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Partners for Water and Sanitation (PAWS)
Wastewater Treatment Works Assessments
Gauteng Province, South Africa

March 2009

Report prepared by Tom Wayling and Rob Smith of Anglian Water (UK), in collaboration with Department of Water and Environmental Affairs (SA) and Partners for Water and Sanitation.

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Executive Summary

The quality of many watercourses across South Africa has been declining for some years. This has been linked to an overall fall in wastewater treatment quality. It has manifested itself in high levels of eutrophication in rivers and increased costs of water treatment. The Department of Water Affairs (DWAF) is the national body for regulating compliance of wastewater treatment, amongst its other catchment management roles. DWAF has since become Department of Water and Environmental Affairs (DWEA), but this document refers to it as DWAF.

DWAF, in conjunction with others, initiated a major project designed to assess the status of wastewater treatment works. It also identified a critical shortfall in its capacity to carry-out these assessments. Consequently, a second part of the project was added, aimed at developing Young Professionals (YPs) from within the Regulatory organisation, DWAF, and the South African Institute of Civil Engineers (SAICE).

Recognising these shortfalls, DWAF sought the assistance of Partners for Water and Sanitation (PAWS). This request led to the enlistment of two experts from Anglian Water in the UK. The assessment programme was set-up to study three sites in a period between 9th and 18th March 2009. The main aims of the programme were to assess the three sites, provide a detailed report, and to start the process of building capacity.

The report, almost inevitably, details a number of issues and consequently could be perceived as rather negative in its bias. However, the object of the exercise was to report on an "as found" basis, so the reader's attention is drawn to the statement of evidence rather than necessarily singling-out any specific individual or situation.

The sites selected were Rooiwal (Tshwane Metro), Northern Works (Joburg City) and Meyerton (Mid Vaal LM). The selection was done on the basis of a cumulative risk score, using sanitary and hydraulic compliance as two major factors.

Common observations were made towards the way in which flows were handled, especially the loss of major parts of plant due to neglect and complex and restrictive funding arrangements. On Rooiwal, approximately 40% of total potential treatment capacity was being lost and thus heavily overloading the remaining plant. At Meyerton major aeration equipment was out of action, and the treatment process effectively lost.

In many cases there were large issues with competency, inexperience and effectiveness of staff. It was considered that Regulation 2834 was constraining flexibility on some sites. In general, management and supervision had the will to do a good job, but not the experience or knowledge. Capital and maintenance contracts fell short of being effective for local management. It was apparent that local management felt very much excluded in the contract process.

The design, configuration and application of BNR reactors was found to be ineffective on two sites, with little or no hope of achieving effective nutrient removal simultaneously with COD and ammonia treatment. Recent consultant reports had been done on both Rooiwal and Meyerton, but these had failed to either spot these issues, or draw sufficient attention to resolving them where found.

Northern Works was the exception in that it was being run reasonably effectively, and was complying with its sanitary standards. It was clearly overloaded hydraulically, but plans were actively in place to remedy this. Although the overall loading had the potential to impact on the environment, it was considered that the risk scoring should be revised to focus more on numerous other sites with much greater compliance issues.

Standby power was an issue at all three sites. Absence of standby power sources at major sites such as Rooiwal and Northern Works could, and most likely already had, led to significant pollution of receiving watercourses. Health and safety standards left a lot to be desired. Several issues were noted at all sites. Some of these were “design” in that capital construction left out important items such as fall protection barriers and some “people” in that limited attention was being paid to personal hygiene standards.

The YP part of the project did establish a firm grounding for development. The time available was short, but a growing level of engagement and excitement was apparent. The basic process knowledge of the YPs was lower than first expected, but they all showed significant learning and effort in the time available.

Recommendations were made on three levels, short-term (within 6 months), medium term (12 months), and longer term (three years). These timescales were stated based on practicalities and importance.

Major recommendations included refurbishing major essential plant, restoring it to normal function (e.g. biological filters at Rooiwal and floating aerators at Meyerton), and the installation and maintenance of adequate flow measurement and sanitary sampling processes - Without the ability to accurately measure flow and biological loadings it is impossible to correctly design and operate major works such as these. Maintenance of plant operationally needs to be properly organised and monitored, along with adequate levels of supervision. The cumulative risk scoring process needs revising to better reflect current trends and situations. The overall training and development strategy needs to continue, but to include ensuring appointment of quality supervision and management. The YP programme should be developed, and the assessment process widened to include all sites across municipalities as it would be expected to highlight many common factors (good and bad) that could then facilitate sharing of good practice and learning.

A basic financial evaluation of the works visited was also carried-out by others during this project. Whilst this did not directly involve the authors, they were involved in discussion of its findings. This evaluation is included as an appendix and forms part of the overall package submitted. Further assistance is offered towards process calculations, suggested sampling regimes and a glossary of terms in the appendices.

Acknowledgements

The authors extend their most sincere thanks to the following people and organisations, all of whom played their part in organising and facilitating the inspection visits. Thanks are also extended to the Young Professionals for their involvement and enthusiasm shown during the time in country.

Partners for Water and Sanitation

Ms. Amina Ismail, Country Manager South Africa, Partners for Water and Sanitation.
Ms. Rebecca Scott, PAWS Secretariat, Loughborough, United Kingdom.
Ms. Claire Twelvetrees, PAWS Secretariat, Loughborough, United Kingdom.

Department of Water Affairs and Forestry

Dr. Marlene van de Merwe-Botha (Water Group South Africa)
Mr. Clive Dudoo (Water Group South Africa)
Young Professional group of Sphelele Dlamini (DBSA), Reshoketswe (Shoky) Malepe (DWAF), Tebogo Marokana (DWAF), Philani Ndlovu (DBSA)
Other DWAF officials involved in the programme.

Municipalities in Gauteng Province

All of the management and staff at Rooiwal, Northern Works and Meyerton Wastewater treatment works.

Anglian Water

Mr. Paul Gibbs, Director of Wastewater services, for allowing the authors the time to undertake the visits and prepare the report.

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1) Introduction

This report details the work done as part of an overall project to examine the status of wastewater treatment in South Africa.

For some years it has been observed that the condition of the waterbodies (e.g. rivers and dams) in the country has been declining. This has been particularly evident with some rivers and dams becoming heavily eutrophied, and costs for water treatment rising.

The Department of Water Affairs and Forestry (DWAF) are the Government body responsible for many aspects of environmental protection. DWAF, along with other bodies such as the Department for Provincial and Local Government (DPLG), the Development Bank for South Africa (DBSA), the Water Research Council (WRC), and Water Institute of South Africa (WISA), have been involved in carrying out various studies in –order to seek suitable solutions.

Initial investigations by DWAF and associated bodies have highlighted that the compliance and condition of many wastewater treatment works (WWTWs) has been deteriorating. In many cases severe problems have been highlighted. Examples of major issues have included failure to comply with nutrient removal (i.e. phosphates and nitrates), and hydraulic overloading well beyond design capacities at plants. Information also showed several instances of not meeting sanitary limits (e.g. COD).

The Department of Water Affairs and Forestry (DWAF) have carried-out an initial high level assessment of a number of works in a number of provinces. One outcome of this assessment was the risk scoring of all of the works. This scoring facilitated a second stage to be initiated, this being the selection of three works for more detailed investigation. This assessment was performed on three of the selected works.

This project was initiated to focus on the Province of Gauteng, as this geographical area contains the large metropolitan areas of Pretoria and Johannesburg. These cities have large populations and large wastewater treatment works. The topography of the region also means that there are no major river systems for the works to discharge their effluents into. Hence, any discharge would be likely to have a disproportionate impact on the receiving watercourses, making compliance even more critical.

This initial work also highlighted an issue with lack of capacity and relevant skills in the Country as a whole to actually carry-out detailed assessments and take the work forward. Consequently, a project has been commissioned to enlist specialists from the UK water sector to carry-out these assessments, and to mentor some young professionals (YPs) in the process. Due to the lack of available skills, Partners for Water and Sanitation (PAWS) were asked to assist, subsequently sourcing the assistance of two wastewater staff from Anglian Water in the UK.

A major product of the First Order Assessment was that of a cumulative risk index score, rating all of the works in the Province against a number of criteria.

The three works selected by DWAF for this detailed assessment, based on these scores were:

(i) Rooiwal WWTW (Tshwane Metro, north of Pretoria)
(ii) Northern Works WWTW (Joburg City, northern Johannesburg)
(iii) Meyerton WWTW (Midvaal LM, south of Johannesburg)

The inspections programme was set for 9th - 18th March, 2009.

2) Objectives

The objectives of the programme are to build capacity using the DWAF Gauteng WWTW programme. This programme is to assess and identify municipal compliance both for effluent quality and hydraulic loading of the treatment plants. It also includes compliance to Regulation 2834, relating to skills requirements.

Within this context, the objectives considered on this visit session, and this report were

(i) To visit, inspect and assess each of the three chosen sites with regard to organic and hydraulic loading, set against design and compliance standards.

(ii) To assess the management, staff, technical and other arrangements at the three sites.

(iii) To start the process of building people based capacity by engaging and involving selected young professionals (YPs) in the above processes.

3) Deliverables

The expected deliverable outputs from this project were

(i) Joint site inspection and assessment of three chosen treatment plants. This to include data collection and taking of photographs.

(ii) Capacitating four YPs in performing WWTW compliance assessments.

(iii) Joint preparation and production of initial feedback (in country), and full reports (remotely).

Whilst not directly part of the remit, a financial evaluation of the sites to be visited was carried-out alongside the assessments work. The authors were not directly involved, but did engage in discussions on the subject whilst in country and since. This document is presented as a separate appendix.

4) Site Assessments

The following section deals with the actual site inspections, taking each site separately but covering the same generic areas. Whilst mentioned throughout, significant findings of both site-specific and higher level nature are discussed in later sections. The details listed were obtained largely from either discussion with on site personnel, or visual inspections. Some information and reference was also obtained from reports found during the visits.

5) Rooiwal WWTW

5.1) Site Details

Rooiwal WWTW is a large treatment plant, operated by Tshwane Metro, and is located approximately 30km to the north of Pretoria, adjacent to the R101. Site co-ordinates are 25^{o} 33'1. 81"S / 28^{o} 13'53. 20E. Its current classification is A, according to DWAF Regulations.

The site comprises of three separate works, East, West and North. The East works was the first to be built in 1954 as biological filter plant. The West works, also a biological filter plant, followed in the early 1960s, and the larger North works as an activated sludge plant in 1984. The sludge plant is a separate unit, located to the north of the main North works. No actual construction date was found, but it was estimated that this may have been in the mid 1980s. No information was available as to what happened to the sludge prior to this. Site staff did state reference to sludge cannons being used to disperse liquid sludge onto nearby land. They also stated that this had led to significant deterioration of the land quality (i.e. now too soft to access effectively). However, these we were not able to gain access to confirm or observe any of these elements at the time of the visit.

Whilst the whole site has a quoted theoretical capacity of approximately 245MLD, it was discovered that this is not the case in reality, due to on site problems and recirculation of flows. A consultant report prepared by SSI Engineers and Environment Consultants Pty Ltd (SSI) in late 2008 indicated a capacity split of West 40.8MLD; East 54.5MLD; and North 150MLD. However, it was not clear where this information was sourced or how accurate it may have been.

5.1.1) East Works

Biological filter works, of conventional design, being made-up of preliminary, primary, secondary (filters) and humus tanks. These are then followed by a disinfection stage, chemical dosing (ferric chloride) and maturation ponds.

Major Plant Listing Rooiwal East Works

Item of Plant	Total No.	No. in Use	Comments
Mechanical screens	2	1	One being worked on at time
Hand raked screens	2	2	
Detroiters	2	1	Downstream of failed screen
PST distributor	1	1	
Primary tanks (PST)	8	7	Poor quality operation
Biological Filters	16	10	Multiple poor or non operation
Humus tanks	12	12	Poor operation
Anaerobic digesters	8	8	Multiple issues
Gas Holder	1	1	Empty
Chlorine dosing	1	0	Not in use
Ferric Chloride dosing	1	0	Not in use
Maturation Pond	1	1	Poor operation
Return pump station	1	1	Returning to North Works

Whilst the East works has many of the pieces of plant and equipment normally associated with a conventional filter works, many of them were found to be either out of action, or performing very poorly. Figures 1 - 10 illustrate examples the following:

- (i) Fig 1 Mechanical screens out of use
- (ii) Fig 2 PSTs out of use
- (iii) Fig 3 PSTs "gassing up" or denitrifying, short circuiting
- (iv) Fig 4 Biological filters ponding due to overloading
- (v) Fig 5 Biological filters not in use due to mechanical issues
- (vi) Fig 6 Humus tank overloading
- (vii) Fig 7 Dosing equipment out of use
- (viii) Fig 8 Digesters leaking
- (ix) Fig 9 Empty gas holder
- (x) Fig10 Boiler out of use (due to lack of gas)

We were informed that the theoretical capacity of this works was some 58MLD. However, it was clear that this works was not able to cater for this share of the flow due to severe mechanical and technical issues and failures. In addition, no functioning flow measurement devices were observed, so it was not possible to gauge the actual amount of flow being directed into it.

At the time of inspection the effluent from the works was being pumped back up into the North works area for further treatment. This was said to be due to the poor quality. Site management stated that this was the case for at least the last 15 years. It is probable that this status has existed since the construction of the North works in the mid 1980s.

5.1.2) West Works

Like the East works, this too is a biological filter plant of conventional design. However, this works was found to be effectively mothballed, with only a very small amount of plant actually functioning at all.

Major Plant Listing Rooiwal West Works

Item of Plant	Total No.	No. in Use	Comments
Mechanical screens	0	0	Non existent & being bypassed
Hand raked screens	0	0	Non existent & being bypassed
Detroiters	0	0	Non existent & being bypassed
PST distributor	1	1	Not clear of flow direction
Primary tanks (PST)	6	4	Used to settle North site sludge
Biological Filters	12	0	Severe neglect & mech issues
Humus tanks	9	0	Not used as no flow in filters
Anaerobic digesters	7	7	Very poor condition
Gas Holder	2	1	One disused, one poor condition
Chlorine dosing	0	0	Not present
Ferric Chloride dosing	0	0	Not present
Maturation Pond	0	0	Not present

Akin to the East works, the West works also has many of the pieces of plant and equipment normally associated with a conventional filter works, but many of them were found to be either out of action, or performing very poorly.

However, in this case, the situation was far worse, the works effectively being out of use. The only exceptions to this were the psts and the digesters, but even these were not being operated very effectively. The psts were being used to re-settle the primary sludge from the North works, and the condition and operation of the digesters was certainly in doubt.

Figures 11-17 Illustrate examples the following:

- (xi) Fig 11 Inlet works abandoned and taken apart.
- (xii) Fig 12 Inlet works abandoned and taken apart.
- (xiii) Fig 13 PSTs re-settling north works primary sludge
- (xiv) Fig 14 Biological filters totally out of use
- (xv) Fig 15 Biological filters not in use due to mechanical issues
- (xvi) Fig 16 Digesters leaking
- (xvii) Fig 17 Empty gas holder

Interviewing of site staff indicated that the capacity of the West works was approximately 40MLD. However, the treatment process had been effectively abandoned, so all of this load would be passed directly to the North works site.

When questioned as to the reasons for this action, various comments were offered, including a failure of site staff some 18 months previously. We were informed that a decision was made (it was not clear by whom) to return the filtrate flows from the sludge treatment plant onto these biological filters. Such filtrates would have contained high quantities of polymer, which would have been harmful to the process, especially if not put through primary settlement first. We were also informed that the inlet works had suffered significant damage from trees falling. Inspection of the inlet works indicated that whilst this may have occurred, the neglect appeared far greater and longer in time. (See figures 11-12).

