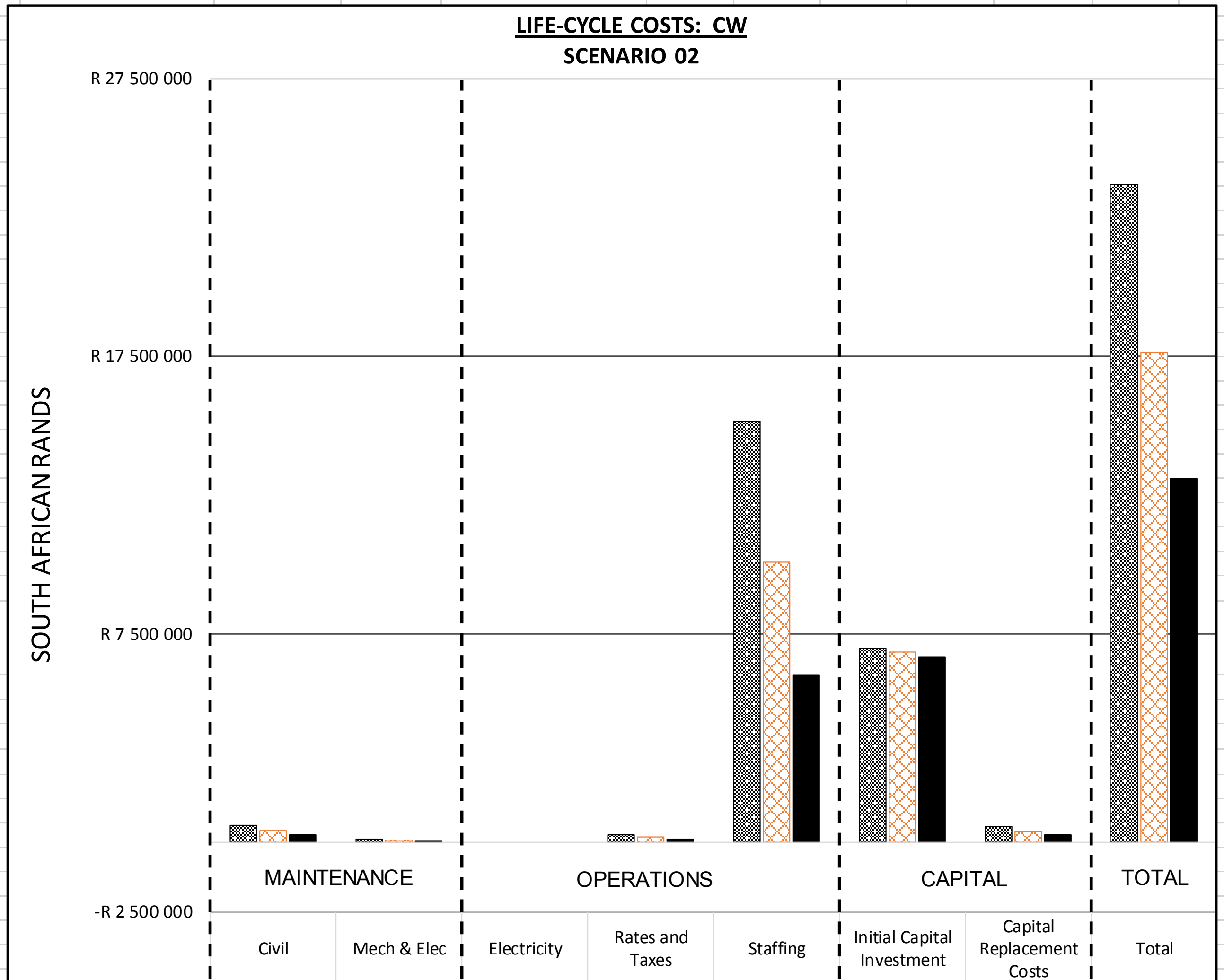
CW LCC Estimation: Scenario 02

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	7 456 247.35	0.00	**7 456 247.35**	
1	19 944.54	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**364 564.04**	
2	21 220.99	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**394 547.57**	
3	22 579.13	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**427 008.75**	
4	24 024.20	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**462 153.11**	
5	25 561.75	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**633 096.78**	Mech replacement
6	27 197.70	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**541 400.24**	
7	28 938.35	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**586 005.30**	
8	30 790.41	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**634 301.36**	
9	32 760.99	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**686 594.86**	
10	34 857.69	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**924 440.27**	Mech replacement
11	37 088.59	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**804 529.79**	
12	39 462.26	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**870 920.42**	
13	41 987.84	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**942 811.72**	
14	44 675.06	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 020 660.86**	
15	47 534.27	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 352 090.11**	Mech replacement
16	50 576.46	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 196 255.03**	
17	53 813.35	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 295 117.87**	
18	57 257.41	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 402 181.34**	
19	60 921.88	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 518 127.65**	
20	64 820.88	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**1 980 694.67**	Mech replacement
21	68 969.42	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 779 686.77**	
22	73 383.46	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**1 926 967.80**	
23	78 080.00	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 086 478.82**	
24	83 077.12	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 259 238.09**	
25	88 394.06	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**2 905 902.74**	Mech replacement
26	94 051.28	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 649 006.29**	
27	100 070.56	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**2 868 505.48**	
28	106 475.08	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 106 249.49**	
29	113 289.48	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 363 758.54**	
30	120 540.01	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 269 357.96**	Mech replacement
31	128 254.57	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**3 944 797.68**	
32	136 462.86	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 272 046.05**	
33	145 196.49	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 626 519.94**	
34	154 489.06	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**5 010 489.45**	
35	164 376.36	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 280 994.32**	Mech replacement
36	174 896.45	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**5 876 959.58**	
37	186 089.82	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 365 013.19**	
38	197 999.57	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**6 893 704.21**	
39	210 671.54	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 466 423.17**	
40	224 154.52	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**8 086 844.00**	Residual value

Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**
NPV Year 0 (7.0%)	625 761.87	97 598.63	-	280 418.07	15 140 592.39	6 968 455.47	570 628.49	**23 683 454.92**
NPV Year 0 (9.0%)	435 824.38	67 974.52	-	195 302.78	10 074 584.85	6 840 593.90	397 512.12	**17 614 280.44**
NPV Year 0 (12.0%)	277 127.29	43 222.90	-	124 187.02	6 015 675.27	6 657 363.71	248 192.81	**13 117 576.19**

Operational & Maintenance Inputs

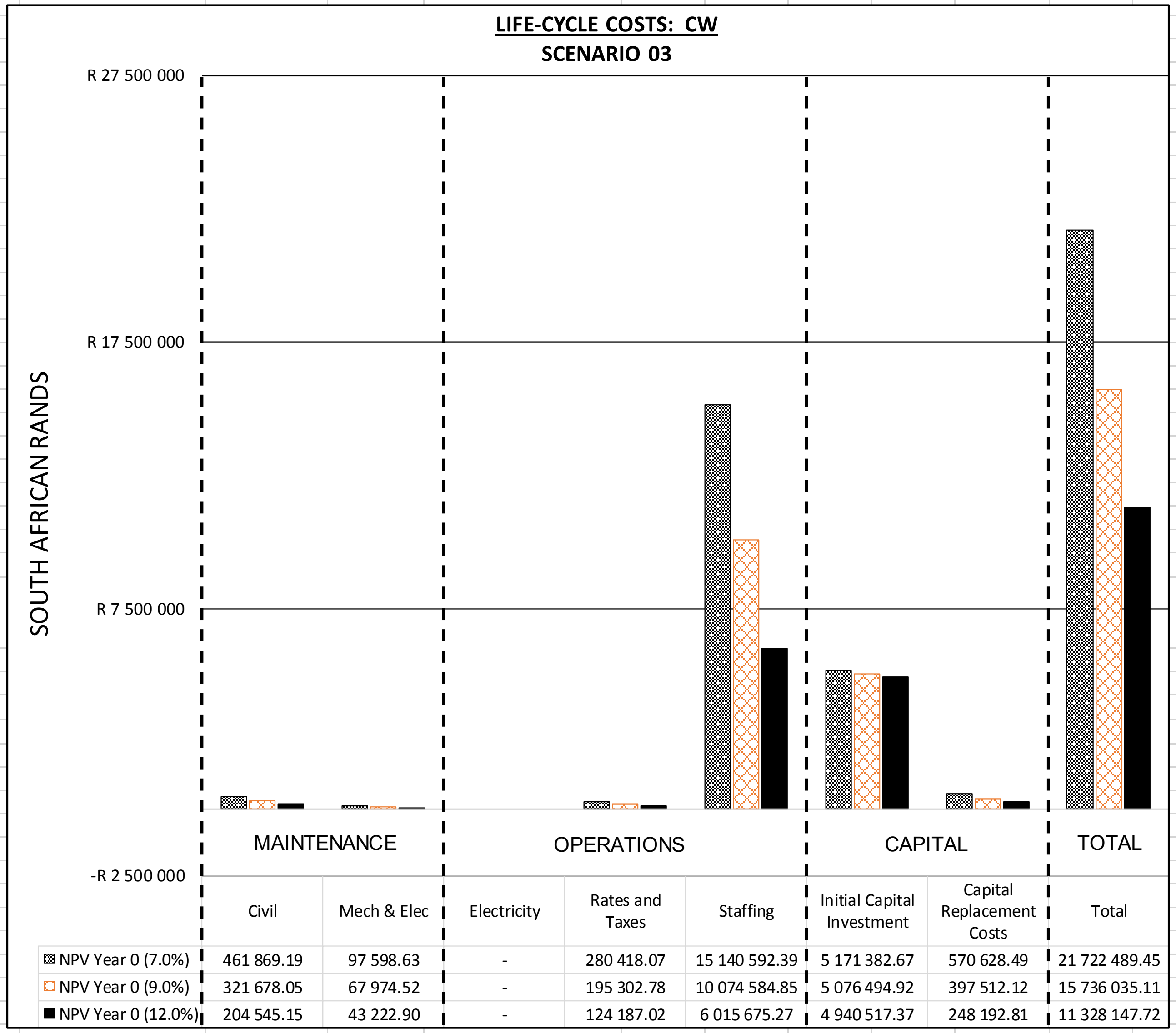
Annual Rates and Taxes				**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec	R	8 400.00		Process Controll	30	2	85
Property Tax Rate	R	0.02	R/Prop Value	Trainee Process	0	0	70
Property Tax:	R	-		General Mainter	40	1	20
Total Rates and Taxe	R	8 400.00		Security	0	0	60
Electricity Pricing				Salary (Staff) Inc	8.4 % per year		
Electricity price incre		8.5	% per year				
Eskom Averaged cha		1.65	R/kWh				
				Total Power Installed			
Inflation/Discounted rates				Flow Meters	0 kWh	24 hrs/day	
				Paddle Wheel: :	0 kWh	24 hrs/day	
Inflation Rate @		6.4	%				
Interest Rate @		7.0	%				
Interest Rate @		9.0	%				
Interest Rate @		12.0	%				
Civil Maintenance		0.3	% of capital cost				
Mech & Elec Mainter		3	% of capital cost				