The psts were being used only to re-settle and thicken primary sludges from the North works psts, as they were so thin. Site staff told us that the supernatant flows from the primary tanks passed to the West works humus tanks (i.e. bypassing the filters). The "effluent" from these was then pumped back up to the North works downstream of the psts. The flow diagram obtained from site implied that the supernatant was passed to the bioreactors 3.1 and 3.2. Site staff were not able to confirm this flow direction. Furthermore, they were not able to confirm the fate of the sludges from either the psts or the humus tanks, but the suggestion was that they were being passed over to the aerobic digester and thus up to the sludge dewatering plant. There was the suggestion that the sludge went into the West works digesters, but this was not confirmed.

5.1.3) North Works

The newest of the three individual works, being some 25 years old. This plant was built as an activated sludge plant, utilising biological nutrient removal (BNR) technology. However, no detailed information as to the original design configuration existed.

It is possible that originally there was no ammonia limit. If this was the case, then nitrates would not have been present in the RAS recycle as none would have been formed from the ammonia. With no nitrates, the phosphate removal would have been possible. However, this is considered an unlikely scenario.

The plant consists of preliminary screening and grit removal, followed by psts; two balance tanks, 6 BNR reactors, final settlement tanks (fsts), disinfection, and maturation ponds.

A certain proportion of the effluent from the maturation ponds was said to be pumped over to the adjacent power station. However, no precise quantity of this flow was obtainable, as it is not measured in any way. Management estimated that this may be up to 45MLD.

Primary sludge was being passed over to the West works for secondary thickening at the time of inspection. Site information implied that this could be either to the East works, or the West works digesters. Waste (surplus) activated sludge (WAS or SAS) was being dealt with by a combination of aerobic digestion, and a dissolved air flotation (DAF) unit.

The capacity of the works was quoted as being approximately 150MLD with actual dry weather flows of around 130MLD. However, we were informed that rainfall could easily raise this flow up to approximately 250MLD. Site observations also implied higher flows, even though conditions were dry. Figure 18 shows the inlet flumes in "flooded" conditions, so flow figures obtained are probably not reliable?

In contrast to the East and West works, most of the plant did seem to be in use and in reasonable condition visually.

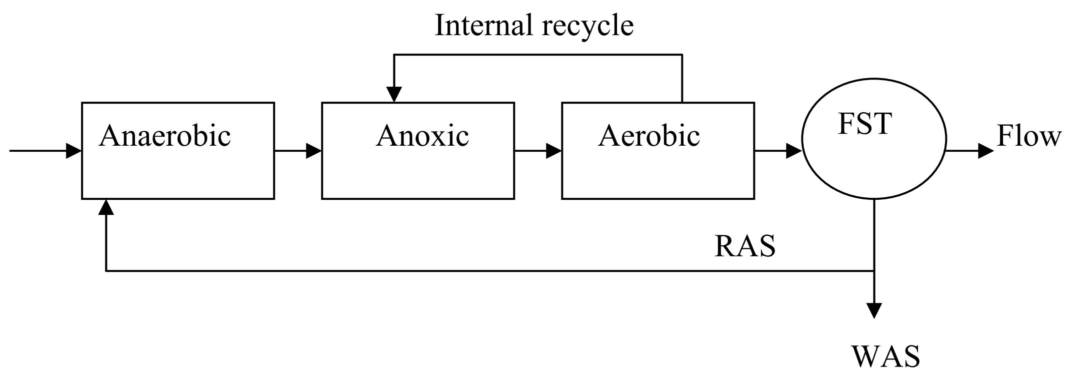
Major Plant Listing Rooiwal North Works

Item of Plant	Total No.	No. in Use	Comments
Mechanical screens	2	1	
Air lift degritters	6	6	
Primary tanks (PST)	3	3	Wholly overloaded
Balance tanks	2	2	Pumped inflow, gravity out
BNR reactors	6	6	Doubts on configuration
Final settlement tanks	18	18	
Disinfection	1	1	
Maturation Pond	2	2	Heavy solids loading
Aerobic digester	1	1	Not effective
Overflow tank	1	0	Empty at inspection
Drum thickeners	2	0	Not in use
Return pump station	1	1	Pumps to sludge dam
RAS pump station	3	3	

5.1.4) North Works Biological Nutrient Removal (BNR) Process

The North works consists of 6 BNR reactors, set in pairs (1.1 & 1.2; 2.1&2.2; 3.1& 3.2) (see Fig 19). These units were said to be designed as 3 Stage Phoredox units for biological removal of both phosphorus (P) and nitrogen (N). The diagram below (Jansen et al) indicates the flow patterns and configuration of this system.

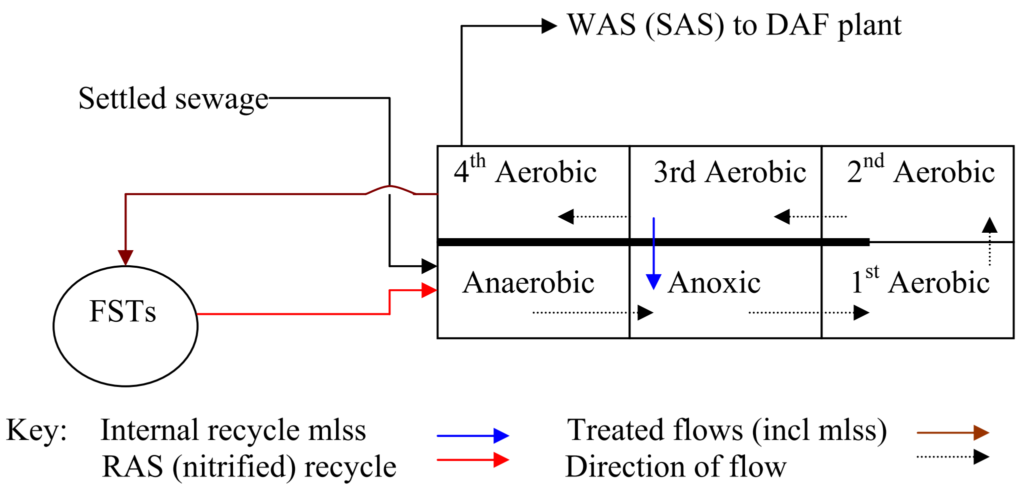
Figure 20, Literature Design Configuration for 3 Stage Phoredox Process:



From site observations, it was found that the system configuration was not suitable for reliable biological removal of phosphorus, due to the feeding of nitrified RAS directly into the anaerobic zone. The result of this would be to turn the anaerobic zone into an anoxic zone. This system relies on a high internal recycle to anoxic zone for maximum denitrification prior to the FST stage.

Anaerobic zones work in the absence of oxygen. Anoxic zones work with no elemental oxygen, but do include "bound" oxygen in the form of nitrates and or phosphates. The presence of oxygen in the form of nitrates in the anaerobic zone would hinder the release / uptake of phosphates. There would be preferential use of the nitrates (before phosphates) as an oxygen source.

Figure 21: The diagram below illustrates what was found to be present in reactor 3.



It was observed that there was an internal recycle from 3rd stage aerobic into the anoxic zone, providing a substrate feed for this zone. RAS flows from the FSTs were being pumped directly into the front end of the anaerobic zones.

Closer inspection found that the original pipe and channel construction actually fed these flows into the front of the anoxic zones. However, the RAS screws had been taken out of action (fig 22) and replaced by pumps closer to the FSTs. These pumps passed the RAS flows along long, above ground pipelines (fig 23), depositing it into a channel close to the incoming settled sewage flows and thus directly into the front end of the anaerobic zones. Site staff were not able to confirm when or why this action was taken. The net result of this action was to provide a feed of nitrate bearing RAS into the anaerobic zone, thus hindering the P removal process. This is of course, assuming that the aerobic process was converting the ammonia to nitrates in the main bulk of the reactor.

It should be noted that this arrangement has been effected for reactor three only. For reactors one and two the RAS screws were still in use. However, no detailed information was obtained as to the reasons or effectiveness of these different set-ups.

The air control for the reactors was observed to be poor and restrictive. Only one manifold existed, and this fed to 24 actuated valves. Achieving a good air balance across the reactors would have been very difficult.

5.1.5) Sludge Handling and Treatment

The handling and subsequent treatment of sludge was being carried out in a number of different stages. The extent of actual treatment performed was limited, but did include some attempts at anaerobic digestion, thickening and dewatering. This section describes the plant observed at the three separate works, and then deals with the dewatering facility separately.

East Works Sludge Handling Plant and Equipment

The east works has eight anaerobic digesters reportedly of approx. 17570m3 total capacity. Site management did state that these were overloaded. They also stated that daily sludge production was 40-60tDS per day, but they did not clarify if this was before or after digestion.

All of these were seen to be in a relatively poor condition, and some showing signs of leaking sludge (fig 8). The methane gas generated should be collected in a nearby gas holder, but this was seen to be empty (fig 9). There was also a boiler (fig.10) intended for burning the gas to provide steam injection heating and mixing of the digesters. This too, was out of action, due to the lack of gas. Site staff informed us that the digesters were not separately heated, and so the digestion was being carried-out at ambient temperatures. Air temperature on the day was approximately 25^{o}C. This temperature is below a more ideal 37^{o}C required for effective mesophilic digestion (and assumes that no heat loss occurred through the concrete walls of the structures). No information was available as to the feed rates of the digesters. The nearby psts were also only desludged manually, so digester feed would have been erratic, irrespective of actual volumes and rates.

Digested sludges are passed to a pumping station, and thus up to the sludge-holding dam for entry into the dewatering process. Figure 24 shows the apparent erratic nature of the pumping process. That is, the wet well has clearly been overflowing onto the surrounding ground. Site staff were of the opinion that this was due to the lack of capacity in the holding dam causing back-ups, but were unable to substantiate this with any recorded detail. (E.g. recorded well levels, pump run hours or activities) This had led to MLSS levels rising from 4000mg/l to 7000mg/l. This would be detrimental to treatment. This situation also raised question as to the effectiveness of site supervision.

West Works Sludge Handling Plant and Equipment

There are seven anaerobic digesters and two gas holders. Observed condition was very similar to that at the east works. In this case the extent of leakage was much worse (fig 16), sludge being observed around the base of structures and down along a nearby access road. Considering the extent of the spills, it would seem that this sludge had been leaking for some time.

One of the gas holders had been out of service for some time and the other said to have an internal gas bag in a perished condition. Again, there was a boiler, but this too was out of use due to lack of gas. Consequently, these digesters were only operating at ambient temperatures. Digested sludges are then passed to a pumping station, and thus up to the sludge-holding dam for entry into the dewatering process.

These digesters were receiving flows from the west works psts, but this was originally generated in the north works as no treatment of flows was being carried out in the west works.

North Works Sludge Handling Plant and Equipment

The north works generates both primary sludge and activated sludges. These are dealt with separately until they reach the sludge holding dam.

Primary sludge from the psts was said to be very thin, and in need of further settlement to thicken them. This sludge was being pumped over to the psts in the west works for gravity settlement. Observation of this process showed this sludge to be black and most likely septic in these tanks (fig.13). After settlement it was then being sent to the west digesters, and thence onto the holding dam.

Waste activated sludge (WAS or SAS) was being pumped from the BNR reactors and FSTs into the dissolved air flotation (DAF) plant and the aerobic digester (fig 25). The intention of this process was to perform some degree of thickening prior to pumping to the holding dam (and therefore reduce pumped volumes). However, little evidence as the effectiveness of this process was available. There were also two drum thickeners present (fig.26), but these were not being used. The reason given for this was that it was not possible or practical to pump sludge over 2% dry solids. This is regarded as an odd comment, as it is common practice in the UK to pump sludge between 3-6% dry-solids. Site management also made some comments to the effect of the control PLCs (Programmable Logic Controls) being too complex for available site skills to operate.

Sludge Holding Dam and Dewatering Facility

All of the sludge produced ultimately ends up in the sludge dewatering facility, located to the north of the treatment sites (fig.27).

The sludge arrives through one of three pumping mains, which deposit their flows very close to the bank area (fig 28). Sludge is initially aerated to liberate gases before being pumped into the dewatering building. The condition of the pumps and the general area was seen to be poor, with several mechanical tasks apparently started but not finished (fig.29). There was considerable evidence of the dam overflowing (fig.30), lack of maintenance (fig.31), and security (fig.32).

Inside the building there were three sludge gravity belt thickeners, all of which were in use (figs 33). Whilst the equipment appeared rather old and rather worn, the product did appear to be reasonable for this process. Figure 34 shows the cake product, which was estimated at approximately 15 – 20% dry solids. There was a small lab and some limited analytical equipment present, but staff were not able to provide any specific detail as to sludge characteristics.

As is commonplace with this type of equipment, a cationic polymer was being dosed to encourage separation of solids and water. The dosing system appears to have been changed around several times in recent years, resulting in a large quantity of redundant or unused equipment (fig.35). Polymer is purchased in 1000 litre IBCs (Intermediate Bulk Containers), and the dosing system although working, seen to be a little unorthodox. (fig 36). Discussion with site staff also implied that this chemical was expensive, but this may have been due to the fact it was being imported from Switzerland. It is possible that bulk delivery, if available, may be more cost effective.

Dewatered cake drops onto a belt conveyor and is passed to a further inclined conveyor outside the building (fig.37). This second unit then elevates it up into the raised 400m3 capacity holding hopper (fig 37). The condition of these conveyors was old, but they were functioning.

Tractors towing slurry spreaders are then used to collect cake from the hopper (via bottom doors). The cake is then taken out for spreading onto the nearby land. There are two tractor units, each of which carries 12 tonnes and makes 30 return trips over a 24hr period. This equates to a movement of approximately 750 – 800 tonnes of cake product every day. Assuming a dry solids rate of 18%, this then represents an application of approximately 140 tDS (tonnes dry solids) per day. However, as the land area used was not known, the application per hectare could not be determined.

Dewatering liquors (i.e. water extracted from the sludge, including polymer, and washwater used to clean the belts) are returned to the main site for treatment. No information was available as to exactly where these re-entered the treatment train, but it was assumed that they would end-up in the north works as all flows ultimately did. Hence, any nutrients released from the sludge would produce a load onto the BNR process at some point.

The SSI report stated that each belt capacity was 250kg DS/hr/meter belt. This equated to a capacity in the region of 45tDS/day in total. This supported the earlier statement of site management that overall sludge daily production was approximately 40-60tDS/day.

The quoted daily sludge product volume was approximately 750tonnes, and 45tDS is the daily dry solids site feed to the sludge dewatering plant.

Each machine has capacity of 625kg DS/hr. This equates to 45tDS/day in total. Therefore, as site product rate was said to be 750 tonnes / day, some doubt must be expressed as to the volumes quoted for cake removal. As 750 tonnes per day at between 15-20% DS would equate to a belt throughput of some 130tDS per day. This is clearly well in excess of the rated belt capacity.

Visual inspection of the cake did suggest that it was in the region of 15 – 20% dry solids.

With the above calculations, either the product volume per day is incorrect, or the belt capacity is wrongly quoted.

It was reported that the sludge spreaders were only three years old, having been sourced from Ireland. Their condition was seen to be poor, and one was missing a wheel, but was still being used (fig.38). Using this equipment in this condition would have accelerating its eventual breakdown.

5.2) Sanitary and Non Sanitary Compliance

Rooiwal does have standards set by DWAF for a number of determinands. Some of these are the conventional "sanitary" items, such as COD, suspended solids and ammonia. Others are "non-sanitary", such as electrical conductivity and faecal coliforms. However, it was not possible to fully determine if these have been set based on an historical and empirical basis, or if they related directly to the needs and capacity of the receiving watercourse (the Apies River). The SSI report quoted these as:

Effluent Standards for Rooiwal WWTW

Determinand	Maximum Limit (mg/l)
Chemical oxygen demand (COD)	50
Total suspended solids (TSS)	10
Ammonia (as N)	1.0
Phosphate (as P)	0.9
Nitrate (NO3 as N)	6.0
pH	6.5 – 8.5
Faecal coliforms (CFU/100ml)	150
Electrical conductivity (mS/m)	80
Residual chlorine (ug/l)	0.2

These indeed do represent a sizeable challenge for this works to reliably meet.

At the time of the inspection no actual licence was in place, which was considered to be a potential hindrance to any enforcement action. It was also considered to be a potential barrier to making a good case for investment funding.

5.2.1) Historical and Current Compliance

Little or no historical compliance information was available on site. However, the first order report and risk score certainly placed the compliance as poor. General observations on site supported this.

First order assessment shows significant non-compliance, with some of the determinands being rather erratic (e.g. COD and TSS).

Determinand	July -Dec 07	Jan -July 08	12-13 Jan 09	25-26 Jan 09
	(1st order)	(1st order)	(site)	(site)
Faecal Colif (150)	> 5000 CFU	>5000 CFU		
Conductivity (80)	Av 80mS/m	Av 75 mS/m	54.6	60.0
TSS (10)	> 50 mg/l	> 50 mg/l	35.6	8.4
COD (50)	>100 mg/l	>100 mg/l	26	181
Phosphates (0.9)	> 4 mg/l	> 4 mg/l	1.73	2.53
Ammonia (1.0)	> 7 mg/l	> 5 mg/l	4.21	0.91
Nitrate (6.0)			4.06	4.48
pH (6.5 – 8.5)			7.96	8.00
Chlorides ** (0.2)			58.6	61.1

** quoted as mg/l, but standards are in ug/l.

The above results were taken from the First order report and the only sample analysis sheets obtainable from site at the time. Items highlighted in red indicate direct non-compliance with the standards. These and the patterns of results shown across the period indicate a number of concerns:

(i) Sample analysis only seems to have been done on an approximately once or twice a month basis. This is considered insufficient for a works of this size. It also does not allow accurate plotting of trends or incidents.

(ii) The only site information available was two sheets covering 12-13th Jan and 25-26th Jan 2009. Whilst this covered a whole page, it only actually examined the north works secondary sedimentation (i.e. fsts) effluent and the final effluent.

(iii) The items covered were not all of those listed in the effluent standards (i.e. nothing was listed for faecal coliforms).

(iv) The sheets also listed analysis from the "west works effluent". This may be of use to gauge the impact on the north works to which it pumps, but is of little use as an effluent as the works does no biological treatment.

(v) No evidence was found to indicate that the works was actually complying or fully treating its flows.

Very little data was available on site. Little or no evidence existed to demonstrate that compliance was being monitored in a real structured manor.

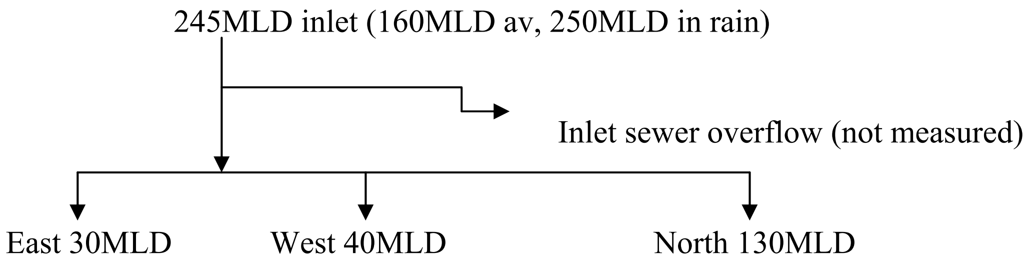
It was quoted that the incoming sewage had strength of COD up to 1000mg/l. However, no evidence was obtained on site to verify this, and therefore it was not possible to perform any biological loading calculations.

5.3) Hydraulic Compliance

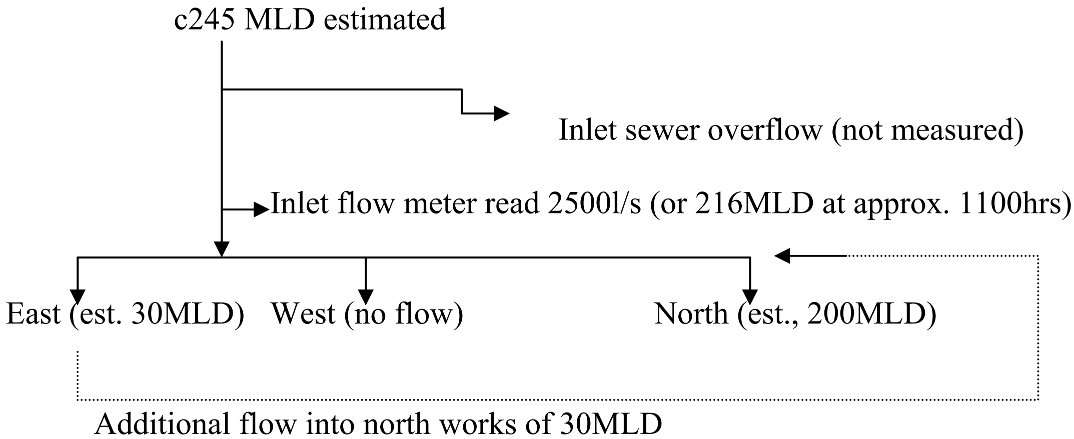
The Rooiwal works site has a nominal hydraulic capacity of approximately 245 MLD. However, the term compliance here only relates to the flows versus the capacity, as no licence standard is set for volumes or rates of flow.

Although the site has three separate treatment streams, the way in which it was being run effectively means that all flows have to pass through the north works.

Site staff report that the approximate flow splits were:



Site investigations showed this to be different in reality:



Hence, although the north works was nominally capacity of 150MLD, it actually had to pass all flows.

It must be noted that none of these flow figures can actually be relied on as flow measurement was found to be either in a poor state, or non-existent.

Figure 18 shows three measuring flumes downstream of the north works psts. All three of these were either "flooded flumes" or in poor physical condition. In order to achieve accurate flow measurement in a flume it is necessary to create a functional "standing wave", with a free fall away from the flume. In addition to being flooded, some of the upstream valves appeared to be partially closed. This was causing upstream turbulence, which would lead to inaccuracies.

A single flow meter read-out was observed at approximately 1100hrs on the third day, in a control panel in the north works inlet (i.e. before psts). This read at 2500l/s (equivalent to 216MLD). However considering the state of (or lack of) measuring equipment on site, this could not be relied upon.

All of the flow measurement equipment on the west works inlet (closer to the psts) was old and not in service (fig 39). No serviceable flow measurement was observed on the east works.

It was reported that there is a scheme currently in place off site, which would divert some element of the flows away from the east works. It was estimated that this would reduce the flows down to approximately 10MLD.

However, this was not due to take effect for a further three years, so was not considered any further in this report.

5.4) Site Monitoring

The level of site monitoring or inspection was observed to be very light. No evidence of any structured programme was found. This was the case for work orders, supervision and asset telemetry (or SCADA) monitoring.

5.4.1) Work Orders and Supervision

Whilst it was made clear that literacy was an issue in the workforce, no evidence of either written or alternative work instruction was found. This was a bit surprising, seeing as a works of this size would require a large number of maintenance tasks to be carried-out. The number and frequency of such tasks would be significant. Hence, relying on staff to "remember" all of the required actions and timings would be very likely to result in them not being done.

The only reasonable alternative to this would be for supervision to issue tasks and monitor their completion on a daily basis. It was clear that the level of suitable staff for this type of operation did not exist.

In any case, the recording of maintenance tasks is an essential action to facilitate necessary changes in regimes, repair, replacement or refurbishment planning and to ensure compliance is being achieved.

Site management did refer to the existence of the computer programme SAP. This software has the capability to be used to plan, issue and record work activity of a variety of types. This is the case down to single asset level if set-up correctly. (It also has costing functionality). However, comments from staff were that it "wasn't very accessible". It was not clear if this was due to lack of staff training / competence, lack of IT access, or a combination of both.

5.4.2) Asset and Effluent Monitoring

There are various ways in which to monitor the performance of assets. These range from the simply physical "go and look at it", to the more complex and remote "command and control" versions of SCADA systems.

No evidence of any real automated and continuous monitoring of plant and equipment was found. No telemetry or SCADA system was present, albeit staff did refer to plans for a SCADA system at some point in the future. There were some auto-analysers on the final effluent from the BNR reactors on the north works. These were set-up to monitor phosphorus, ammonia and nitrates. These were not functioning on the days of the inspection. Furthermore, they were not linked back to any recording devices other than those in the sampler control building.

Hence, the only real method of monitoring was based on staff actually inspecting the plant and effluent streams. Other than the sample data seen, no records appeared to be kept of this so effectiveness was not easily judged.

5.5) Staff

The nominal staff numbers required by DWAF regulations was quoted as 106. The actual numbers said to be currently in post was 50.

This was split as per below:

Position	Nominal Number	Actual in Post
Functional Head	1	1
Senior process controller	4	2
Process controller	18	4
Tractor driver	10	5
Supervisor	5	2
Tool store attendant	4	1
Motor and pump attendant	34	15
General worker	30	20
Total	106	50

A clear observation was that there are some key posts not filled (i.e. process controllers and supervisors). Site management did state that they had experienced difficulty in recruitment and retention, but were not clear as to the main reasons for this.

The staff on site were working a type of 24/7 pattern. This divided into three shifts of eight hours, but a large proportion of them worked only the standard day shift. This left the more essential work to be done by a very small number of people.

Day shift: 0700hrs – 1500hrs (5 people)
Late shift: 1500hrs – 2300hrs (5 people)
Night shift: 2300hrs – 0700hrs (5 people)

Of these shifts of five people, they were divided up as follows:

East works (predominantly inlet) 2 people
North works (inlet etc) 2 people
Process controller (normally on north) 1 person

This arrangement was clearly being impacted by the lack of process controllers.

The remaining staff were predominantly general workers, being on site between 0700hrs and 1545hrs.

5.6) Power and Standby Arrangements

No detailed inspection was carried out on the power supplies, but they are reported to be old and in need of upgrading. No facilities for standby power generation were found at any point on the site.

5.7) Health and Safety

Whilst some degree of effort had been extended towards safety, several areas were observed to be of concern. These in themselves did not necessarily result in non-compliance of standards, but were definitely a threat to staff well being (and therefore the site operation!).

These included:

(i) Use of gaseous / liquid chlorine: Whilst none of this was actually in use, gaseous and liquid chlorine is highly toxic and dangerous. Whilst it is accepted there is a need for disinfection, this method represents a major potential hazard to both site staff and potentially any nearby members of the public. No observations were made as to the condition of the equipment as it was considered unsafe to enter the chlorination buildings. Chlorine gas equipment should not be worked on (e.g. changing containers over) without the wearing of full breathing apparatus to protect staff from any leaks.

(ii) Use of personal protective equipment: Most of the site staff were observed to be wearing general ppe, such as overalls and boots, but no means all. Figure 1 shows work being done on the east works screens. Some staff can clearly be seen not wearing any ppe. No use of gloves was observed at any point on site (even when handling sludge at the digesters).

(iii) Drinking water supplies: Clearly in a hot climate it is important to keep hydrated with drinking water, and any taps on site should be clearly labelled. Some labelling on taps was observed (fig 40), but the presence of drinking water taps adjacent to sewage and sludge tanks poses a very high risk of infection and back siphonage into the potable supply.

(iv) Explosive gases: With a number of anaerobic digesters on site, the presence of methane is always likely to be high. There were some signs indicating "no smoking", but these were very limited.

(v) Confined Spaces: The presence of confined spaces on any wastewater plant is common. Also commonplace is the potential for toxic or flammable/explosive gases – typically hydrogen sulphide (H2S) and methane respectively. H2S is highly toxic at even low concentrations. No evidence was observed as to how these were being controlled (e.g. procedures for entry into spaces which may contain these gas states).

(vi) Machinery: Pumps and other associated equipment often have fast moving parts, which can entrap and harm the unwary. Some evidence of caution was observed (e.g. on north works blowers – fig 41), but this did seem limited.

(vii) Slips, Trips and Falls: Hand railing was in place in a number of locations, but absent in many others. An example of this was the sludge holding dam. The psts were fitted with a long protruding arm designed to trigger the descum valves. This projected approximately 1meter out from the tank, with no protection for any nearby staff. Whilst the tank bridge moves only very slowly, anybody working nearby could be caught unawares and swept into the tank.

In addition, the sludge dewatering dam offered no fall protection or life saving devices. Aerated sludge normally offers less buoyancy than water, so anybody falling in would struggle to stay afloat without high-level buoyancy aids.

5.8) Significant Observations and Conclusions - Rooiwal WWTW

1) Hydraulic Conditions

The initial desktop first order study suggests that the site is up to, but not exceeding its design capacity of 245MLD. Whilst it was clear that the site is hydraulically stressed, it was very difficult to determine the precise nature of the problem.

Little, if any reliable flow measurement was observed. No real reliance of flow data could be determined due to lack of actual measurement, apparent lack of calibration and maintenance of meters and flooded condition of measuring flumes (north works).

Perhaps the most significant factor in terms of hydraulics was that due to flow diversions on site, the north works had in fact to deal with virtually all flows. Such a condition meant that the other two works were in effect being wasted, and thus the north was heavily overloaded.

It was not clear precisely why this situation had arisen, but it had existed for some years. It was considered that a decision might have been made when the north works was built that it could replace the east and west works. Evidence on site implied that this was not a good decision, and no real consideration had been given to its impacts since. This also implied a lack of current knowledge or expertise.

The 2008 consultant report did talk of areas relating to the flow management, but failed to draw sufficient attention to them. It did recommend a further flow-balancing dam, but did nothing to address the lost capacity in the east and west works. Considering the time spent on that study it was surprising that very little attention had been apparent on the more fundamental issues of what was actually on site and how it was being managed.

Question is also drawn on the initial scope of the report. The executive summary stated that it was a feasibility study for the upgrading not extension of the site. However, the report did not appear to fully consider the root causes of the problems, and therefore perhaps did not fully address the correct issues.

Furthermore, if deciding that a further flow balance dam was appropriate, then it is not understood why this should be placed downstream of the primary treatment phase. As was quickly evaluated in the YP calculation exercise, the hydraulic loading on the north works primary tanks was far in excess of recommended values. Siting balance facilities downstream of these would do nothing to remediate this. Statements were made that the topography of the site meant that the dams would have to be lower down. If it was understood that this dam would be pump fed like the existing two dams were, then levels would be less critical and it could have been built upstream of the primary stages.

This was also relevant for the two existing balance dams, which would have perhaps then left space for gravity fed primary tanks. It was considered that this amount of expenditure would have been better applied to constructing more primary tank capacity on the north works.

The consultant report made early mention of the effective non-use of the east and west works, and then concluded therefore to only look at the north works. This is considered an unusual decision, as it would be possible to improve the whole situation by examining the feasibility of re-activating these plants.

2) Organic or Biological Loading

Similar to that of hydraulics, this was being hugely impacted upon by the internal diversion of flows. The effective closure of the west works deprived the whole site of approximately 20% capacity. Furthermore, the poor condition of the east works and ultimate re-treatment in the north works was costing the site a further 20% capacity.

Whilst there was some degree of treatment being achieved in the east works, this was probably less than 50% of what might have been possible if the site had been loaded correctly.

Site staff informed us that a part of the inlet works had been badly damaged by weather. Closer inspection suggested that the whole area had literally been abandoned and subsequently neglected. No timescale could be determined, but it was considered that this had been some years ago and was perhaps done in the same hope that the then new north works would deal with the flows.