	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	Total
NPV Year 0 (7.0%)	625 761.87	97 598.63	-	280 418.07	15 140 592.39	6 968 455.47	570 628.49	23 683 454.92
NPV Year 0 (9.0%)	435 824.38	67 974.52	-	195 302.78	10 074 584.85	6 840 593.90	397 512.12	17 614 280.44
NPV Year 0 (12.0%)	277 127.29	43 222.90	-	124 187.02	6 015 675.27	6 657 363.71	248 192.81	13 117 576.19

CW LCC Estimation: Scenario 03

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	5 533 379.46	0.00	**5 533 379.46**	
1	14 720.88	3 110.70	0.00	8 937.60	332 571.20	0.00	0.00	**359 340.39**	
2	15 663.02	3 309.79	0.00	9 509.61	360 507.18	0.00	0.00	**388 989.60**	
3	16 665.45	3 521.62	0.00	10 118.22	390 789.78	0.00	0.00	**421 095.08**	
4	17 732.04	3 747.00	0.00	10 765.79	423 616.13	0.00	0.00	**455 860.96**	
5	18 866.89	3 986.81	0.00	11 454.80	459 199.88	0.00	132 893.55	**626 401.93**	Mech replacement
6	20 074.38	4 241.96	0.00	12 187.90	497 772.67	0.00	0.00	**534 276.91**	
7	21 359.14	4 513.45	0.00	12 967.93	539 585.57	0.00	0.00	**578 426.09**	
8	22 726.12	4 802.31	0.00	13 797.88	584 910.76	0.00	0.00	**626 237.07**	
9	24 180.59	5 109.66	0.00	14 680.94	634 043.27	0.00	0.00	**678 014.46**	
10	25 728.15	5 436.67	0.00	15 620.52	687 302.90	0.00	181 222.47	**915 310.72**	Mech replacement
11	27 374.75	5 784.62	0.00	16 620.24	745 036.35	0.00	0.00	**794 815.95**	
12	29 126.74	6 154.84	0.00	17 683.93	807 619.40	0.00	0.00	**860 584.90**	
13	30 990.85	6 548.75	0.00	18 815.70	875 459.43	0.00	0.00	**931 814.72**	
14	32 974.26	6 967.87	0.00	20 019.91	948 998.02	0.00	0.00	**1 008 960.06**	
15	35 084.61	7 413.81	0.00	21 301.18	1 028 713.85	0.00	247 127.00	**1 339 640.45**	Mech replacement
16	37 330.03	7 888.29	0.00	22 664.46	1 115 125.82	0.00	0.00	**1 183 008.60**	
17	39 719.15	8 393.14	0.00	24 114.98	1 208 796.39	0.00	0.00	**1 281 023.66**	
18	42 261.18	8 930.31	0.00	25 658.34	1 310 335.28	0.00	0.00	**1 387 185.11**	
19	44 965.89	9 501.85	0.00	27 300.48	1 420 403.45	0.00	0.00	**1 502 171.66**	
20	47 843.71	10 109.96	0.00	29 047.71	1 539 717.33	0.00	336 998.78	**1 963 717.49**	Mech replacement
21	50 905.71	10 757.00	0.00	30 906.76	1 669 053.59	0.00	0.00	**1 761 623.06**	
22	54 163.67	11 445.45	0.00	32 884.79	1 809 254.09	0.00	0.00	**1 907 748.01**	
23	57 630.15	12 177.96	0.00	34 989.42	1 961 231.44	0.00	0.00	**2 066 028.96**	
24	61 318.48	12 957.35	0.00	37 228.74	2 125 974.88	0.00	0.00	**2 237 479.44**	
25	65 242.86	13 786.62	0.00	39 611.38	2 304 556.77	0.00	459 553.91	**2 882 751.54**	Mech replacement
26	69 418.40	14 668.96	0.00	42 146.51	2 498 139.54	0.00	0.00	**2 624 373.41**	
27	73 861.18	15 607.77	0.00	44 843.89	2 707 983.26	0.00	0.00	**2 842 296.10**	
28	78 588.29	16 606.67	0.00	47 713.89	2 935 453.85	0.00	0.00	**3 078 362.71**	
29	83 617.95	17 669.50	0.00	50 767.58	3 182 031.97	0.00	0.00	**3 334 087.00**	
30	88 969.49	18 800.35	0.00	54 016.71	3 449 322.66	0.00	626 678.23	**4 237 787.44**	Mech replacement
31	94 663.54	20 003.57	0.00	57 473.78	3 739 065.76	0.00	0.00	**3 911 206.65**	
32	100 722.01	21 283.80	0.00	61 152.10	4 053 147.29	0.00	0.00	**4 236 305.19**	
33	107 168.22	22 645.96	0.00	65 065.84	4 393 611.66	0.00	0.00	**4 588 491.67**	
34	114 026.98	24 095.30	0.00	69 230.05	4 762 675.04	0.00	0.00	**4 970 027.37**	
35	121 324.71	25 637.40	0.00	73 660.77	5 162 739.74	0.00	854 580.05	**6 237 942.67**	Mech replacement
36	129 089.49	27 278.20	0.00	78 375.06	5 596 409.88	0.00	0.00	**5 831 152.63**	
37	137 351.22	29 024.00	0.00	83 391.07	6 066 508.31	0.00	0.00	**6 316 274.59**	
38	146 141.70	30 881.54	0.00	88 728.09	6 576 095.01	0.00	0.00	**6 841 846.33**	
39	155 494.77	32 857.95	0.00	94 406.69	7 128 486.99	0.00	0.00	**7 411 246.40**	
40	165 446.43	34 960.86	0.00	100 448.72	7 727 279.89	0.00	0.00	**8 028 135.91**	Residual value
Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**	
NPV Year 0 (7.0%)	461 869.19	97 598.63	-	280 418.07	15 140 592.39	5 171 382.67	570 628.49	**21 722 489.45**	
NPV Year 0 (9.0%)	321 678.05	67 974.52	-	195 302.78	10 074 584.85	5 076 494.92	397 512.12	**15 736 035.11**	
NPV Year 0 (12.0%)	204 545.15	43 222.90	-	124 187.02	6 015 675.27	4 940 517.37	248 192.81	**11 328 147.72**	



Operational & Maintenance Inputs

Annual Rates and Taxes			**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec	R	8 400.00	Process Controll	30	2	85
Property Tax Rate	R	0.02 R/Prop Value	Trainee Process	0	0	70
Property Tax:	R	-	General Mainter	40	1	20
Total Rates and Taxe	R	8 400.00	Security	0	0	60

Electricity Pricing

Salary (Staff) Inc 8.4 % per year

Electricity price incre 8.5 % per year

Eskom Averaged cha 1.65 R/kWh

Total Power Installed

Inflation/Discounted rates			
	Flow Meters	0 kWh	24 hrs/day
	Paddle Wheel: ;	0 kWh	24 hrs/day