The secondary phase of the west works had been abandoned and neglected. Many of the filter arms and equipment had been removed or were inaccessible due to vegetative growth. It could not be confirmed, but it would seem that approximately two years ago a lack of site supervision resulted in sludge press filtrate being pumped directly over the filter beds. This effluent would contain a very high level of ammonia bearing polyelectrolyte, and would have almost certainly caused rapid damage to the biological process. No efforts had been expended to remedy this situation since, but any attempted would have been very costly.

The east works was being used, but much of the equipment was either out of use or heavily overloaded. Equipment issues included missing distribution arms, and damaged or broken centre column bearings. The consequence of not having all of the filters operational was that those in use were heavily overloaded, causing severe ponding and very poor effluent.

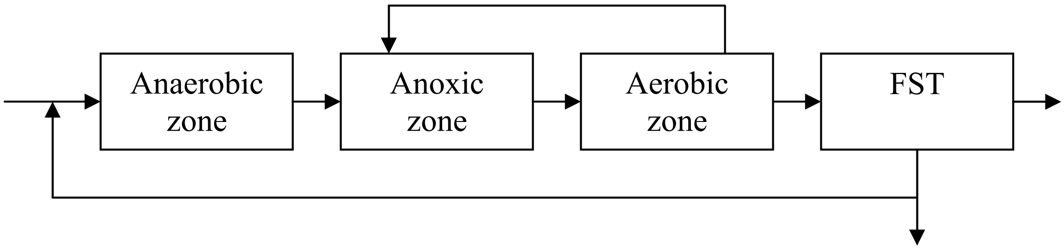
Site management did refer to the rather restrictive purchasing rules preventing them from sourcing repairs or replacements. However, a relatively simple cost-benefit analysis would almost certainly have concluded that having to re-treat and manage all of the effluent in the north works was proving far more expensive than replacing / repairing the filter arms and columns. Refurbishment of this distribution plant would be a straight-forward process for any reasonably competent contractor provided they could source the bearings and seals. The civil structures did appear to be in reasonable condition.

3) BNR Configuration

We were told initially that the north works was being run in a Phoredox configuration. However, site inspection did contradict this. Combined removal of both nitrogen and phosphorus biologically can be achieved by a number of ways, but all are based on modifications of the original Bardenpho system.

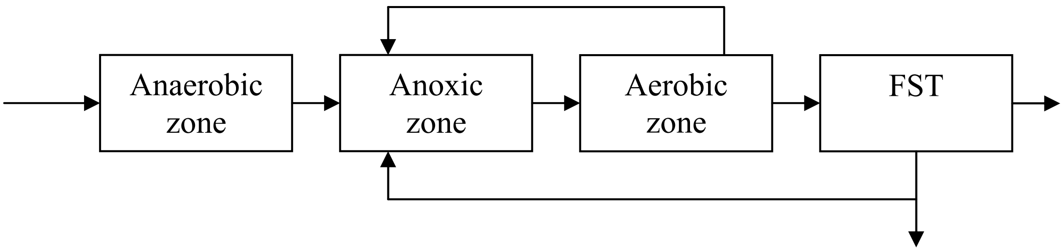
The basic configuration found on site was as fig 90 (a) and (b) below.

(a)



The original design construction was found to be:

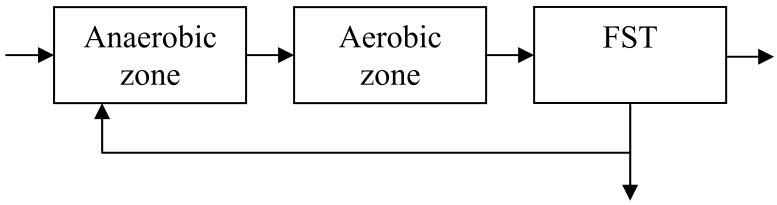
(b)



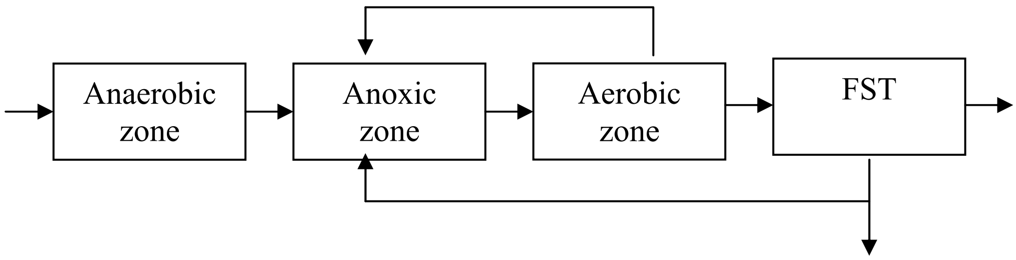
Rooiwal North works has three separate BNR reactors. Figure 90 (a) above was found to be only on reactor three. Reactors one and two retained their original configuration. (i.e. (b) above). This may have reduced the concentration of nitrates entering the anaerobic zones for these reactors. However, it is likely that some nitrates were still present due to higher climatic temperatures (Wastewater Handbook).

Fig 91shows the basic arrangements of some of these various systems (taken from Jansen et al, 2002 and Wastewater Handbook)

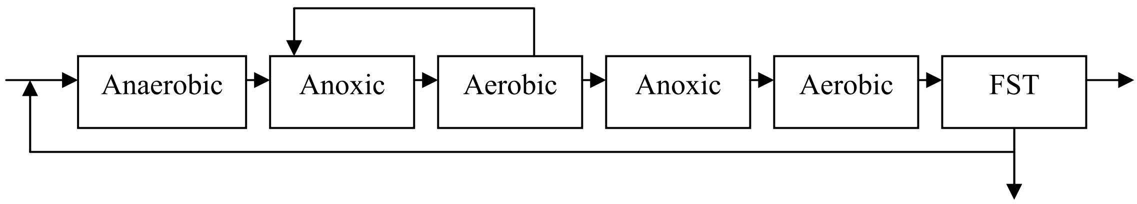
1) <u>Phoredox</u>



2) <u>Modified pre-D and A^2/O</u>



3) <u>Modified Bardenpho (5stage)</u>



As can be seen, the original design configuration matches closer to the "Modified pre-D and A^2/O arrangement. The modification achieved by diverting the RAS made the system into a form of the modified Bardenpho, but without the benefit of the secondary anoxic zone to further remove nitrates. A full Phoredox modification would have added these.

Literature sources (Jansen et al and Wastewater Handbook) suggest that the configurations attempted at Rooiwal were likely to suffer from problems with nutrient removal.

Jansan et al (2002) state that the Bardenpho process was not originally intended for removal of phosphorus. They also describe that the Phoredox system does suffer from passing nitrates into the anaerobic zone, and being dependent on a high internal recycle to the anoxic zone to maximise denitrification. The five stage versions insert a secondary anoxic zone to be more sure of successful denitrification prior to the FST stage. They also quote significant contact times as being necessary:

Anaerobic 1 – 2 hrs; Anoxic 2 – 4 hrs; Aerobic 3 – 8 hrs; Anoxic (2) 2 – 4 hrs; Aerobic (2) 0.5 – 1 hrs

It was not clear whether or not these were being achieved at Rooiwal considering the high flows.

Other sources (Wastewater Handbook) state that the Phoredox system is only really applicable if nitrogen removal is not required. If so, then it would not be necessary to maintain high sludge ages, nor is it required to have an anoxic zone for denitrification. Furthermore, they state that in hotter climates it is not possible to completely prevent nitrification even at low sludge ages, so presence of nitrates in the RAS would be inevitable.

In summary, the configuration both by design and modification was considered unlikely to be successful at reliably removing both N and P whilst achieving full carbonaceous and ammonia removal. Full conventional treatment of the COD and ammonia would result in nitrates, which would then inhibit P removal. Incomplete nitrification would lower the loading on the anaerobic zone, but then increase effluent ammonia levels. The consultant report did suggest the possible conversion to the Johannesburg process, but did not bring this into the executive summary or recommendations.

4) Staff Quantity and Quality

Several issues were found in this area. The total quoted contingent was 106, against an actual presence of no more than 50. Clearly, such a lack in resources was placing a heavy burden on getting work done.

A number of staff were said to be of poor educational standards. This was clearly limiting the work that could be carried out by them to more menial tasks such as grounds maintenance. There were a number of people observed on site not actually doing very much. On the days of inspection less than 10 people were actually observed to be doing any technical work. Some were seen to be working on the inlet screens at the east works, but we were later told that some of these were outside contractors. Despite the numbers potentially available, and an amount of equipment being available, several areas of the site (particularly the east works) required improvements in grounds work.

A series of discussions were held with site management, and they appeared to possess some degree of knowledge and experience. Site supervision was less strong, showing a strong desire to do a good job, but definitely lacking in the experience needed for such a large works.

It was not totally clear, but the implication was that the constraints of Regulation 2834 were causing issues. It is understood that this documents does stipulate staff types and numbers required. Whilst this has good intention of ensuring adequate experience and capabilities, it was clearly not working on this site. The balance of staff listed was very much biased towards the less technical roles.
Looking at the nominal numbers, only 23 out of 106 were in technical roles (i.e. only 22%). The actual technical roles filled numbered only 7 from 50 (a mere 14%).

A large and complex works such as this requires a much greater flexibility to recruit more technical roles at the cost of less technical ones. It is possible that some roles (e.g. grass cutting) could potentially go out to contract?

Furthermore, little or no role definition seemed to exist. No job role outlines or descriptions were seen. It is essential that every member of staff fully understand their role. The role of motor and pump attendant was vague. Discussions with site staff implied that they did little more than watch the pumps and then report any failures. As this group were one of the larger on site, expanding their tasks to actually maintaining and fixing pumps would have been useful.

No effective supervision was apparent. No clear supervisory role was evident from the nominal structure. If such task was expected of the site manager or senior process controllers then this was not obvious. Also, due to the size of the site and the low numbers of these people it is unlikely that they would have been able to achieve any effective supervision.

5) Lack of Site Maintenance and Monitoring.

No structured process for maintaining the mechanical, electrical and process issues was observed. Within the municipality it was known that the SAP system did exist. This does have the capability of planning and recording works maintenance schemes. However, site management did state that it was "not very available". It was not clear if this was due to IT issues, or lack of training and authorised access.

Not withstanding lack of computerised access, no localised systems were seen. Some basic local "tick / check list" would have been hugely beneficial in planning, informing, executing and recording tasks at both staff and managerial levels. In the absence of these, it had to be assumed that much of the work done was on a reactive basis.

No automatic monitoring system was in place. This could have been either telemetry or SCADA. Staff did mention the expected access to SCADA, but could not give any timescale. Such a lack meant that the site was hugely exposed to failures going unnoticed for some time. There were auto analysers on the north works effluent, but they were broken on the day, and were reliant on somebody checking them everyday.

Several areas of the site were suffering from lack of attention. Examples of such included equipment not working due to mechanical breakdowns that may have been prevented by regular lubrication and adjustment. Grounds maintenance standards were far from consistent across the site, despite there being a significant number of staff potentially available.

The digesters on both east and west works were not functioning correctly. Their physical condition was poor, and several of them were leaking sludge. If sludge can leak out then gas can also. This was evident in that the gas holders were empty. No gas meant that the boilers were not working, so the digesters were not being heated. No heating meant that the process was incomplete and no gas was being generated. Furthermore, incomplete digestion was then imposing a greater load on downstream processes. (E.g. sludge dewatering would be more difficult).

Several sludge spillages had not been cleaned-up for some time. This indicated both lack of attention by staff, and less than adequate supervision.

A form of effluent and process sampling was seen, but was considered to be wholly inadequate for the site needs. It is essential to do regular checks to fully understand how each part of the process is performing. Examples of such would include daily ammonia and turbidity levels, at least weekly MLSS and RAS concentrations, along with sludge settleability (SSVI), also regular P and N levels across the different reactors.

6) Site Capacity

The initial observations did suggest that the site is severely lacking in capacity. However, due to many of the factors mentioned in the above sections, this can in no way be properly quantified. No reliable judgement can be made without a series of sustained and verified measurements being made on flows, actual unit capacities and biological factors.

7) Standby Power Generation

This did not exist on site. This posed a huge threat to continued compliance and operations. Some mention of power shortfalls were discussed, which did include mention of power cuts, but no plans appeared to be in place. Only a very small proportion of the site could operate without power. Significant environmental damage would be highly likely if this condition continued.

8) Health and Safety

This area has been detailed previously, but the overall attention to safety was considered to be inadequate. Several areas were noted that were presenting threats to the overall safety and well being of staff. Some of these were due to the staff themselves (e.g. no gloves being worn), and some more by design (e.g. unprotected drinking water taps very close to contamination sources).

5.9) Rooiwal – Ways Forward

This section contains a brief outline of the suggested early ways to make progress on this site. It is not exhaustive, nor necessarily in chronological order.

- Set-up and implement localised monitoring and supervisory regime across the whole site.
- Implement "technical" and "people" based training for supervisory and leading-hand personnel, in conjunction with WSSCU programme.
- Formally assess all site staff against structured guidelines linked to WSSCU.
- Implement plan of immediate calibration of flow meters, followed by regular (at least twice yearly) programme of repeat calibrations. This may also require the installation of some new ones to measure flows not currently measured.
- Devise and implement programme of sampling across the site. This to determine the actual flows and loads being received and dealt with at different stages of the site, compared with design capacities.
- Implement programme of immediate repairs to all biofilter arms and centre columns – especially on the east works.
- Implement plan of repairs to civil structures of digesters to restore full mesophylic digestion stages.
- Critically examine the configuration of the BNR plants in relation to full treatment of COD, ammonia and nutrients.
- Carry-out cost-benefit analysis of reinstating the west works against enhancing the north works.
- Examine the rationale and outputs of the recent consultant report, to ascertain if best value for capital investment is likely to be achieved.

6) Northern Works WWTW

Northern Works WWTW is a very large treatment plant, indeed the largest in South Africa. This site is operated by Johannesburg Water (JW), a semi-private company wholly owned by Johannesburg City Council. The history of this arrangement is such that it was originally directly operated by the City Council. In 2000 operational control passed to a French contractor. This contract lasted for five years, after which Joburg Water was formed in its present state. All assets are owned by the City Council, but JW are effectively autonomous and have the ability to raise capital on the assets.

The site is located in the northern area of Johannesburg, close to the Diepsloot area, at co-ordinates 25°57'2.31"S/27°59.18"E. It is classed as a category A site under DWAF regulations. The total land plot was said to be approximately 400 hectares. Discharge of FE is to the Jukskei River.

The site has a total theoretical flow capacity of 630MLD, but this is based on the outfall capacity of the incoming (2.9m diameter) sewer rather than the site itself. Actual likely total capacity was reported as being 540MLD. Whilst divided into five nominal treatment streams, there were only three in practical use at the time of inspection. These streams are named Units 1, 2, 3, 4 and 5.

Unit one was built as a biological filter plant in 1962. Unit two followed as a second biofilter plant in 1963, unit three then came on line in 1979 as the first of the activated sludge plants. Unit four, also an activated sludge plant followed this. Unit five was under construction at the time of inspection.

The current configuration is such that unit one is only used for "internal" flows, and unit two has been largely demolished to make way for unit five. Approximate hydraulic capacities were given as below.