Inflation Rate @ 6.4 %

Interest Rate @ 7.0 %

Interest Rate @ 9.0 %

Interest Rate @ 12.0 %

Civil Maintenance 0.3 % of capital cost

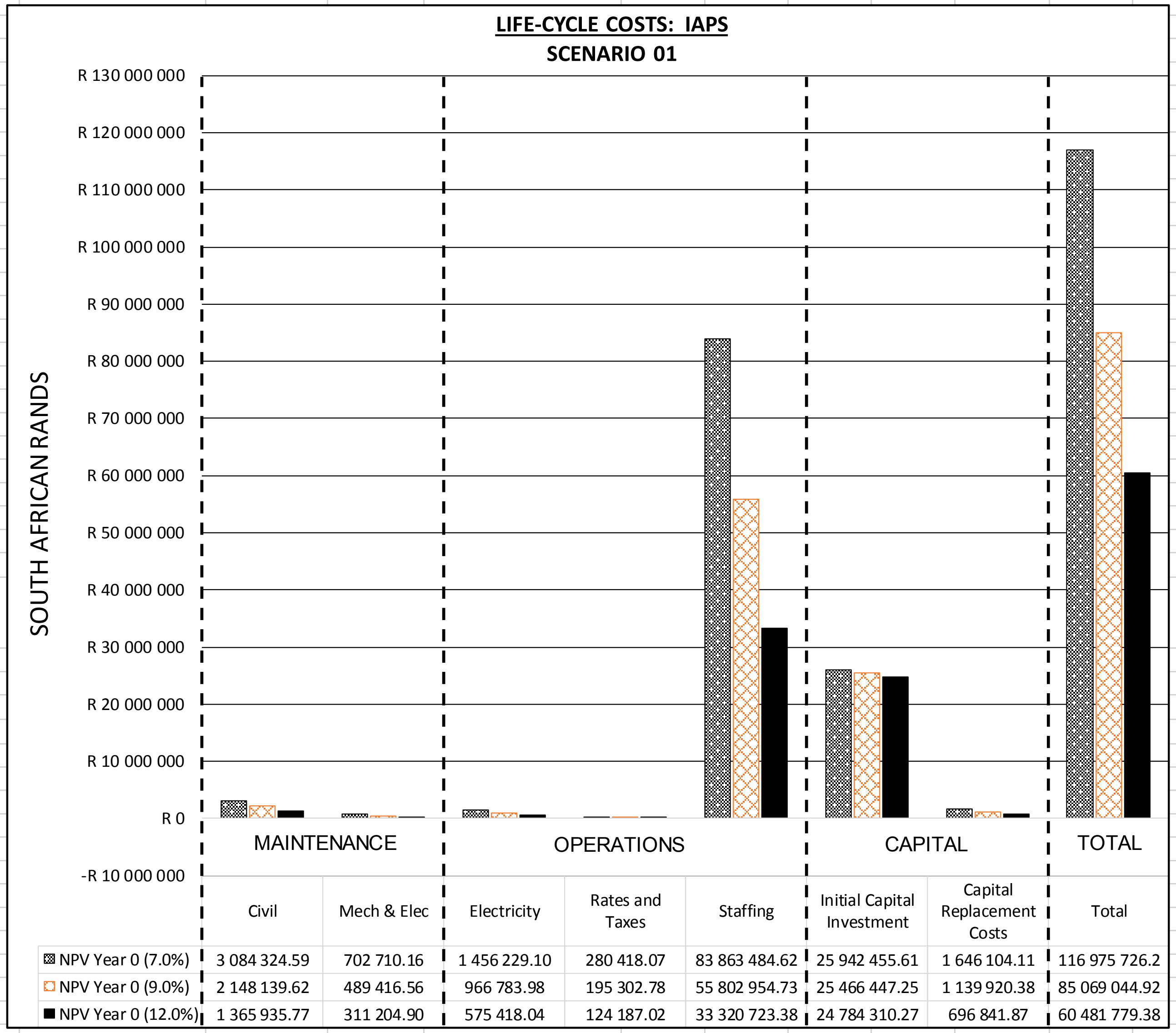
Mech & Elec Mainter 3 % of capital cost

IAPS LCC Estimation: Scenario 01

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	27 758 427.50	0.00	**27 758 427.50**	
1	98 304.86	22 397.07	31 365.18	8 937.60	1 842 106.24	0.00	0.00	**2 003 110.95**	
2	104 596.37	23 830.48	34 031.22	9 509.61	1 996 843.16	0.00	0.00	**2 168 810.84**	
3	111 290.54	25 355.63	36 923.87	10 118.22	2 164 577.99	0.00	0.00	**2 348 266.26**	
4	118 413.13	26 978.39	40 062.40	10 765.79	2 346 402.54	0.00	0.00	**2 542 622.26**	
5	125 991.58	28 705.01	43 467.71	11 454.80	2 543 500.35	0.00	132 893.55	**2 886 012.99**	Mech replacement
6	134 055.04	30 542.13	47 162.46	12 187.90	2 757 154.38	0.00	0.00	**2 981 101.92**	
7	142 634.56	32 496.82	51 171.27	12 967.93	2 988 755.35	0.00	0.00	**3 228 025.94**	
8	151 763.17	34 576.62	55 520.83	13 797.88	3 239 810.80	0.00	0.00	**3 495 469.30**	
9	161 476.01	36 789.52	60 240.10	14 680.94	3 511 954.91	0.00	0.00	**3 785 141.49**	
10	171 810.48	39 144.05	65 360.51	15 620.52	3 806 959.12	0.00	978 601.35	**5 077 496.03**	Mech replacement
11	182 806.35	41 649.27	70 916.15	16 620.24	4 126 743.69	0.00	0.00	**4 438 735.70**	
12	194 505.96	44 314.83	76 944.03	17 683.93	4 473 390.16	0.00	0.00	**4 806 838.90**	
13	206 954.34	47 150.98	83 484.27	18 815.70	4 849 154.93	0.00	0.00	**5 205 560.21**	
14	220 199.41	50 168.64	90 580.43	20 019.91	5 256 483.95	0.00	0.00	**5 637 452.34**	
15	234 292.18	53 379.43	98 279.77	21 301.18	5 698 028.60	0.00	247 127.00	**6 352 408.15**	Mech replacement
16	249 286.88	56 795.71	106 633.55	22 664.46	6 176 663.00	0.00	0.00	**6 612 043.59**	
17	265 241.24	60 430.64	115 697.40	24 114.98	6 695 502.69	0.00	0.00	**7 160 986.95**	
18	282 216.67	64 298.20	125 531.68	25 658.34	7 257 924.92	0.00	0.00	**7 755 629.81**	
19	300 278.54	68 413.29	136 201.87	27 300.48	7 867 590.61	0.00	0.00	**8 399 784.78**	
20	319 496.37	72 791.74	147 779.03	29 047.71	8 528 468.22	0.00	1 819 793.41	**10 917 376.48**	Mech replacement
21	339 944.14	77 450.41	160 340.25	30 906.76	9 244 859.55	0.00	0.00	**9 853 501.10**	
22	361 700.56	82 407.23	173 969.17	32 884.79	10 021 427.75	0.00	0.00	**10 672 389.51**	
23	384 849.40	87 681.30	188 756.55	34 989.42	10 863 227.69	0.00	0.00	**11 559 504.35**	
24	409 479.76	93 292.90	204 800.85	37 228.74	11 775 738.81	0.00	0.00	**12 520 541.06**	
25	435 686.46	99 263.65	222 208.93	39 611.38	12 764 900.87	0.00	459 553.91	**14 021 225.20**	Mech replacement
26	463 570.40	105 616.52	241 096.68	42 146.51	13 837 152.54	0.00	0.00	**14 689 582.65**	
27	493 238.90	112 375.98	261 589.90	44 843.89	14 999 473.36	0.00	0.00	**15 911 522.03**	
28	524 806.19	119 568.04	283 825.04	47 713.89	16 259 429.12	0.00	0.00	**17 235 342.29**	
29	558 393.79	127 220.39	307 950.17	50 767.58	17 625 221.17	0.00	0.00	**18 669 553.10**	
30	594 130.99	135 362.50	334 125.94	54 016.71	19 105 739.74	0.00	3 384 062.45	**23 607 438.33**	Mech replacement
31	632 155.37	144 025.70	362 526.64	57 473.78	20 710 621.88	0.00	0.00	**21 906 803.38**	
32	672 613.32	153 243.34	393 341.41	61 152.10	22 450 314.12	0.00	0.00	**23 730 664.29**	
33	715 660.57	163 050.92	426 775.43	65 065.84	24 336 140.51	0.00	0.00	**25 706 693.26**	
34	761 462.85	173 486.17	463 051.34	69 230.05	26 380 376.31	0.00	0.00	**27 847 606.72**	
35	810 196.47	184 589.29	502 410.70	73 660.77	28 596 327.92	0.00	854 580.05	**31 021 765.20**	Mech replacement
36	862 049.04	196 403.00	545 115.61	78 375.06	30 998 419.47	0.00	0.00	**32 680 362.19**	
37	917 220.18	208 972.80	591 450.44	83 391.07	33 602 286.70	0.00	0.00	**35 403 321.18**	
38	975 922.27	222 347.06	641 723.73	88 728.09	36 424 878.78	0.00	0.00	**38 353 599.93**	
39	1 038 381.30	236 577.27	696 270.24	94 406.69	39 484 568.60	0.00	0.00	**41 550 204.10**	
40	1 104 837.70	251 718.21	755 453.21	100 448.72	42 801 272.36	0.00	0.00	**45 013 730.21**	Residual value
Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**	
NPV Year 0 (7.0%)	3 084 324.59	702 710.16	1 456 229.10	280 418.07	83 863 484.62	25 942 455.61	1 646 104.11	**116 975 726.26**	
NPV Year 0 (9.0%)	2 148 139.62	489 416.56	966 783.98	195 302.78	55 802 954.73	25 466 447.25	1 139 920.38	**85 069 044.92**	
NPV Year 0 (12.0%)	1 365 935.77	311 204.90	575 418.04	124 187.02	33 320 723.38	24 784 310.27	696 841.87	**60 481 779.38**	