Treatment stream	Capacity (MLD)	Comments
Unit one	50	Not used for FE production
Unit two	50	Largely demolished
Unit three	150	BNR Activated sludge process
Unit four	260	BNR Activated sludge process
Unit five	(50)	Under construction
Total	410 (460)	Plans for future expansion in place

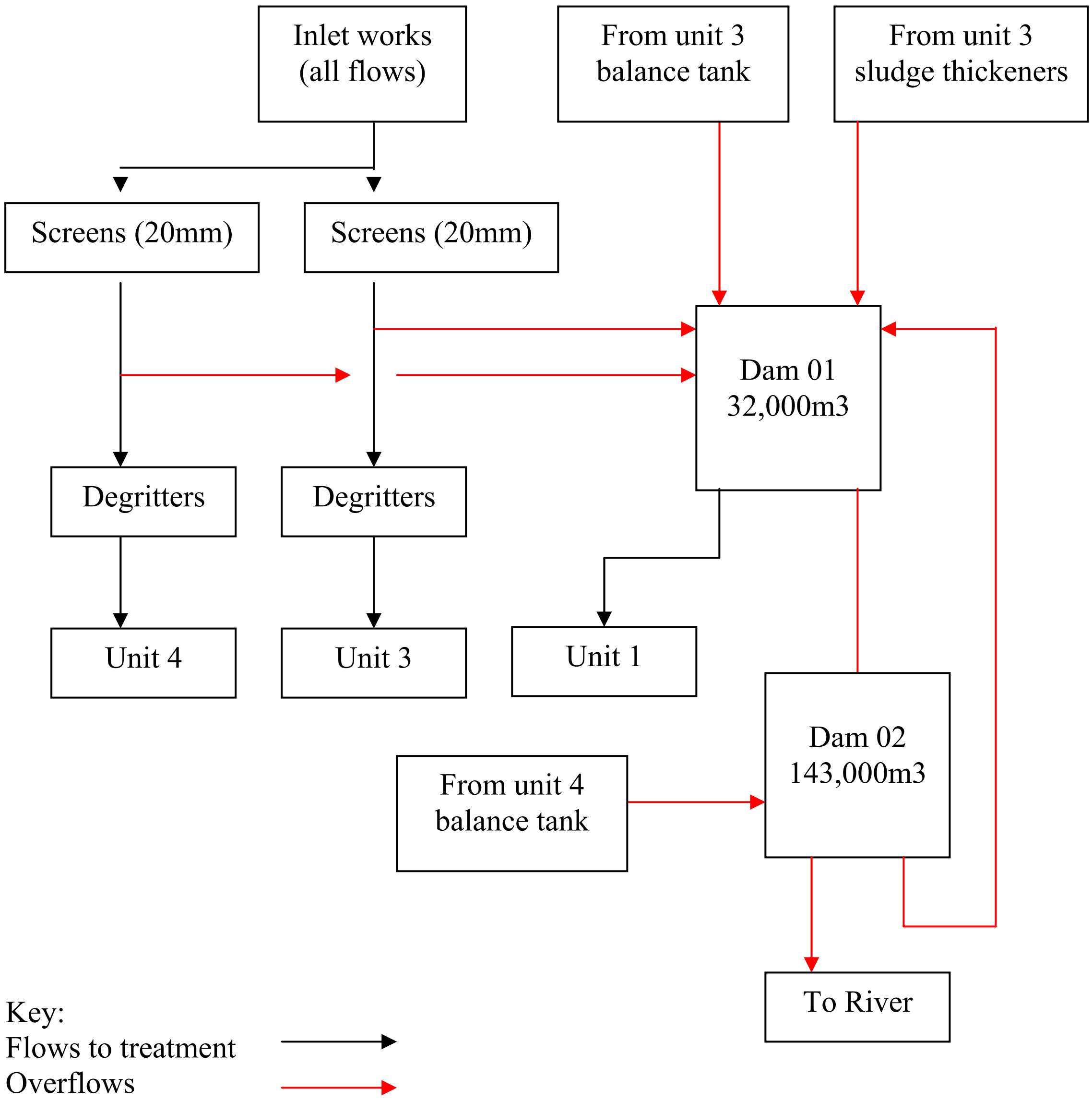
Sludge is dealt with on site by a combination of digestion, belt thickening and composting (referred to as the "Jo-Gro" process). It was stated that approximately 70% of the sludge produced is directly caked (i.e. dewatered) and then sent onto local farms. The costs of this transport is borne by JW, but administered by a separate head office department. The remaining 30% of cake is put though the composting process. The product compost is then sold on to the public.

Site management also stated that further plans were being progressed for on-site solar drying beds. When implemented, the plans are to deal with 70% of sludge cake on site in this process. The expectation was that this would be effective in the 2010/11 year.

6.1) Site Details

The site has a common inlet and preliminary stage. This consists of flow splitting, storm overflow gate, automatic screens and airlift degritting processes. Also part of this stage are two balancing dams of 32,000m3 and 143,000m3 capacity. These are used for flow balancing, receiving flows from a number of sources, and distributing them to either unit one or overflowing to river. Fig 42 below describes this flow management.

6.1.1) Northern Works WWTW, Preliminary Flow Management



As this diagram shows, all flows are subjected to screening and degritting before being passed to treatment. In addition, flows are split off to balancing dams prior to any of the primary treatment stages. (Albeit there are further flow balancing tanks later in the process). All grit and screenings removed are collected and stored in skips (fig.43), for subsequent removal from site to landfill by a separate department of the City Council.

6.1.2) Unit One

Constructed in the early 1960s, as a biological filtration plant with a nominal capacity of 50MLD. At the time of inspection this unit was only being used for treatment of "on-site" flows and overflows. The unit is set-up as a double-filtration process (i.e. flows are passed through two sets of filter beds, with an intermediate humus tank settlement stage). No reason was given for this configuration.

Major Plant and Equipment Listing for Unit One

Item of Plant	Total No.	No. In Use	Comments
Primary Tanks (PST)	10	10	11.6m diameter
Primary filters	4	4	33.6m diameter
Primary humus tanks	24	24	9.2m diameter
Secondary filters	8	8	33.6m diameter
Secondary humus tanks	24	0	Not in use
Anaerobic digesters	6	0	Not in use
Earth dam	1	1	Supplies farms (via ps)
Irrigation ps	1	1	Supplies farms
Lime dosing unit	1	1	Pre pst inlet

This treatment unit was not examined in any detail due to time constraints and the fact that it did not directly contribute to the final effluent discharge.

However, preliminary observations did suggest some shortcomings in maintenance. Some of this unit sits close to the perimeter fencing, and some degree of vegetation growth on the filters was apparent. This may have been due to the double filtration configuration. That is, effluent passing onto the secondary filters can contain nitrates from the breakdown of ammonia in the primary filters. This, especially in warmer temperatures, can promote growth of mosses and algae on the secondary units. This element of growth did throw some doubt on the use of all of the filters.

When questioned, site management suggested that this growth was only there as the maintenance teams had yet to get around to removing it.

No quality or hydraulic data was observed for this unit. Nor was any information obtained on the relationship with the receiving farms.

6.1.3) Unit Two

Also built as a biological filter plant in the early 1960s, this unit was said to have been abandoned some years previously. Furthermore, the majority of it had been demolished to make way for the construction of unit five.

The remaining plant consisted of six anaerobic digesters. Two of these were in use, the other four in poor condition, but plans were in place to refurbish two more in the near future. In addition to this, there was a single sludge transfer ps, and one gas holder. Both of these items appeared in reasonable condition.

6.1.4) Unit Three

Currently the second largest unit on site, and one seen to be dealing with a significant proportion of the flows. Quoted as having a capacity of 150MLD, this plant consists of three BNR reactors, built to treat biological and nutrient loading. Much of this plant is automated via PLCs, all relaying back to a SCADA system.

This unit was originally built as a 5-stage Phoredox process, but had subsequently been upgraded to the "Joburg Configuration".

Whilst this unit consisted of a large number of plant items, several of them were not in use. It was not made clear exactly why this was the case, nor was the impact on flow capacities obtainable.

Major Plant and Equipment Listing for Unit Three

Item of Plant	Total No.	No. In Use	Comments
Flat bottom pst	1	1	2500m3 volume
Circular pst	2	2	
Acid fermenters	2	2	Elutriators
Acid ps	1	1	
Balance tanks	3	3	10,000m3 volume each
BNR reactors	3	3	29,185m3 volume
Flat floor fst	9	6	38m diameter
WAS gravity thickeners	3	3	28m diameter
Chlorine contact channel	1	1	
Sludge storage tank	1	1	3520m3 volume
Filter belt press	3	3	2m wide
Sludge transfer ps	1	1	
Raw sludge thickeners	2	0	Gravity thickeners
Sludge digesters	2	0	Poor condition
Gas Holder	1	0	Poor condition
Lime dosing unit	1	1	Precip. P from return liquors

Unit three was not examined in detail, but did appear to be functioning reasonably well for process. Flows were high on the day of inspection, although it was a dry day.

All plant, with the exception of the digesters and gas holder, did appear to be in reasonable physical condition on general visual observation. The digesters were showing significant civil deterioration. They had though been removed from service, and site staff did not think that there were any likely plans to refurbish them in the near future.

6.1.5) Unit Four

Currently the main part of the whole site, being used to cater for the majority of flows. Rated at a capacity of some 260MLD, it was clearly taking a very heavy hydraulic load on the days of the inspection. Figure 44 shows the inlet channel close to overflowing.

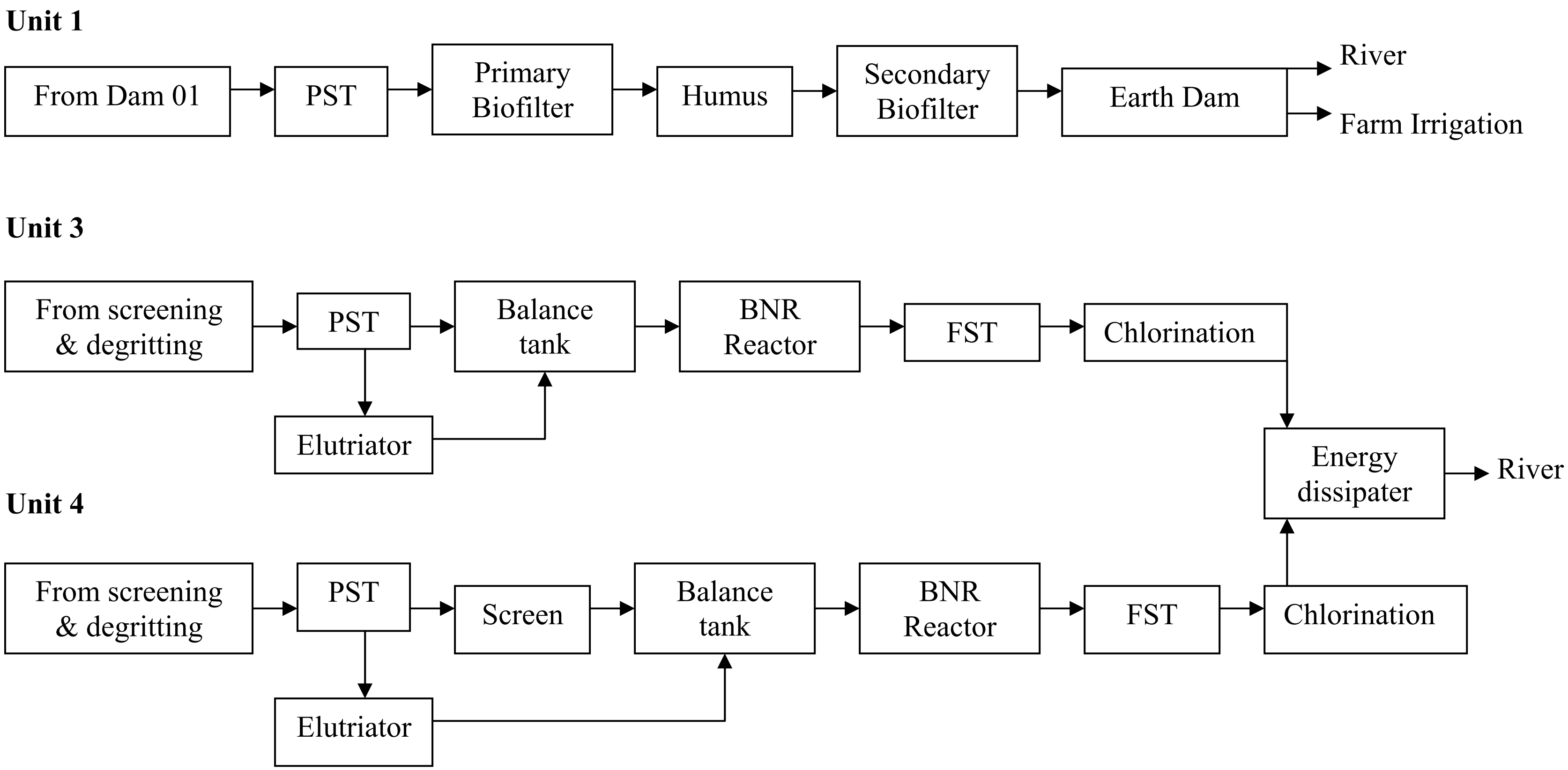
Like unit three, this is also a BNR activated sludge process, but this one was built at the outset in the Joburg configuration for removal of both phosphates and nitrates.

Initial and general impressions of this unit were good. Housekeeping was a high standard and virtually all of the plant in usable condition and in use. One very obvious factor though was one of flow. The unit is clearly hydraulically stressed; a fact very evident in the psts (fig.45) shows the launder channels completely flooded.

Major Plant and Equipment Listing for Unit Four

Item of Plant	Total No.	No. In Use	Comments
PSTs	8	7	35m diameter
Balance tanks	2	2	20,250m3 volume
Acid fermenters	2	2	Elutriators
Acid ps	1	1	
BNR reactors	4	4	27,670m3
FST	12	12	38m diameter
Chlorine contact channels	2	2	In series
WAS ps	1	1	
WAS thickeners	2	2	Gravity 28m diameter
Sludge liquor thickeners	2	2	Gravity 28m diameter
Filter belt press	5	5	2m wide belts
Composting shed	1	1	
Sludge storage tank	1	1	3520m3 volume