Operational & Maintenance Inputs

Annual Rates and Taxes			**Staff Member**	**Hrs/week per Indiv**	**No of Staff**		**Hourly Rate**
Services (Water, Elec	R	8 400.00	Process Controll	56	3		100
Property Tax Rate	R	0.02 R/Prop Value	Trainee Process	30	2		70
Property Tax:	R	-	General Mainter	40	2		20
Total Rates and Taxe	R	8 400.00	Security	56	3		60
Electricity Pricing			Salary (Staff) Inc	8.4 % per year			
Electricity price incre		8.5 % per year					
Eskom Averaged cha		1.65 R/kWh	**Total Power Installed**				
Inflation/Discounted rates			Flow Meters	0 kWh	24 hrs/day		
			Paddle Wheel: :	2 kWh	24 hrs/day		
Inflation Rate @		6.4 %					
Interest Rate @		7.0 %					
Interest Rate @		9.0 %					
Interest Rate @		12.0 %					
Civil Maintenance		0.4 % of capital cost					
Mech & Elec Mainter		4 % of capital cost					

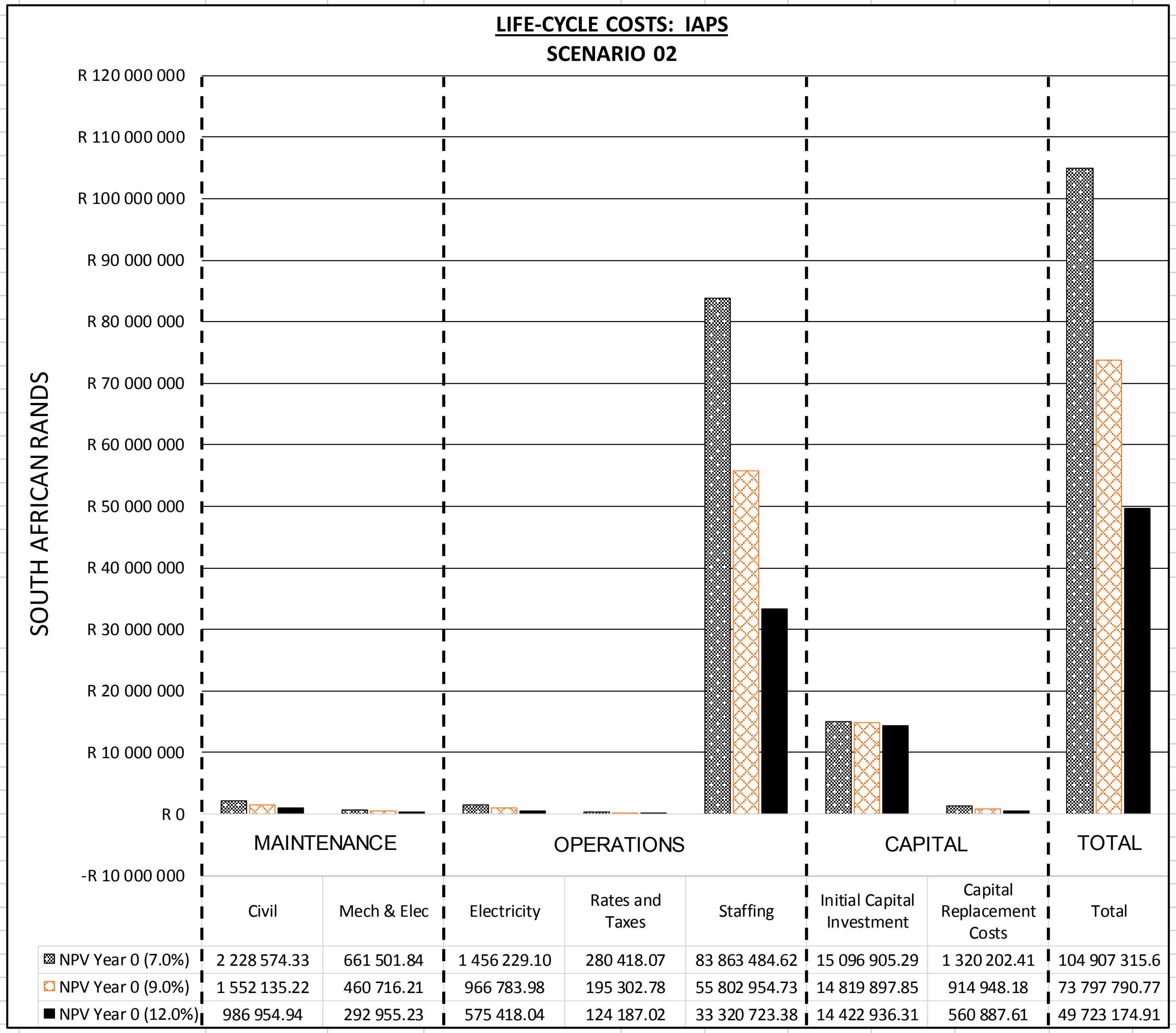


IAPS LCC Estimation: Scenario 02

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	16 153 688.66	0.00	**16 153 688.66**	
1	71 030.04	21 083.66	31 365.18	8 937.60	1 842 106.24	0.00	0.00	**1 974 522.72**	
2	75 575.96	22 433.01	34 031.22	9 509.61	1 996 843.16	0.00	0.00	**2 138 392.96**	
3	80 412.82	23 868.73	36 923.87	10 118.22	2 164 577.99	0.00	0.00	**2 315 901.63**	
4	85 559.24	25 396.32	40 062.40	10 765.79	2 346 402.54	0.00	0.00	**2 508 186.30**	
5	91 035.03	27 021.69	43 467.71	11 454.80	2 543 500.35	0.00	132 893.55	**2 849 373.13**	Mech replacement
6	96 861.28	28 751.08	47 162.46	12 187.90	2 757 154.38	0.00	0.00	**2 942 117.10**	
7	103 060.40	30 591.15	51 171.27	12 967.93	2 988 755.35	0.00	0.00	**3 186 546.10**	
8	109 656.26	32 548.98	55 520.83	13 797.88	3 239 810.80	0.00	0.00	**3 451 334.75**	
9	116 674.26	34 632.11	60 240.10	14 680.94	3 511 954.91	0.00	0.00	**3 738 182.33**	
10	124 141.42	36 848.57	65 360.51	15 620.52	3 806 959.12	0.00	736 971.39	**4 785 901.52**	Mech replacement
11	132 086.47	39 206.88	70 916.15	16 620.24	4 126 743.69	0.00	0.00	**4 385 573.42**	
12	140 540.00	41 716.12	76 944.03	17 683.93	4 473 390.16	0.00	0.00	**4 750 274.23**	
13	149 534.56	44 385.95	83 484.27	18 815.70	4 849 154.93	0.00	0.00	**5 145 375.41**	
14	159 104.77	47 226.65	90 580.43	20 019.91	5 256 483.95	0.00	0.00	**5 573 415.71**	
15	169 287.48	50 249.16	98 279.77	21 301.18	5 698 028.60	0.00	247 127.00	**6 284 273.18**	Mech replacement
16	180 121.88	53 465.10	106 633.55	22 664.46	6 176 663.00	0.00	0.00	**6 539 547.98**	
17	191 649.68	56 886.87	115 697.40	24 114.98	6 695 502.69	0.00	0.00	**7 083 851.62**	
18	203 915.26	60 527.63	125 531.68	25 658.34	7 257 924.92	0.00	0.00	**7 673 557.82**	
19	216 965.83	64 401.40	136 201.87	27 300.48	7 867 590.61	0.00	0.00	**8 312 460.18**	
20	230 851.65	68 523.09	147 779.03	29 047.71	8 528 468.22	0.00	1 370 461.71	**10 375 131.39**	Mech replacement
21	245 626.15	72 908.56	160 340.25	30 906.76	9 244 859.55	0.00	0.00	**9 754 641.27**	
22	261 346.22	77 574.71	173 969.17	32 884.79	10 021 427.75	0.00	0.00	**10 567 202.65**	
23	278 072.38	82 539.49	188 756.55	34 989.42	10 863 227.69	0.00	0.00	**11 447 585.53**	
24	295 869.01	87 822.02	204 800.85	37 228.74	11 775 738.81	0.00	0.00	**12 401 459.44**	
25	314 804.63	93 442.63	222 208.93	39 611.38	12 764 900.87	0.00	459 553.91	**13 894 522.35**	Mech replacement
26	334 952.13	99 422.96	241 096.68	42 146.51	13 837 152.54	0.00	0.00	**14 554 770.82**	
27	356 389.06	105 786.03	261 589.90	44 843.89	14 999 473.36	0.00	0.00	**15 768 082.24**	
28	379 197.96	112 556.33	283 825.04	47 713.89	16 259 429.12	0.00	0.00	**17 082 722.36**	
29	403 466.63	119 759.94	307 950.17	50 767.58	17 625 221.17	0.00	0.00	**18 507 165.50**	
30	429 288.50	127 424.57	334 125.94	54 016.71	19 105 739.74	0.00	2 548 491.47	**22 599 086.94**	Mech replacement
31	456 762.96	135 579.75	362 526.64	57 473.78	20 710 621.88	0.00	0.00	**21 722 965.01**	
32	485 995.79	144 256.85	393 341.41	61 152.10	22 450 314.12	0.00	0.00	**23 535 060.27**	
33	517 099.52	153 489.29	426 775.43	65 065.84	24 336 140.51	0.00	0.00	**25 498 570.58**	
34	550 193.89	163 312.60	463 051.34	69 230.05	26 380 376.31	0.00	0.00	**27 626 164.19**	
35	585 406.30	173 764.61	502 410.70	73 660.77	28 596 327.92	0.00	854 580.05	**30 786 150.35**	Mech replacement
36	622 872.30	184 885.54	545 115.61	78 375.06	30 998 419.47	0.00	0.00	**32 429 667.99**	
37	662 736.13	196 718.22	591 450.44	83 391.07	33 602 286.70	0.00	0.00	**35 136 582.56**	
38	705 151.24	209 308.19	641 723.73	88 728.09	36 424 878.78	0.00	0.00	**38 069 790.03**	
39	750 280.92	222 703.91	696 270.24	94 406.69	39 484 568.60	0.00	0.00	**41 248 230.37**	
40	798 298.90	236 956.96	755 453.21	100 448.72	42 801 272.36	0.00	0.00	**44 692 430.16**	Residual value
Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**	
NPV Year 0 (7.0%)	2 228 574.33	661 501.84	1 456 229.10	280 418.07	83 863 484.62	15 096 905.29	1 320 202.41	**104 907 315.67**	
NPV Year 0 (9.0%)	1 552 135.22	460 716.21	966 783.98	195 302.78	55 802 954.73	14 819 897.85	914 948.18	**73 797 790.77**	
NPV Year 0 (12.0%)	986 954.94	292 955.23	575 418.04	124 187.02	33 320 723.38	14 422 936.31	560 887.61	**49 723 174.91**	

Operational & Maintenance Inputs

Annual Rates and Taxes			**Staff Member**	**Hrs/week per Indiv**	**No of Staff**		**Hourly Rate**
Services (Water, Elec	R	8 400.00	Process Controll	56	3		100
Property Tax Rate	R	- R/Prop Value	Trainee Process	30	2		70
Property Tax:	R	-	General Mainter	40	2		20
Total Rates and Taxe	R	8 400.00	Security	56	3		60
Electricity Pricing			Salary (Staff) Inc	8.4 % per year			
Electricity price incre	8.5	% per year					
Eskom Averaged cha	1.65	R/kWh	**Total Power Installed**				
Inflation/Discounted rates			Flow Meters	0 kWh	24 hrs/day		
			Paddle Wheel: :	2 kWh	24 hrs/day		
Inflation Rate @	6.4	%					
Interest Rate @	7.0	%					
Interest Rate @	9.0	%					
Interest Rate @	12.0	%					
Civil Maintenance	0.5	% of capital cost					
Mech & Elec Mainter	5	% of capital cost					



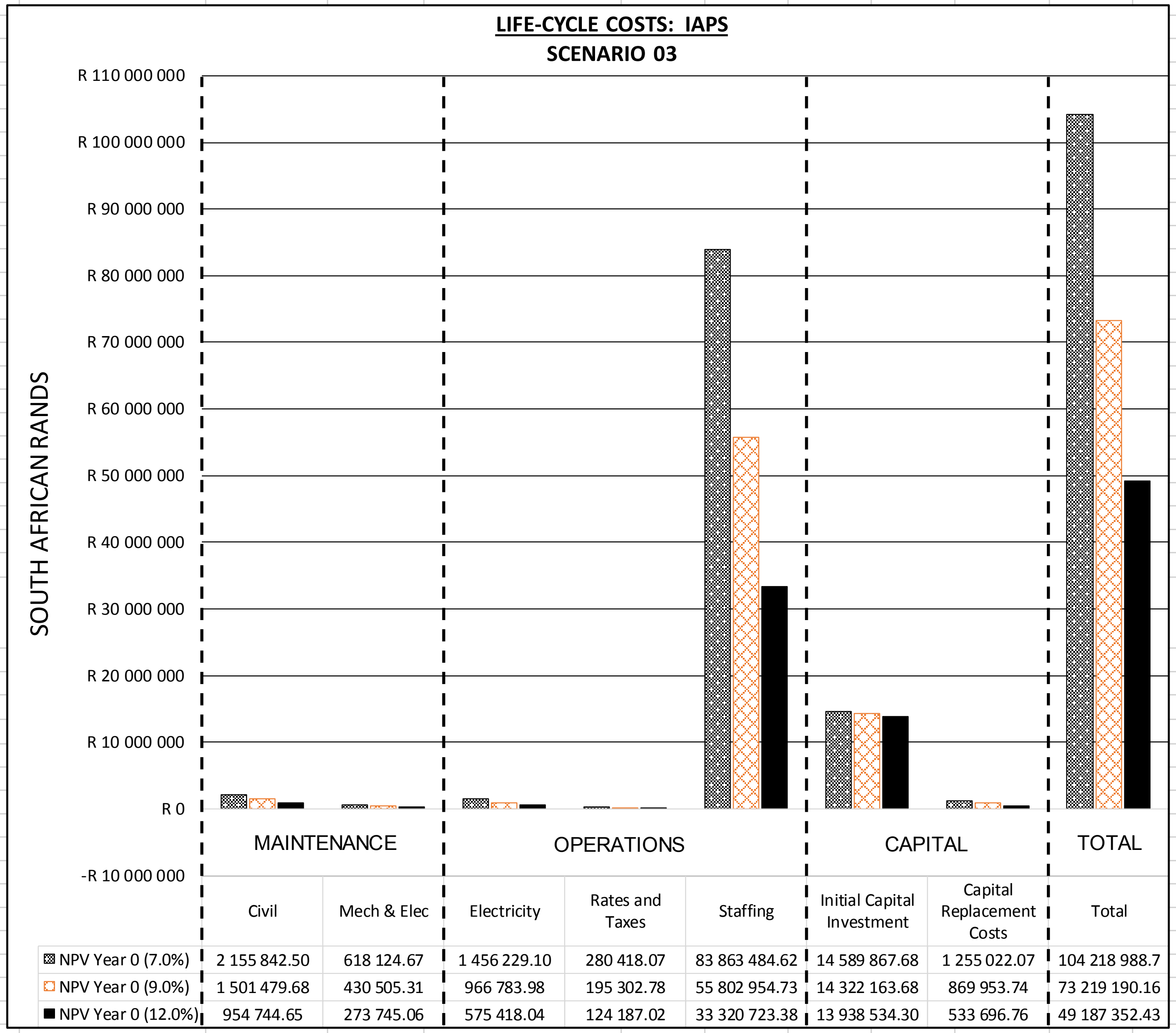
IAPS LCC Estimation: Scenario 03

Year	MAINTENANCE COSTS		OPERATIONAL COSTS			CAPITAL COSTS		Total	
	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Implementation	Cap. Replacement		
0	0.00	0.00	0.00	0.00	0.00	15 611 158.41	0.00	**15 611 158.41**	
1	68 711.90	19 701.12	31 365.18	8 937.60	1 842 106.24	0.00	0.00	**1 970 822.04**	
2	73 109.46	20 962.00	34 031.22	9 509.61	1 996 843.16	0.00	0.00	**2 134 455.45**	
3	77 788.47	22 303.56	36 923.87	10 118.22	2 164 577.99	0.00	0.00	**2 311 712.11**	
4	82 766.93	23 730.99	40 062.40	10 765.79	2 346 402.54	0.00	0.00	**2 503 728.65**	
5	88 064.01	25 249.77	43 467.71	11 454.80	2 543 500.35	0.00	132 893.55	**2 844 630.20**	Mech replacement
6	93 700.11	26 865.76	47 162.46	12 187.90	2 757 154.38	0.00	0.00	**2 937 070.62**	
7	99 696.91	28 585.17	51 171.27	12 967.93	2 988 755.35	0.00	0.00	**3 181 176.64**	
8	106 077.52	30 414.62	55 520.83	13 797.88	3 239 810.80	0.00	0.00	**3 445 621.65**	
9	112 866.48	32 361.16	60 240.10	14 680.94	3 511 954.91	0.00	0.00	**3 732 103.59**	
10	120 089.93	34 432.27	65 360.51	15 620.52	3 806 959.12	0.00	688 645.39	**4 731 107.75**	Mech replacement
11	127 775.69	36 635.93	70 916.15	16 620.24	4 126 743.69	0.00	0.00	**4 378 691.70**	
12	135 953.33	38 980.63	76 944.03	17 683.93	4 473 390.16	0.00	0.00	**4 742 952.08**	
13	144 654.35	41 475.40	83 484.27	18 815.70	4 849 154.93	0.00	0.00	**5 137 584.64**	
14	153 912.22	44 129.82	90 580.43	20 019.91	5 256 483.95	0.00	0.00	**5 565 126.33**	
15	163 762.61	46 954.13	98 279.77	21 301.18	5 698 028.60	0.00	247 127.00	**6 275 453.28**	Mech replacement
16	174 243.41	49 959.19	106 633.55	22 664.46	6 176 663.00	0.00	0.00	**6 530 163.61**	
17	185 394.99	53 156.58	115 697.40	24 114.98	6 695 502.69	0.00	0.00	**7 073 866.65**	
18	197 260.27	56 558.60	125 531.68	25 658.34	7 257 924.92	0.00	0.00	**7 662 933.81**	
19	209 884.93	60 178.35	136 201.87	27 300.48	7 867 590.61	0.00	0.00	**8 301 156.24**	
20	223 317.56	64 029.77	147 779.03	29 047.71	8 528 468.22	0.00	1 280 595.37	**10 273 237.65**	Mech replacement
21	237 609.89	68 127.67	160 340.25	30 906.76	9 244 859.55	0.00	0.00	**9 741 844.12**	
22	252 816.92	72 487.84	173 969.17	32 884.79	10 021 427.75	0.00	0.00	**10 553 586.48**	
23	268 997.20	77 127.07	188 756.55	34 989.42	10 863 227.69	0.00	0.00	**11 433 097.92**	
24	286 213.02	82 063.20	204 800.85	37 228.74	11 775 738.81	0.00	0.00	**12 386 044.63**	
25	304 530.66	87 315.24	222 208.93	39 611.38	12 764 900.87	0.00	459 553.91	**13 878 120.99**	Mech replacement
26	324 020.62	92 903.42	241 096.68	42 146.51	13 837 152.54	0.00	0.00	**14 537 319.78**	
27	344 757.94	98 849.24	261 589.90	44 843.89	14 999 473.36	0.00	0.00	**15 749 514.32**	
28	366 822.45	105 175.59	283 825.04	47 713.89	16 259 429.12	0.00	0.00	**17 062 966.10**	
29	390 299.08	111 906.83	307 950.17	50 767.58	17 625 221.17	0.00	0.00	**18 486 144.83**	
30	415 278.22	119 068.86	334 125.94	54 016.71	19 105 739.74	0.00	2 381 377.28	**22 409 606.76**	Mech replacement
31	441 856.03	126 689.27	362 526.64	57 473.78	20 710 621.88	0.00	0.00	**21 699 167.61**	
32	470 134.82	134 797.38	393 341.41	61 152.10	22 450 314.12	0.00	0.00	**23 509 739.83**	
33	500 223.44	143 424.42	426 775.43	65 065.84	24 336 140.51	0.00	0.00	**25 471 629.63**	
34	532 237.75	152 603.58	463 051.34	69 230.05	26 380 376.31	0.00	0.00	**27 597 499.02**	
35	566 300.96	162 370.21	502 410.70	73 660.77	28 596 327.92	0.00	854 580.05	**30 755 650.61**	Mech replacement
36	602 544.22	172 761.90	545 115.61	78 375.06	30 998 419.47	0.00	0.00	**32 397 216.26**	
37	641 107.05	183 818.66	591 450.44	83 391.07	33 602 286.70	0.00	0.00	**35 102 053.92**	
38	682 137.90	195 583.06	641 723.73	88 728.09	36 424 878.78	0.00	0.00	**38 033 051.57**	
39	725 794.73	208 100.37	696 270.24	94 406.69	39 484 568.60	0.00	0.00	**41 209 140.64**	