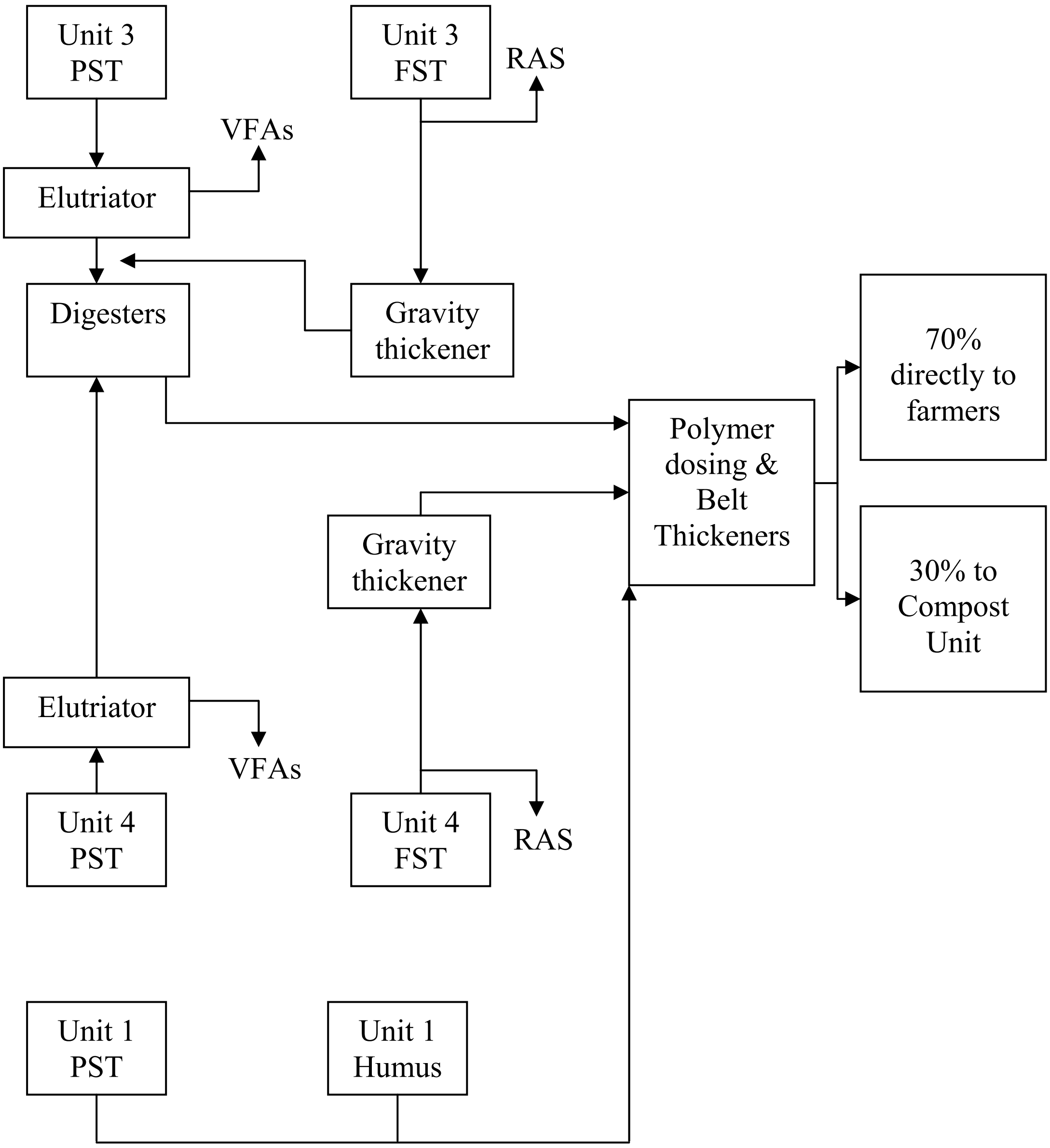
Northern Works WWTW Treatment Process Flow Arrangements



6.1.6) Sludge Treatment and Management

Sludge is derived from a variety of sources across the whole site. According to site flow diagrams, all sludge is then conveyed ultimately to the dewatering unit. Post belts, 30% of the cake goes to the composting unit, with 70% directly taken away to farmers.

Northern Works WWTW, Sludge Management Flow



(VFA – volatile fatty acids)

We were informed that all of the primary sludges are subjected to digestion, but only the WAS from Unit three are. This process flow was derived from discussions with site staff. However, the flow diagram provided did not indicate the positioning of the digesters in the process.

Primary sludge from both Unit three and four are passed through Elutriators to wash out and release volatile fatty acids (VFAs). These are then passed on (via balance tanks) to the BNR units to aid nutrient removal.

Following this stage they are then pumped into the anaerobic digesters. There were two sets of digesters on site, but only a small number were actually in use. The old Unit two site had a bank of six digesters, only two of which were being used (fig.46) These two had been refurbished relatively recently. The others were in a poor physical condition. Site management did state that there were plans to bring two more of these back into service over the next couple of years. Two digesters were present at the Unit three site, but these were found to be in poor condition and not in service. There was no current expectation to refurbish these units.

Hence, observations were that all primary sludges from both Units three and four were being digested in two of Unit two's digesters. Methane derived from this process is used in a nearby boiler to provide heat for the digestion process. Site management did state that there was often a surplus of methane. A flare stack was present, but it was not in use at the time of inspection. There were no stated plans to utilise methane for alternative power generation.

After gravity thickening or digestion, sludge is passed into the dewatering unit where it is dosed with polymer. Sludge arrives at approximately 3.5% dry solids and dewaters to approximately 18% when passed through the six filter belt presses. Figure 47 shows some of the belt presses. These were built by Solids Technology from Ireland. Each belt is 2.2m wide, but the units differed slightly in their throughput. We were told that four more units had been ordered.

Two belts run at 50m3/hr, and the remaining four run at 15m3/hr. That is, total capacity currently sits at 160m3/hr (or 3840m3/day). If the feed is consistently at 3.5% ds, then this represents a throughput of some 135tDS/day. Assuming 1m3 = 1 tonne, then dry solids treated. However, this assumes 100% recovery of the solids.

The above dry solids figures were verbally provided, and no analytical data was provided to support them. However, these are not considered atypical for plant such as this, and visual observation did generally vindicate these claims. On inspection all but one of the belts was in use.

Post thickening the cake is conveyed into the nearby composting unit. In here it is mixed with ground wood chippings and placed into windrows (fig.48). Staff claimed that the compost reaches temperatures of around 55^{o}C. This is sufficient to kill a wide variety of seeds and pathogens. It is held in these conditions, with occasional turning for periods of 21 days (or longer if wet). After this time it is moved and stored for 2-3 months. The compost did appear to be heating well, and was dry, with no obvious significant leachate. Odour levels in the unit were also very low.

After storage the compost is put through a sieve machine which reclaims the wood for re-use (fig.49). This machine was old, but did seem to be working well.

The woodchip was being sourced at no initial cost. JW operate a process whereby local people can deposit uncontaminated waste wood. This is then chipped on site, and re-used several times. This does represent a useful contribution to local community, and a good re-use of waste materials. Staff did seem to think that this resource was a reliable one.

Return filtrate liquors from the dewatering process are pumped over to the slaked lime dosing plant (fig 50). The intention of this process is to adjust the pH to between 9.2 and 9.5. This pH encourages the precipitation of phosphates when the liquors are pumped back into the pst inlets. This process is not currently automated. Fig 51 suggests that more control over lime usage is required, as spills were evident.

6.2) Sanitary and Non Sanitary Compliance

Northern Works has a set of standards set by DWAF. It is not known if these were originally based on river needs, or if they were or where empirically based. (Although wording in the report implies that they are "general" limits, rather than site specific). The receiving bodies for the effluent are the Jukskei river and nearby farmland. Standards set are as follows (from first order report):

Effluent Standards for Northern Works WWTW

Determinand	Maximum Limit (mg/l)
Chemical Oxygen Demand (COD)	75
Total Suspended Solids (TSS)	25
Ammonia (as N)	6
Orthophosphate	2
Nitrates (NO3 as N)	15
pH	5.5-9.5
E.coli (count/100m/l)	0
Faecal coliforms	Not quoted
Electrical conductivity (mS/m)	Not quoted
Residual chlorine	Not quoted

6.2.1) Historical and Current Compliance

Northern Works has been placed on the higher end of the cumulative risk scale due to the hydraulic characteristics rather than direct biological ones. No historical data was obtainable in the time available on site, but some discussion was held with staff.

Examining the first order report data, it would seem that there have indeed been past issues with treatment but these have since been largely resolved. This report shows samples taken over a 12-month period between April 2007 and March 2008. Whilst this was clearly out of date at the time of inspection, it did prove useful.

In all, there were approximately 40 samples taken (i.e. almost weekly), and these show a good trend pattern. With the possible exception of phosphates, most parameters where largely compliant. Ammonia was rather erratic up until January 2008, but always within 50% of the limit. Furthermore, even with phosphates, the majority of samples were below the 2mg/l limit.

There was an issue with ammonia and phosphate in 2007. The ammonia was due to lack of aeration capacity, which has since been remedied, and now includes tapered aeration in unit four (now 110KWh, 75KWh and 45KWh in each lanes). The phosphorus was affected by losing one of the elutriators, and thus there were insufficient volatile fatty acids (VFAs) being produced. This has since been put right.

Discussions with staff implied that the general levels achieved were around 0.4mg/l phosphate and 0.1mg/l nitrate. Observation of the auto analysers supported this on the day of inspection (fig.52).

The site was equipped with a range of final effluent auto analysers, continually monitoring for COD, ammonia, turbidity, and phosphates. At the time nitrates were not monitored, nor was residual chlorine. Staff stated that the latter would be installed soon. These monitors were interrogated on screen, and recent history implied good compliance trends. All of this information was observed as being fed back to the on-site SCADA system.

6.3) Hydraulic Compliance

No actual standard or limit was found to exist for flows (albeit no licence was available for inspection to confirm this). However, it was very clear that the site is hydraulically stressed. The current quoted capacity totals 410MLD, and this will increase to 460MLD when unit five comes on line later this year. The weather was dry at the time of inspection, but the flows evidently high.

Staff quoted that during rainfall these flows can exceed 460MLD, but no evidence was seen to demonstrate the actual levels. The flows were being trended in the SCADA unit. Unfortunately, insufficient time was available to fully interrogate it, as it was not working until well into the second day.

We were told that the incoming sewer has a theoretical capacity of some 630MLD. Staff were of the opinion that to raise treatment capacity to that level would not be possible on site. To prove this would take some extensive mathematical modelling. Raising capacity from 460MLD to 630MLD represents an increase of some 37% (or equivalent to another unit three). The cost of such a move would be very high, and it is likely to be more economic to either extend outside of the existing boundaries, or do some counter-infiltration work on the catchment.

Perhaps the most evident sign of the hydraulic issue was at the inlet channels and primary tanks on unit four. As can be seen in fig 45, the psts launder channels are totally flooded. This action would have been making the sludge settlement less efficient, and would pass extra biological loading onto the BNR units. However, it was probable that the large number and volume of tanks (both at primary and secondary stages) would have been attenuating this somewhat. The balance tanks would also have assisted this. This thought is borne out by inspection of the fsts. These did appear to be running reasonably well, and their launder channels were not flooded.

6.4) Site Monitoring

The site assets were being monitored continually and automatically via a series of PLCs, all feeding back to a central SCADA system. This system had two view and control screens, one in the office building and a second on the ground floor control room. This automatic system was installed during the early 2000s by the French contractors.

6.4.1) Work Orders and Supervision

No details of the literacy levels of the workforce were seen, but on site management did state that the general level was adequate.

The site managers had access to, and utilised the SAP system plan and issue work instructions to their staff. This was done in conjunction with a work planner /co-ordinator. Both the process and maintenance managers planned the workload (including any known emergencies), and then the work planner generates paper work orders that are then issued to site staff. Management did though state that this had been problematic in the past due to issues with cable thefts.

Whilst no copies of these orders were seen, simple observation of the site clearly displayed a degree of maintenance being carried out. Equipment was generally working and appeared in reasonable order.

There were some signs of inadequate supervision. These included a sludge spillage from a wet well (fig 53). This had been caused by a power failure some five days previously, but had not yet been cleaned-up. Another was the extent of lime spillage around the slaked lime hoppers.

6.4.2) Asset and Effluent Monitoring

Most of the site was being monitored and controlled continuously by PLCs and a SCADA system. This included trending and "command/control" functionality. Command functionality was limited to restricted personnel.

A bank of auto analysers was present and working, albeit not monitoring all of the necessary determinands (i.e. nitrates and residual chlorine not measured).

The phosphate monitor was linked (via the SCADA), to an emergency ferric chloride chemical dosing system. This was installed to ensure P removal was supported if the BNR process was insufficient. This process is good in principal, but was very dependent on the continued function of the auto analyser. Site management did agree that that this dependency was rather fragile. Furthermore, on a site this size if the BNRs failed to that degree, then there would certainly be a significant process issue to resolve.

We were informed that some of the assets did receive routine analysis. That is, the main aerator gearboxes on the BNRs had their oil sampled yearly. This check enables pro-active spotting of wear by looking for metal contamination and oil deterioration.

When done well, this enables a pro-active refurbishment and replacement programme to be put in place. Inspection of the gearboxes on unit four did show this. The larger 110KWh units had been replaced, and the new 75KWh units were awaited. Each reactor has a pattern of 15 aerators (5* 110KWh, 5* 75KWh, and 5* 45KWh). Hence, being proactive about this work is necessary, especially seeing as the lead time on delivery was some twenty two weeks.

One of the psts on unit four was inoperative, and clearly had been for a few days (fig 54). In this case they were waiting for the repair of the drive wheel bearing.

In addition there was also a small spares store for essential items (fig 55), and a small workshop and maintenance store (fig 56). These allowed for items to be maintained by replacing items such as bearings and small drive motors before they became a major issue. This was considered to be good practice.

6.5) Staff

Site staff was split into two main categories, namely process and maintenance. A manager based on site headed each of these sections. Both of these managers were experienced, and appeared to have a good understanding of their roles and responsibilities.

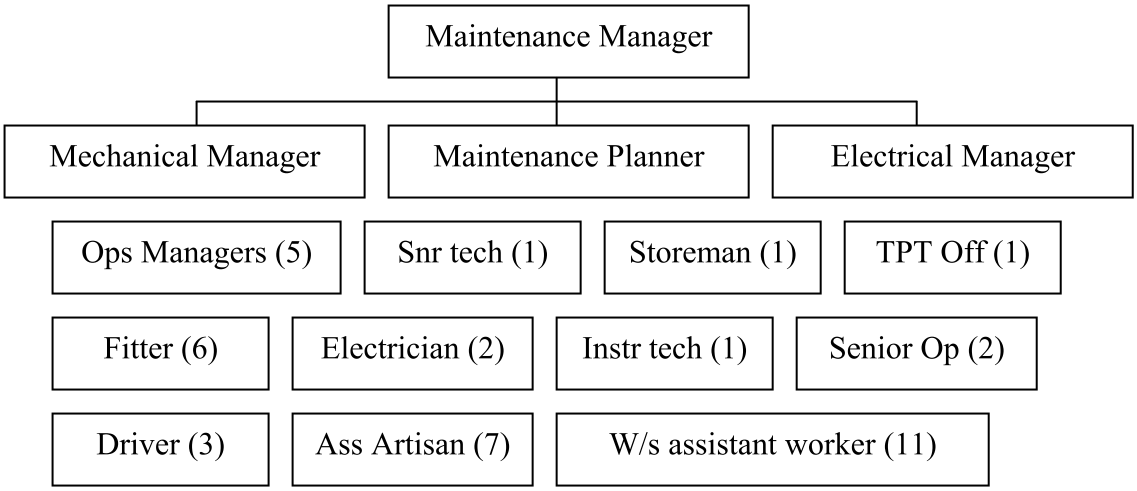
The nominal numbers stated as required as combined operational and mechanical/electrical staff was approximately 100. The actual numbers said to be currently in post was 114. The breakdown was as follows:

Process operations	= 50
Maintenance	= 49
Contract	= 15
Total	= 114

The contract personnel were said to be "semi-permanent" in that they remained on site, and were responsible for some of the larger, less frequent tasks such as cleaning out tanks.

No further detail was available other than a staff organogram for the maintenance group. The generic levels of this are detailed below.

Maintenance Staff Structure at Northern Works WWTW



Management reported issues with staff retention. For process this was largely for managers, and for maintenance it was largely at the lower end of the scale. In the above structure, six positions were vacant.

No staff were expected to work around the clock. The general shift pattern was 0700hrs to 1600hrs, with the exception of two people in the sludge dewatering plant who worked over a longer day period. There was no night shift.

The PLCs monitor the health of the assets, and report to the SCADA. When this detects a movement outside of pre-set parameters it sends out an SMS text message to pre-determined personnel on standby. This process was demonstrated, and worked in a reasonably quick timescale. The messages detailed a fault with sufficient information for a decision to be made towards calling out staff to attend the problem. Clearly this system is dependent on the health of the SCADA, and the text system, but did represent an element of good practice.

6.6) Power and Standby Arrangements

On a large works is it essential to have some form of standby power generation. At Northern Works there was only one such unit, this being a 100KVa unit at the inlet. This was installed to power the inlet screens, permitting flows to continue to pass into the works.