40	772 245.59	221 418.80	755 453.21	100 448.72	42 801 272.36	0.00	0.00	**44 650 838.69**	Residual value

Net Present Value	Civil	Mech & Elec	Electricity	Rates and Taxes	Staffing	Initial Capital Investment	Capital Replacement Costs	**Total**
NPV Year 0 (7.0%)	2 155 842.50	618 124.67	1 456 229.10	280 418.07	83 863 484.62	14 589 867.68	1 255 022.07	**104 218 988.71**
NPV Year 0 (9.0%)	1 501 479.68	430 505.31	966 783.98	195 302.78	55 802 954.73	14 322 163.68	869 953.74	**73 219 190.16**
NPV Year 0 (12.0%)	954 744.65	273 745.06	575 418.04	124 187.02	33 320 723.38	13 938 534.30	533 696.76	**49 187 352.43**

Operational & Maintenance Inputs

Annual Rates and Taxes				**Staff Member**	**Hrs/week per Indiv**	**No of Staff**	**Hourly Rate**
Services (Water, Elec	R	8 400.00		Process Controll	56	3	100
Property Tax Rate	R	-	R/Prop Value	Trainee Process	30	2	70
Property Tax:	R	-		General Mainter	40	2	20
Total Rates and Taxe:	R	8 400.00		Security	56	3	60
Electricity Pricing				Salary (Staff) Inc	8.4 % per year		
Electricity price incre		8.5	% per year				
Eskom Avaraged cha		1.65	R/kWh				
				Total Power Installed			
Inflation/Discounted rates				Flow Meters	0 kWh	24 hrs/day	
				Paddle Wheel: :	2 kWh	24 hrs/day	
Inflation Rate @		6.4	%				
Interest Rate @		7.0	%				
Interest Rate @		9.0	%				
Interest Rate @		12.0	%				
Civil Maintenance		0.5	% of capital cost				
Mech & Elec Mainter		5	% of capital cost				



Annexure 20: Stakeholder Ranking of Sustainability Aspects

Ranking of Sustainability Issues: Technical Stakeholders												
ISSUE DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Social	4	3	5	6	2	6	6	6	5		0.023	6
Health	2	1	4	4	1	5	3	5	1		0.038	2
Technical	5	5	6	3	3	1	1	3	3		0.033	3
Economic / Financial	1	4	1	2	4	2	4	2	4		0.042	1
Institutional	6	6	3	1	6	4	2	1	2		0.032	4
Environmental	3	2	2	5	5	3	5	4	6		0.029	5

Ranking of Sustainability Issues: Institutional Stakeholders												
ISSUE DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Social	6	6	5	5							0.045	6
Health	5	5	1	6							0.059	5
Technical	1	1	6	2							0.1	1
Economic / Financial	2	2	3	3							0.1	1
Institutional	3	4	4	1							0.083	3
Environmental	4	3	2	4							0.077	4

Ranking of Sustainability Issues: Social Stakeholders												
ISSUE DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	TOTAL	RANK
Social	1	6	4	1							0.083	3
Health	2	2	3	3							0.1	1
Technical	3	6	2	6							0.059	5
Economic / Financial	4	1	1	5							0.091	2
Institutional	5	3	5	2							0.067	4
Environmental	6	6	6	4							0.045	6

Ranking of Sustainability Issues: All Stakeholders																			
ISSUE DESCRIPTION:	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	SH11	SH12	SH13	SH14	SH15	SH16	SH17	TOTAL	RANK
Social	4	3	5	6	2	6	6	6	5	6	6	5	5	1	6	4	1	0.013	6
Health	2	1	4	4	1	5	3	5	1	5	5	1	6	2	2	3	3	0.019	2
Technical	5	5	6	3	3	1	1	3	3	1	1	6	2	3	6	2	6	0.018	3
Economic / Financial	1	4	1	2	4	2	4	2	4	2	2	3	3	4	1	1	5	0.022	1
Institutional	6	6	3	1	6	4	2	1	2	3	4	4	1	5	3	5	2	0.017	4
Environmental	3	2	2	5	5	3	5	4	6	4	3	2	4	6	6	6	4	0.014	5

Annexure 21: MCDM Ranking Results

MULTI-CITERIA DECISION MAKING STP Technology Selection
PERFORMANCE EVALUATION OF REALISTIC TECHNOLOGIES

TECHNOLOGIES EVALUATED:		**GENERAL COMMENTS:**
WSPo	Waste Stabilisation Ponds	Only complete cells marked:
CW	Constructed Wetlands	Refer to Relative Importance Scale for definitions Go to
IAPS	Integrated Algal Pond System	Options in rows are evaluated against those in columns
		CI = *Consistency Index* CR: *Consistency Ratio*

PERFORMANCE CRITERIA: C1 - SOCIAL
Criteria Description: Can easily be operated with limited resources (staff and equipment)

C1 - SOCIAL	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	**1.000**	5.000	7.000	3.271	0.731	Eigen Max	3.065	1.000
CW	0.200	**1.000**	3.000	0.843	0.188	CI	0.032	0.258
IAPS	0.143	0.333	**1.000**	0.362	0.081	CR	0.056	0.111

Comment: Adequately Consistent

PERFORMANCE CRITERIA: C2 - HEALTH
Criteria Description: Sufficient Buffer / Retention Time to accommodate shock loading / component fai

C2 - HEALTH	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	**1.000**	9.000	7.000	3.979	0.785	Eigen Max	3.080	1.000
CW	0.111	**1.000**	0.333	0.333	0.066	CI	0.040	0.084
IAPS	0.143	3.000	**1.000**	0.754	0.149	CR	0.069	0.189

Comment: Adequately Consistent

PERFORMANCE CRITERIA: C3 - HEALTH
Criteria Description: Effective Pathogen Removal without Chlorination / Similar

C3 - HEALTH	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	**1.000**	3.000	1.000	1.442	0.429	Eigen Max	3.000	1.000
CW	0.333	**1.000**	0.333	0.481	0.143	CI	0.000	0.333
IAPS	1.000	3.000	**1.000**	1.442	0.429	CR	0.000	1.000

Comment: Adequately Consistent

PERFORMANCE CRITERIA: C4 - TECHN.
Criteria Description: Technology has been tried and tested in the wider industry

C4 - TECHN.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	**1.000**	5.000	7.000	3.271	0.731	Eigen Max	3.065	1.000
CW	0.200	**1.000**	3.000	0.843	0.188	CI	0.032	0.258
IAPS	0.143	0.333	**1.000**	0.362	0.081	CR	0.056	0.111

Comment: Adequately Consistent

MULTI-CITERIA DECISION MAKING STP Technology Selection
PERFORMANCE EVALUATION OF REALISTIC TECHNOLOGIES

PERFORMANCE CRITERIA:	C5 - ECONO.
Criteria Description:	NPV/m2 of STP Land

C5 - ECONO.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	1.000	3.000	9.000	3.000	0.655	Eigen Max	3.080	1.000
CW	0.333	1.000	7.000	1.326	0.290	CI	0.040	0.442
IAPS	0.111	0.143	1.000	0.251	0.055	CR	0.069	0.084

Comment: Adequately Consistent

PERFORMANCE CRITERIA:	C6 - ECONO.
Criteria Description:	OCEAC Costs / Household

C6 - ECONO.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	1.000	3.000	9.000	3.000	0.655	Eigen Max	3.080	1.000
CW	0.333	1.000	7.000	1.326	0.290	CI	0.040	0.442
IAPS	0.111	0.143	1.000	0.251	0.055	CR	0.069	0.084

Comment: Adequately Consistent

PERFORMANCE CRITERIA:	C7 - FINAN.
Criteria Description:	Capital Cost

C7 - FINAN.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	1.000	0.500	7.000	1.518	0.346	Eigen Max	3.022	0.579
CW	2.000	1.000	9.000	2.621	0.597	CI	0.011	1.000
IAPS	0.143	0.111	1.000	0.251	0.057	CR	0.019	0.096

Comment: Adequately Consistent

PERFORMANCE CRITERIA:	C8 - INSTIT.
Criteria Description:	Simplified O&M Activities

C8 - INSTIT.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	1.000	3.000	5.000	2.466	0.637	Eigen Max	3.039	1.000
CW	0.333	1.000	3.000	1.000	0.258	CI	0.019	0.405
IAPS	0.200	0.333	1.000	0.405	0.105	CR	0.033	0.164

Comment: Adequately Consistent

MULTI-CITERIA DECISION MAKING STP Technology Selection
PERFORMANCE EVALUATION OF REALISTIC TECHNOLOGIES

PERFORMANCE CRITERIA:	C9 - ENVIRO.
Criteria Description:	Consistently achieve a reasonable level of effluent quality

C9 - ENVIRO.	WSPo	CW	IAPS	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY		IDEAL AHP: PRIORITY VECT.
WSPo	**1.000**	3.000	0.333	1.000	0.250	Eigen Max	3.018	0.382
CW	0.333	**1.000**	0.167	0.382	0.095	CI	0.009	0.146
IAPS	3.000	6.000	**1.000**	2.621	0.655	CR	0.016	1.000

Comment: Adequately Consistent

Scale of relative importance for Pairwise comparisons

RETURN TO PERFORMANCE CRITERIA
RETURN TO WEIGHTING OF CRITERION

Intensity of importance	Definition	Explanation
1	Equal importance	Two options contribute equally to the selection criteria.
3	Weak importance of one over another	Experience and judgement slightly favour one option over another.
5	Essential or strong importance	Experience and judgement strongly favour one option over another.
7	Demonstrated importance	An option is strongly favoured in its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one option over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

NOTE: A selection of 9 will represent the highest importance, while a selection of 1 will represent the lowest relative importance. Parameters can have the same score.

MULTI-CITERIA DECISION MAKING STP Technology Selection
WEIGHTING OF PERFORMANCE CRITERIA

PERFORMANCE CRITERIA DESCRIPTION:

C1 - SOCIAL	Can easily be operated with limited resources (staff and equipme
C2 - HEALTH	Sufficient Buffer / Retention Time to accommodate shock loadin
C3 - HEALTH	Effective Pathogen Removal without Chlorination / Similar
C4 - TECHN.	Technology has been tried and tested in the wider industry
C5 - ECONO.	NPV/m2 of STP Land
C6 - ECONO.	OCEAC Costs / Household
C7 - FINAN.	Capital Cost
C8 - INSTIT.	Simplified O&M Activities
C9 - ENVIRO.	Consistently achieve a reasonable level of effluent quality

GENERAL COMMENTS:

Only complete cells marked:
Refer to Relative Importance Scale for definitions — Go to
Options in columns are evaluated against those in rows
CI = *Consistency Index*
CR = *Consistency Ratio*

CRITERIA	C1 - SOCIAL	C2 - HEALTH	C3 - HEALTH	C4 - TECHN.	C5 - ECONO.	C6 - ECONO.	C7 - FINAN.	C8 - INSTIT.	C9 - ENVIRO.	EIGEN VECTOR	PRIORITY VECTOR	TEST FOR CONSISTENCY	
C1 - SOCIAL	**1.000**	0.500	2.000	0.333	3.000	2.000	3.000	1.000	0.333	1.080	0.095	Eigen Max	9.475
C2 - HEALTH	2.000	**1.000**	2.000	0.500	3.000	5.000	3.000	2.000	0.500	1.649	0.144	CI	0.059
C3 - HEALTH	0.500	0.500	**1.000**	0.200	3.000	1.000	2.000	3.000	0.500	0.915	0.080	CR	0.041
C4 - TECHN.	3.000	2.000	5.000	**1.000**	9.000	5.000	7.000	3.000	1.000	3.124	0.274		
C5 - ECONO.	0.333	0.333	0.333	0.111	**1.000**	0.500	2.000	0.500	0.333	0.445	0.039		
C6 - ECONO.	0.500	0.200	1.000	0.200	2.000	**1.000**	3.000	0.500	0.333	0.647	0.057		
C7 - FINAN.	0.333	0.333	0.500	0.143	0.500	0.333	**1.000**	0.333	0.200	0.354	0.031		
C8 - INSTIT.	1.000	0.500	0.333	0.333	2.000	2.000	3.000	**1.000**	0.200	0.799	0.070		
C9 - ENVIRO.	3.000	2.000	2.000	1.000	3.000	3.000	5.000	5.000	**1.000**	2.406	0.211		

Comment: Adequately Consistent

MULTI-CITERIA DECISION MAKING: STP Technology Selection

FINAL DECISION MATRIX AND OPTIONS RANKING

TECHNOLOGIES EVALUATED:

WSPo	Waste Stabilisation Ponds
CW	Constructed Wetlands
IAPS	Integrated Algal Pond System

PERFORMANCE CRITERIA DESCRIPTION:

C1 - SOCIAL	Can easily be operated with limited resources (staff and equipment)
C2 - HEALTH	Sufficient Buffer / Retention Time to accommodate shock loading / co
C3 - HEALTH	Effective Pathogen Removal without Chlorination / Similar
C4 - TECHN.	Technology has been tried and tested in the wider industry
C5 - ECONO.	NPV/m2 of STP Land
C6 - ECONO.	OCEAC Costs / Household
C7 - FINAN.	Capital Cost
C8 - INSTIT.	Simplified O&M Activities
C9 - ENVIRO.	Consistently achieve a reasonable level of effluent quality

FINAL PRIORITISATION USING ORIGINAL AHP

OPTIONS	CRITERIA									FINAL PRIORITY	SCORE OUT OF 100
	C1 - SOCIAL	C2 - HEALTH	C3 - HEALTH	C4 - TECHN.	C5 - ECONO.	C6 - ECONO.	C7 - FINAN.	C8 - INSTIT.	C9 - ENVIRO.		
	0.095	0.144	0.080	0.274	0.039	0.057	0.031	0.070	0.211		
WSPo	0.731	0.785	0.429	0.731	0.655	0.655	0.346	0.637	0.250	0.587	58.7
CW	0.188	0.066	0.143	0.188	0.290	0.290	0.597	0.258	0.095	0.175	17.5
IAPS	0.081	0.149	0.429	0.081	0.055	0.055	0.057	0.105	0.655	0.238	23.8

FINAL PRIORITISATION USING IDEAL MODE AHP

OPTIONS	CRITERIA									FINAL PRIORITY	SCORE OUT OF 100
	C1 - SOCIAL	C2 - HEALTH	C3 - HEALTH	C4 - TECHN.	C5 - ECONO.	C6 - ECONO.	C7 - FINAN.	C8 - INSTIT.	C9 - ENVIRO.		
	0.095	0.144	0.080	0.274	0.039	0.057	0.031	0.070	0.211		
WSPo	1.000	1.000	1.000	1.000	1.000	1.000	0.579	1.000	0.382	0.857	57.0
CW	0.258	0.084	0.333	0.258	0.4421	0.4421	1.0000	0.4055	0.1456	0.266	17.7
IAPS	0.111	0.189	1.000	0.111	0.0838	0.0838	0.0959	0.1644	1.0000	0.381	25.4