Such lack of emergency power would (and had – e.g. recent sludge surcharging fig 53) lead to significant issues on site. Although the site was on a hill, there was still a lot of pumping stages dependent on electrical power. Furthermore, all of the aeration equipment would suffer in a power fail, along with all of the monitoring equipment. A biological process will survive for a few hours without fresh oxygen from the aerators, but will soon suffer. On a works of this size and in this climate, it is likely significant damage would be done to the biological stages within 12 hours. Furthermore, once the biological state moves towards anoxic, anaerobic or septic, the microbiology changes. Recovery from such states is far from instant, and can easily lead to effluent quality failures.

6.7) Health and Safety

Northern Works did exhibit a reasonable attitude towards safety. Examples of some issues included:

(i) Use of gaseous/liquid chlorine: Originally the site was built with gaseous chlorine as a disinfectant. This form of chlorine is highly dangerous and difficult to manage. Fortunately, this method had been abandoned in favour of hypochlorite dosing (fig 57). The chemical in this form is far easy to manage and less dangerous. It also provides a good recycling function, as this chemical is a waste product from the swimming pool disinfection process.

(ii) Use of personal protective equipment: A small number of site staff were present on the process site, but they did appear to be wearing suitable ppe. A large number of contractors were on site. Their standards were good, all personnel being equipped with high visibility clothing and hard hats.

(iii) Drinking water supplies: It is accepted that in such climates that regular drinking of water is essential. However, some taps were seen to be present at the inlet works. These were clearly signed as drinking water (fig 58 with hose) but were located directly next to the inlet channel and screens. This one in particular had a hose pipe connected and was laid on the ground very close to a large puddle of water. At the time staff were washing the area down with washwater. There was a high risk of back siphonage into the potable supply. A risk also existed in that workers might be tempted to take a drink without first washing their hands. This tap could have been located in a nearby building with some washing facilities.

6.8) Significant Observations and Conclusions Northern Works WWTW

There were many positive areas were observed at Northern Works. Whilst far from perfect, it was immediately obvious to us that significant differences existed.

1) Hydraulic Conditions

Clearly a big issue at this works. Only unit four was inspected in detail, but flows were obviously very high, despite the weather being dry.

Unit one was only being used for "internal flows" such as spills. Some potential capacity was being lost here, but the inability of the unit to meet sanitary requirements did mean that it was not being licensed to the full. Discussions with management indicated that it was not likely to either.

Unit two had been abandoned and largely demolished so offered no hydraulic capacity.

Unit three was operational, albeit with some loss of fst capacity. Other than some smaller scale refurbishment work it was not likely that the 150MLD capacity was going to be increased.

Unit four had inlet flows that were very nearly breaching the channels. Primary tank launder channels were being breached, but this did not appear to be adversely affecting performance. Also, one of the pst was out of action due to drive wheel failure.

Unit five was under construction and expected to create a further 50MLD capacity. Whilst behind its original plan date, completion was expected within one month.

The site was obviously hydraulically stressed, but plans were in place and actively dealing with the issue. The unit five construction represented a significant capital investment of the correct type. Whilst doubt on the full capacity of unit three existed, the attitude towards dealing with the problems was very positive.

Further plans had been drawn-up to extend the unit 5 in the near future. However, this was close to finite as the topography of the site and the potential capacity of the incoming sewer were expected to prevent full capacity requirements being met on site. Hence, extensive flow modelling would be required to select a suitable strategy for managing catchment flows in the near future.

2) Organic or Biological Loading

No major issues were identified in this area. Previous reports did suggest that there had been some non-compliance, but more recent observations indicate that these were relatively isolated. Generally the site did seem to be performing well biologically. Discussions with DWAF did suggest that the impact of the works on receiving watercourse was high, but this would have been more to do with the overall loading generated by volume rather than strength.

Concern was raised by the potential for the balance dams to create point source pollution. It would seem that Dam 02 has the potential to discharge untreated materials into the river if the transfer back into Dam 01 was insufficient. This could be added to by overflows from balance tanks on unit four. Furthermore, flows into the dams also came from unit three-balance tank and from the sludge thickeners. This combination certainly could pose a pollution threat. No obvious control was being exerted over this issue, albeit all flows arriving in the dams would have undergone a minimum of screening and degritting.

A standby chemical dosing arrangement was supplementing the P removal process. The auto analysers were linked to this equipment and programmed to start should non-compliance be detected. This was a good system, but did suffer the total reliance on the analysers continuing to function fully.

Sludge dewatering liquors were receiving some degree of pre-treatment prior to return to the works. Previous work reported by Pitman (1998) has shown that nutrients removed in BNR processes can be re-released from sludge during subsequent stages such as dewatering.

At Northern Works this was being done by addition of slaked lime to the dewatering liquors to raise the pH and encourage precipitation of phosphates in the primary tanks. However, this process was not automated so its actual effectiveness or operating parameters were not clear.

In addition to this, the use of composting can be effective in stabilising the sludge fraction (Pitman, 1998). Composting has very little liquid discharge, and so would lower the potential for re-release of nutrients. Anaerobic digestion, centrifuging, or filter presses would all have a significant liquid fraction to return to the works for treatment.

3) BNR / Site Configuration

Aerated sludge BNR processes in unit three and four were achieving the majority of the treatment process. Each of these utilised the more recent modification known as the Johannesburg configuration. Of all the BNR options, this one seems to have been the best suited to the demands and environment found in the country. The major change in this case is the addition of a separate anoxic zone or tank. At Northern Works this was referred to as a “pre-anoxic” tank. This unit receives ras flow and assists denitrification prior to flows returning to the anaerobic zone. This configuration seemed to suit the conditions at the site, but consideration would have to be given to further changes should the final effluent nitrate limit need to be reduced.

Literature (Wastewater Handbook) has quoted that this process has advantages if nitrate limits are not too strict. Denitrification rates are increased in the pre-anoxic zone by virtue of the increases in relationship between ras and mlss levels. This means that ras being fed back to the anaerobic zone is low in nitrates, but the effluent from the fst may still contain some.

Operation of BNR aeration technology is more complex than more conventional methods such as biofilters. It does require a greater skill level in the workforce. Currently this does seem to exist at the site, but it would also be a factor when recruiting.

4) Staff Quantity and Quality

Both the Process and Maintenance managers did report some issues with staffing. These were though more to do with retention rather than recruitment. Neither manager had a full compliment, but current numbers did not seem to be presenting a major issue.

There was not sufficient time or resource available to conduct detailed interviews with staff, but the impressions given were very positive. Both managers understood their roles, and were experienced. The appearance and functioning of the site did imply that those running it were indeed capable of doing so to a reasonable standard.

5) Site Maintenance and Monitoring

The site was being continually monitored by a SCADA system. Whilst this was seen to be down on the first day, when it was seen running it was monitoring and trending a number of parameters. Its alarm generation system was demonstrated.

Procedures were in place for work planning, issue and monitoring. No work orders were seen, but the fact the site was running well and appeared to be in order did imply some degree of maintenance.

Ongoing capital investment and refurbishment was also being carried out. The programme of major aerator refurbishment was positive. (Note – this was later queried by another source, but had not been substantiated at the time of writing).

6) Site Capacity

Clearly the site was under hydraulic stress, indicating a lack of capacity. However, active plans were in place to remedy this. The biological treatment capacity was not tested in any great detail, but the more recent sample analysis indicates a currently adequate level. Any future developments and requirements would have to be subject to modelling.

7) Standby Power Generation

This was only present on the inlet works. This posed a huge threat to continued compliance and operations. The purpose of this generator was to power the inlet screens and degritting plant. However, this then left the rest of the site open to flooding and pollution. An example of this was observed in that recent power cut had caused a sludge well to surcharge.

Some mention of power shortfalls were discussed, which did include mention of power cuts, but no plans appeared to be in place. Only a very small proportion of the site could operate without power. Significant environmental damage would be highly likely if this condition continued.

8) Health and Safety

This area has been detailed previously, but the overall attention to safety was considered to be generally adequate.

Some areas were noted that were presenting threats to the overall safety and well being of staff. Some of these were due to the staff themselves (e.g. no gloves being worn), and some more by design (e.g. unprotected drinking water taps very close to contamination sources). A point worthy of note was the move away from gaseous chlorine towards hypochlorite.

6.9) Northern Works – Ways Forward.

This section contains a brief outline of the suggested early ways to make progress on this site. It is not exhaustive, nor necessarily in chronological order.

- Engage in best practice discussions with other municipalities.
- Consider installation of additional standby power generation sources.
- Ensure phase 5 fully implemented.
- Make maintenance regimes more visible and examine approach to aerator oil analysis programme.
- Review / modify provision of drinking water taps across the site to minimise the risks of water supply contamination.

7) Meyerton WWTW

Meyerton WWTW is a much smaller plant than either Rooiwal or Northern Works, but is very much in need of improvement. The site is located approximately 30Km south of Johannesburg, at co-ordinates 26°41'3.86"S/28°0'2.61"E. It is classified as Class B under DWAF regulations. Meyerton WWTW is operated by Mid Vaal Local Municipality (LM), and discharges to the Louisfourie Spruit, a tributary of the Klip.

The site was constructed as a biological nutrient removal (BNR) aeration plant, with a theoretical capacity of 5MLD. Actual dates of construction were not known, but various additions and modifications had been carried-out between 2006-08. Actual flows being received were estimated by site staff as being between 8 and 10MLD.

Originally the plant was built with only one treatment stream (i.e. the BNR), but the 2006-08 modifications attempted to add a further initial or "pre-aeration" stage.

7.1) Site Details

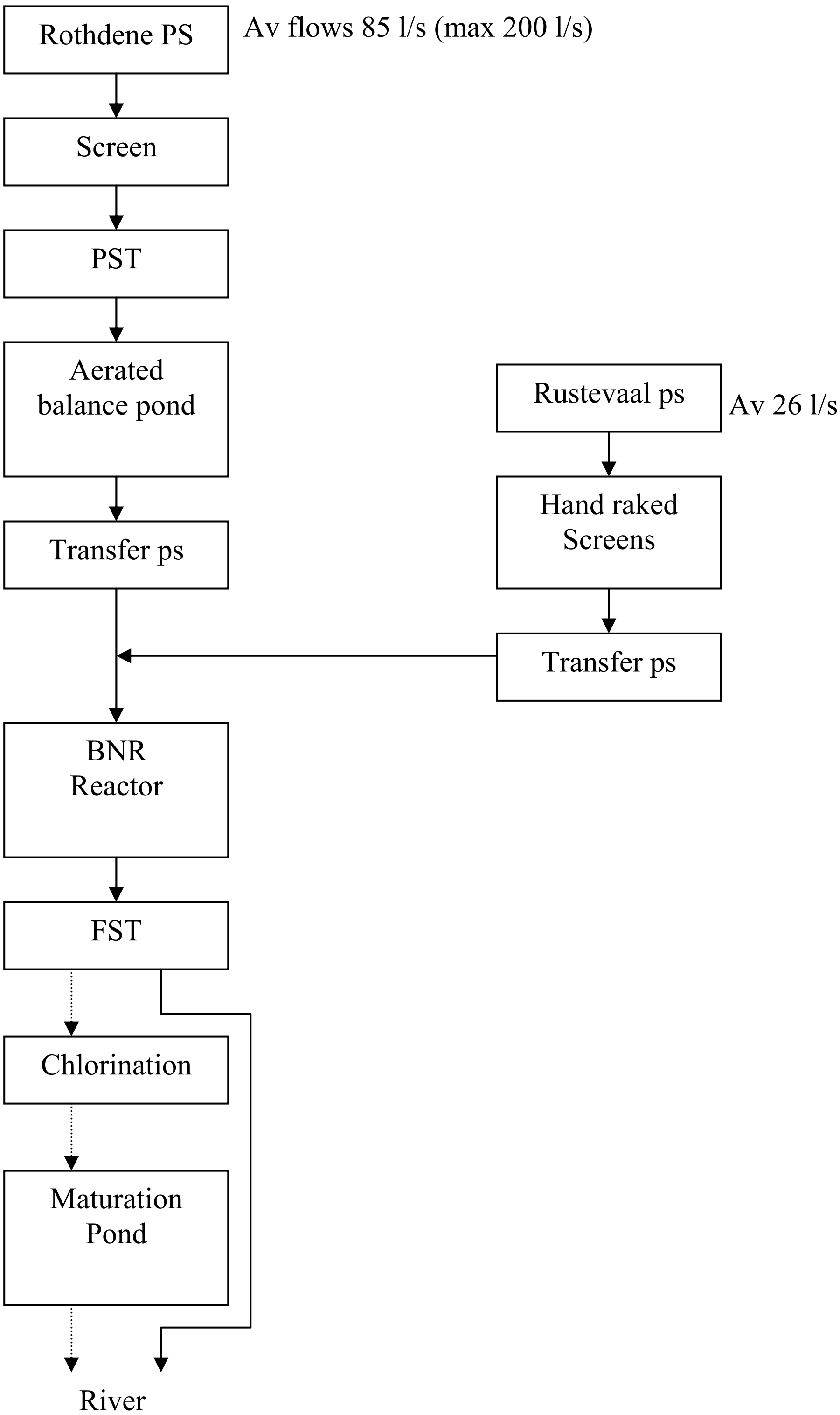
The site is some distance from the main metalled public highway, and is accessed via a long and uneven un-made track. This track is in very poor condition, and has many large potholes. The actual treatment plant is split into two sections, with a long access track between them in a similar condition to that from the highway. There are two main inlet points, both served by pumping stations. One of these is from Rothdene, and the second from Rustevaal.