Annexure 22: STP Technology Advantages and Disadvantages

WSPo Advantages or Disadvantages			
Advantages		**Disadvantages**	
Description:	**Section:**	**Description:**	**Section:**
Community can be involved with most of the O&M activities.	4.6	Pond systems have difficulty to achieve all effluent quality parameters for discharge to a water resource according to the NWA GA.	4.6 & 6.2
Pond systems have high buffer potential in case of component failure / system overload.	4.6	Sludge removal can be complicated if not designed for from the start.	4.4
System works fully under gravity, thus not dependent on any electrical supply.	4.6	Requires the largest land area to comply with GA Discharge Standards to a Water Resource	5.4
Easily maintained by limited staff	4.4	Very high costs to build a STP that must comply with effluent discharge to a water resource.	5.8
Most effective use of land to treat effluent for irrigation purposes.	5.7	Not likely to obtain funding to build a STP that must comply with effluent discharge to a water resource.	6.3
Requires the least amount of staff to operate the STP	5.6	Legislation has imited the appication of the STP technology and approval of the STP is very dependent on interpretation of legislation by government official	6.5
Most O&M Activities can be performed by staff procured from the local community	5.6	Community has expectation that government must provide sanitation services. Thus it is not likely for the community to take ownership of the STP.	6.4
Very low costs to build a STP that must comply with irrigation standards.	5.8	STP's compliance dependent on the continued use of effluent by the local community.	6.5
Has the lowest O&M Costs of all STPs	58		
Has the lowest NPV/m2 of all STPs	5.8		
Has the lowest OCEAC/HH of all STPs	5.8		
Is the prominent technology currently used in the study area	5.8		
Effluent quality is consistent	6.6		
Can reduce pathogens without the need for chemical disinfection	6.6		
Likely to obtain funding for treatment of effluent for irrigation purposes, due to low Scenario 03 costs	6.3		
Can easily comply with NWA GA Standards for irrigation.	6.2		
Community is well aquanted with technology	6.5		
STP can be designed without the need for spare parts or for chemicals from outside of the region	6.5		
	18		7

CW Advantages or Disadvantages			
Advantages		**Disadvantages**	
Description:	**Section:**	**Description:**	**Section:**
Community can be involved with most of the O&M activities.	4.6	Community does not have skills to sample effluent through CW, nor to accutely establish health of CW.	4.6
Community can use their agricultural background to maintain the CW system	4.6	Pond systems have difficulty to achieve all effluent quality parameters for discharge to a water resource according to the NWA GA.	4.6 & 6.2
System works fully under gravity, thus not dependent on any electrical supply.	4.6	If reeds are not maintained then the system can fail	4.6
Use the smallest area of land to treat sewage for compiance with GA Discharge Standards for irrigation	5.7	Sludge removal can be complicated if not designed for from the start.	4.4
Requires the least amount of staff to operate the STP	5.6	Requires the second largest land area to comply with GA Discharge Standards to a Water Resource	5.4
Most O&M Activities can be performed by staff procured from the local community	5.6	Has the most activities to be performed within a month	5.6
Very low costs to build a STP that must comply with irrigation standards.	5.8	Very high costs to build a STP that must comply with effluent discharge to a water resource.	5.8
Has the second lowest O&M Costs of all STPs	5.8	Are not used in South Africa and WSPs are not that well acquanted with it.	4.4
Effluent quality is consistent	6.6	If the wetland component of the STP fails then the effluent quality immediate detoriorates	6.6
Likely to obtain funding for treatment of effluent for irrigation purposes, due to low Scenario 03 costs	6.3	Maturation ponds are required to reduce pathogens	5.3
Can easily comply with NWA GA Standards for irrigation.	6.2	Not likely to obtain funding to build a STP that must comply with effluent discharge to a water resource.	6.3
STP can be designed without the need for spare parts or for chemicals from outside of the region	6.5	Legislation is unclear on wetlands and has imited the appication of pond systems. The approval of the STP is very dependent on interpretation of legislation by government official	6.5
		Community has expectation that government must provide sanitation services. Thus it is not likely for the community to take ownership of the STP.	6.4
		STP's compliance dependent on the continued maintenance of the wetland and use of effluent by the local community.	6.5
	12		13

IAPS Advantages or Disadvantages			
Advantages		**Disadvantages**	
Description:	**Section:**	**Description:**	**Section:**
Community can be involved with most of the O&M activities.	4.6	Community can be involved with some of the O&M activities, but might struggle with some of the Concrete and M&E related activities	4.6
Pond systems provide buffer	4.6	Concrete and M&E Work cannot be provided locally	4.6
Land in rural areas have low value due to large areas being available.	4.6	Limited M&E components, but will still require electricity	4.6
Use the smallest area of land to treat sewage for compiance with GA Discharge Standards to a Water Resource	5.7	Sludge removal can be complicated if not designed for from the start.	4.4
Only technology apply to comply with NWA GA standards for discharging to a water resource	5.7	Requires the largest land area to comply with GA Discharge Standards for irrigation purposes	5.4
Most O&M Activities can be performed by staff procured from the local community	5.6	HRAP system not required for sewage treatment to comply with irrigation standards.	5.7
Effluent quality is consistent	6.6	Requires about three times as much staff than the other two options	5.6
Can easily comply with NWA GA Standards for irrigation.	6.2	Has the highest O&M costs of all technologies	5.6
		Very high costs to build a STP for all three effluent discharge scenarios	5.8
		Has the highest O&M costs of all technologies	5.8
		Has the highest NPV/m2 costs of all technologies	5.8
		Has the highest OCEAC/HH costs of all technologies	5.8
		Only one pilot plant used in South Africa and WSPs are not that well acquanted with it.	4.4
		If the paddlewheel component of the STP fails then the effluent quality immediate detoriorates	6.6
		Maturation ponds are required to reduce pathogens	5.3
		Not likely to obtain funding to build a STP for any of the discharge scenarios	6.3
		Legislation is unclear on iaps and has imited the application of pond systems. The approval of the STP is very dependent on interpretation of legislation by government official	6.5
		Community has expectation that government must provide sanitation services. Thus it is not likely for the community to take ownership of the STP.	6.4
		STP's compliance dependent on the continued operation of the plant. The alga by-product is too small in quantity to have a benefit to the greater community and will rather become a O&M complication.	6.5
	8		19

Annexure 23: Recommendations for future research

Evaluation of the current sewage effluent standards to promote sustainability and encourage development considering the current disparities within the South African developmental status

As part of this research, stakeholder engagement indicated that the effluent discharge standards are too strict to be achieved with low-technology options. This challenge was confirmed by the independent calculations performed as part of this research. South Africa utilises a combination of the Water Resource Quality Objective approach and the Uniform Effluent Discharge Standards approach. This approach has been adopted from the pre-Apartheid government.

South Africa has major inequality with a country that has characteristics from both a developed and a developing country. Inequality still needs to be fully addressed and requires an environment within which sustainable development is promoted. It is proposed that the unilateral application of the current effluent discharge standards be revisited to consider the Economic impacts these have.

It should be considered to rather use a matrix decision making process to select different effluent standards. The selection process must consider:

- Institutional and Financial Strength of the WSA and WSP.
- Nature of the receiving environment
- Self-purification process of the receiving water resources
- Time frames for incremental increases in the requirement for effluent discharge standards.

Establishment of a uniform approach to STP treatment efficiency scoring.

As part of this research, previous literature was reviewed to understand what technologies are being applied in the industry. The performance of these technologies were also evaluated. It became apparent that in previous literature technologies were evaluated based on land area per Person Equivalent (PE). Costs were also evaluated based on either cost per m^2 or Cost per PE.

The problem with these type of evaluations is that these technologies are possibly not being evaluated on a comparative basis. It is difficult to compare the economic performance of the same technology between two countries since the socio-economic differences could be too big to reconcile.

With required land area being a function of the raw sewage strength, required effluent quality and local climatology, it is also difficult to compare the performance of technologies with each other.

It is proposed to rather look at a more universal approach that transcends political boundaries. An option is to rather look at the biological processes to determine a removal efficiency coefficient. This coefficient can then be used to compare different technologies ability to treat a specific type of sewage more accurately. The coefficient will be a function of temperature, raw sewage complexity and the required effluent quality.

A universal coefficient as proposed will assist in better interpreting the Costs/m^2 or m^2/PE commonly reported on in literature.

Standardised Criteria for Sustainability Calculations for the South African Industry

Through the literature review it became apparent that designing for sustainability in the South African environment is very subjective. This varies very much from one professional team to another. Client, Policy makers and Engineers take turn in receiving blame for selecting an inappropriate technology for local application.

Having a standard method of interpreting and implementing sustainability will be beneficial to the local industry. Policymakers will understand what their policies are to promote. Design Engineers will understand what their designs needs to comply with, while Clients in turn will now what to look for when Engineer's propose a specific technology for implementation.

The standard criteria needs to be flexible enough to adapt to local conditions, while being resilient enough to comply with the National Strategy for Sustainable Development. Furthermore the criteria must be easily understood and straightforward enough to implement and govern.

Evaluation of the origin and motivation for the 1Ml/d limit to Pond-Systems.

Through engagement with Stakeholders it has become apparent that the origin of the 1Ml/d legislated limit on pond systems is unknown. It is possible that this is from old legislation that no longer applies but has been re-used without being challenged.

It is recommended that the origin of this limit be researched and challenged. If a pond limit is still required, it is recommended that research be performed into what a more realistic pond limitation should be. Any other control and monitoring requirements associated with the higher pond limitations should also be looked at.