Major Plant and Equipment Listing for Meyerton WWTW

Item of Plant (Rustevaal)	Total No.	No. In Use	Comments
Manual rake screen	2	2	In series
Standby generator	1	1	
Pumping station	1	1	
Sludge digesters (open)	1	1	Poor operation
Sludge drying beds	8	8	

Item of Plant (Rothdene)	Total No.	No. In Use	Comments
Manual rake screen	1	1	
Huber rotary screen	1	1	
Vortex degritter / elevator	1	1	
PST	1	1	Poor operation
Aerated balance pond	1	1	Poor condition
Floating aerators	6	2	Plant failures
Pumping station	1	1	Electrical issues
BNR reactor (4 cell)	1	1	Poor condition
Surface aerators	4	3	Poor condition
FST	1	1	Poor operation
Chlorination building	1	0	
Maturation pond	1	0	Full of sludge
Standby generator	1	1	Siting issues

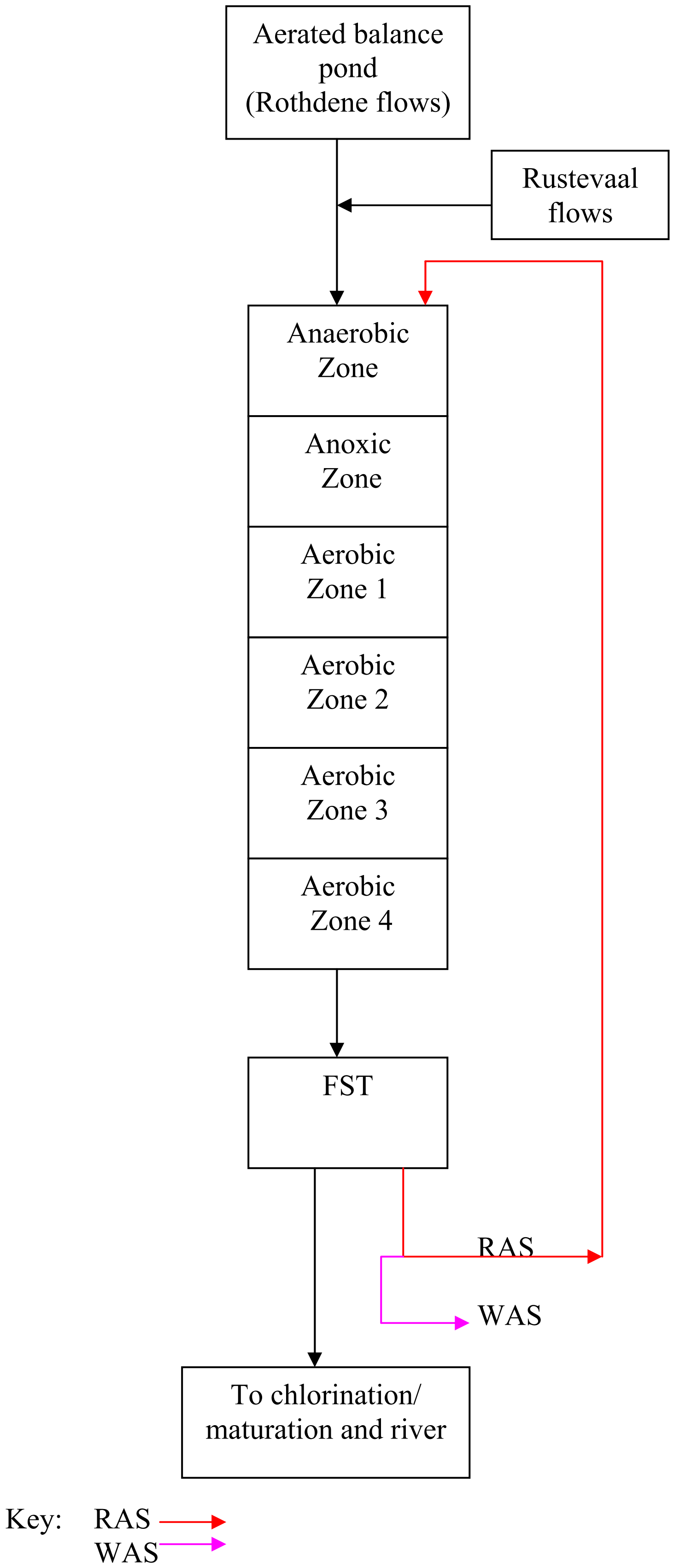
Meyerton WWTW Process Flow Layout



Key:

Sewage flows (actual)
Flows (theoretical)

Meyerton WWTW BNR Process Flow Arrangements



7.1.1) Rustevaal Inlet

The Rustevaal inlet sits at the northern end of the plant, and consists of only two manually raked screens place in series. There is an area for overflows, but this was in poor condition and only very small. A nearby small ps then passes the flows up to the channel feeding the BNR plant. There was a relatively new standby generator located at this inlet (fig 59).

The ground area around this inlet was unmade, very uneven and rough (fig 60). The inlet channels were at ground level with no fall protection in place (fig 61). The pumping station chambers did not have any covers, and showed signs of hydrogen sulphide corrosion. The area immediately outside of the small compound was being used to deposit the rag removed from the screens (fig 60).

7.1.2) Rothdene Inlet

Located over towards the southern end of the site were the newly constructed / modified inlet screen, pst, aerated balance pond, and pumping station. These units were designed to provide preliminary and primary treatment together with some initial aerobic biological treatment prior to flows passing to the BNR plant. The balance pond existed before, but was converted into an aeration plant with the addition of six floating aerators.

The purpose of the upgrading work was to increase the site capacity to 10MLD

7.1.3) Screens and Degritting

Pumped flows pass through two parallel channels, one with a Huber rotary screen and the other a hand raked screen (fig 62). The screen was not rotating at the time, but staff did not indicate any failure. The hand-raked screen was clean. Immediately after this flows go through a vortex degritter with a Huber grit elevator. Both of these units had been installed as part of the recent upgrade work. All of the metalwork and concrete appeared in reasonable order.

Screenings and grit removed dropped from the elevators into some old and small wheelbarrows placed underneath (fig 63). Classification of these waste products appeared reasonable. Disposal was achieved by means of a skip, set behind and below the level of the concrete blocked area. However, access to the skip was far from ideal and unsafe (fig 64). No constructed road existed for skip lorries to access this point, so it is highly likely that these lorries would become bogged-down in wet weather.

7.1.4) Primary Treatment

The primary tank was also only just over a year old, but its condition was poor. The quality of construction and operation was low. The tank was clearly heavily overloaded and not functioning correctly. Fig 65 shows the surface to be thick with scum and the effluent loaded with solids. It is unlikely that any reasonable amount of sludge settlement was occurring. The desludge well contained only the scum being removed slowly from the surface. We were also told that the tank had been built with a flat bottom rather than a slope. This could not be verified without emptying the tank, but a flat floor would have constrained the sludge removal process. The amount of solids passing over the weir would certainly have been putting an excess load onto the subsequent aeration stage. Furthermore, the black colouration indicated septicity but this may have been partially due to retention in the network.

The pst upward flow values were calculated as follows:

	At Max Flow	At Average flow
Surface area (m2)	310	310
Flow (l/s)	200	85
Upward flow rate (m/h)	2.3	0.99
Ideal maximum	1.2	1.2

Hence, at average flows this should be okay, but very much overloaded at anything greater than average.

7.1.5) Aerated Balance Pond

After primary settlement flows pass into the large balance pond. In the upgrade this was fitted with five floating aerators, to provide a first stage aeration stage and increase biological treatment capacity. Unfortunately, only two of these units were functioning at the time. The result was a large pond of very black and septic sludge like sewage, with very doubtful levels of treatment (fig 66). When questioned on the reasons for this lack of functioning equipment, staff mentioned waiting for maintenance contractors to act was the major issue.

Some calculations were done at the time using rough figures supplied by the site staff. These implied that the total available oxygen capacity in the pond was approximately 375kg of oxygen per hour. COD load stated by the consultant report indicated a need for 395kg oxygen per hour. Hence, if the pst functioned correctly and all of the aerators were fully working, then there was a chance that sufficient COD treatment might be achieved in this unit.

On initial arrival at the site we did meet a contractor representative. He explained that he was there to examine the aeration in the pond. He was proposing to install some fly-jet aerators. It was not made clear why this was necessary, or considered a better option than returning the existing units to service. Site staff did state that they were experiencing difficulty with sourcing replacements (i.e. an eight week wait for new units to be made). Unfortunately insufficient time was available to discuss this proposal in any detail.

Sited adjacent to the pond was a transfer pumping station with three Gorman Rupp pumps. This was transferring flows over to the BNR reactor at a stated average rate of 206 l/s. Some discussion was held with management at the time as, whilst the pumps were functioning, the level of maintenance was doubtful (e.g. dry greasing nipples on the pumps).

Pumped flows from this treatment phase discharged into long channel some distance towards the BNR plant. At this point they are joined by flows from the Rustevaal ps catchment (fig 67). The mixing of the flows clearly shows the black material coming from the aeration pond. Also present at this point were two parallel grit channels (disused) and a flow recorder flume (figs 68 and 69). The flow recorder was in poor condition, and staff indicated that it had not been calibrated for at least 12 months. Hence, any reading derived from it would have been doubtful.

Combined flows then travelled though a long channel towards the BNR reactor, being supplemented part away along by pumped discharge from sludge digester supernatant liquors. The ground to the sides of the channel was soggy in several places, indicating surcharging. Whilst unintentional, it is possible that the flows could have been denitrifying due to the mix of treated and untreated materials, and the residence times. However, no data existed to verify this.

7.1.6) Biological Nutrient Removal Aeration Plant

Said to have been installed in the early 1970s, this plant represented the only means of removing phosphates and nitrates (assuming that the new aerated pond achieved some nitrification). It was said to have been built in the Phoredox configuration. There was no evidence of there being sufficient internal recycles to achieve full P and N removal. Also, RAS was being sent back to the start of the anaerobic zone. If the aeration stages were achieving any nitrification, then the RAS would contain nitrates, thus compromising the P removal process.

The general condition of the BNR plant was very poor (figs 70 & 71). The anoxic zone mixer was working, but leaking a large amount of oil. This indicated a lack of maintenance (fig 72).

The second zone aerator had been out of action for at least two months. Consequently, no mixing or aeration was being performed in this zone (fig 73). This would have been dramatically impacting biological treatment. The concrete structure in this zone showed significant deterioration through acid attack. The most likely reason for this was the acids derived from septic sewage (fig 71).

7.1.7) Final Settlement

A single FST was located at the end of the BNR reactor. This was quoted as having a capacity of 220 l/s, and a surface area of 600m2.

	At Max Flow	At Average flow
Surface area (m2)	600	600
Flow (l/s)	226	111
Upward flow rate (m/h)	1.35	0.67
Ideal maximum	1.0	1.0

These figures indicate that the fst should be okay at average flows, and not too far out at maximum flows.

The tank was found to be in very poor condition and operating very poorly. The concrete structure was cracked and damaged (fig 74). The surface of the tank was covered in floating material, and the liquid very grey-black in colour (fig 75). There was no appreciable function to this tank other than a holding area prior to discharge. It had more of an appearance of a poorly operated pst, rather than an fst.

7.1.8) Chlorination

This stage was being bypassed at the time of visit. Figure 76 illustrates this.

7.1.9) Maturation Pond

This unit was not in use due to it being clogged with sludge solids. It would normally function as contact basin for the chlorination, as well as solar disinfection and fine solids settlement. However, due to the very poor treatment process upstream of it, the solids being passed forward had filled it up.

7.1.10) Final Effluent Discharge

"Treated" flows were being discharged directly from the fst into the Louisfourie Spruit, and thus into the Klip river. The colour of the discharge was a grey-black. It also exhibited an offensive odour, indicative of a septic sewage. Lack of grounds maintenance in this area prevented a full view of the flows.

7.1.11) Sludge Handling and Management

The main sources of sludge are raw sludge from the pst (combined with scum draw-off) and WAS from the BNR reactor. All of these are handled in the new digester unit.

7.1.12) New Sludge Digester and Old Drying Beds

Also at the north end of the site were the newly constructed open sludge digesters (fig 78) and the older sludge drying beds (fig 79). We were told that the digester had been completed in 2008 as part of the upgrading works. However, the term "digester" did not seem appropriate, as all it seemed to be functioning as was a storage area prior to the drying beds. It was strongly suspected that this unit was neither anaerobic nor mesophylic. No heating was being done, and the open top structure was not capturing any of the potential gas production.

The digester was built with inlet points around three sides, to facilitate even distribution of sludge. However, evidence suggested that only one side was being used. Fig 80 shows old dried sludge and vegetative growth in one of the chambers, which had clearly not been used for some weeks or months.

WAS and raw sludge are mixed in the digester. Raw sludge is removed from the pst via a gravity valve, and WAS is removed from the RAS line by a set of pumps adjacent to the end of the BNR. These pumps appeared to be in reasonable order, but did have some rather interesting additions (fig 81). Staff stated that they controlled the solids levels (MLSS) in the BNR by means of sludge age. The WAS pumps were set to run for 6 hours a day to achieve a sludge age of 25 days. It was not clear how they had arrived at this control philosophy, or how well managed it was. Furthermore, no actual measurement of sludge settling characteristics was being carried-out. Hence, this method of control had very doubtful benefit. A sludge age of nearer 18 days would be expected for a BNR plant, together with a hydraulic residence time of 22 hours.

It is recommended in literature (Pitman, 1998) that as P is released into solution in anaerobic conditions it is vital that WAS is quickly dewatered to prevent it being released from the sludge into any return liquors. No evidence was observed of this. The dewatering liquors from the new digester and the drying beds were clearly very old by the time they were being returned to the BNR inlet channel.

The embankment area separating the digester from the beds was steeply inclined. Site management stated that the rain run-off down this slope (from the hard surface around the digester) was significant, and had led to various solids being washed into the beds. No evidence of any drainage being built into this structure was observed. Staff believed that part of the reason for the beds operating poorly was blocked under-drainage caused by this washout process.

Significant amounts of vegetative growth were observed to be present, some partially blocking the channels. The surface of the beds contained a large amount of water with strong algal growth. This did imply that the water had been standing for some time.

Site staff informed us that the dewatered sludge was being dumped on nearby fields. There was no evidence of any controls over this process.

7.2) Sanitary and Non Sanitary Compliance

No licence was in place for the site, but a set of DWAF effluent standards did exist. It did appear that most of these were perhaps "general" standards, rather than any relating to the site capability or the receiving water bodies' specific needs.

Effluent Standards for Meyerton WWTW

Determinand	Maximum Limit (mg/l)
Chemical Oxygen Demand (COD)	75
Total Suspended Solids (TSS)	25
Ammonia (as N)	10
Phosphate (as P)	1
Nitrates (N03 as N)	10
pH	6.5-8.5
Faecal coliforms (CFU/100ml)	Not clear
E.coli	0
Electrical conductivity (mS/m)	100
Residual chlorine	Not quoted

7.2.1) Historical and Current Compliance

It was abundantly clear and obvious that this plant is not compliant in any way. The final effluent was a thick, dark grey-black colour with an offensive odour. In all respects, it was little more than septic sewage.

The first order assessment did have some compliance information, but this related only to samples taken in 2007. Even then, it was clear that compliance was not being achieved.

A document was obtained from site management, indicating that some more recent works were being carried-out on analysing plant performance. East Rand Water had been employed to carry-out monthly spot sampling of the catchment industry and the incoming/outgoing site flows. Data obtained from the report for February 2009 is summarised below.

Meyerton WWTW Compliance Analysis By East Rand Water February 2009

Date	COD (mg/l)	TSS (mg/l)	Ammonia (mg/l)	Nitrates (mg/l)	Phosphates (mg/l)	MLSS (mg/l)
04/2/09	75	23	16	0.12	0.07	2440
12/2/09	69	27	19	0.12	0.05	1550
19/2/09	80	29	26	0.10	0.13	1880
24/2/09	125	47	28	0.10	7.10	1030

Clearly a very poor set of results. Even those values not in red do not indicate any real achievement of treatment.

The ammonia levels are certainly suggestive of an inadequate aerobic stage of the process. This is most likely due to the lack of working aerators in both the balance pond and the BNR reactor.

The nitrate levels are very low, but these would be due to the lack of ammonia treatment rather than the biological removal of N. That is, no ammonia treatment means no formation of nitrates.

It was considered very likely that the low phosphate levels were accidental rather than as a result of good performance. If no nitrates were present in the BNR, then this may have being beneficial to uptake of P by the bacteria.

Looking at the influent levels given for these days, the indication was that a large proportion of the COD and TSS were being removed. However, this was very much contradicted by the visual evidence on the days of the inspections. It would be necessary to obtain the results from March samples before being able to support the apparent treatment being suggested by the February ones.

Whilst it should be noted that the sampling regime being carried-out by East Rand Water is a positive step towards managing the site, some concerns still exist.

(i) Samples are only being taken once a week, with no apparent comments as to relevant factors such as rainfall.

(ii) Only spot samples are being done, so true biological loadings are difficult to derive (composite sampling would assist here).

(iii) No data was available for the microbiological parameters.

(iv) MLSS levels were very low, and no indication was given as to how these were being responded to.

(v) The recommendations in the monthly report fell a long way short of providing useful advice as to remedying the issues.

7.3) Hydraulic Compliance

Due to the very poor state of the biological aspects, little attention was paid to the hydraulic aspects. However, the original design capacity was nominally 5 MLD, and the expected design following upgrade works as 10 MLD.

Site staff stated that they believed that the incoming flows were typically between 8 and 10 MLD. These values could not be confirmed in any way as little or no flow measurement was taking place. There was a flow meter on the channel at the combination point upstream of the BNR, but this was known not to have been calibrated for over a year so could not be relied upon. Consequently, no reliable loading calculations were possible.

7.4) Site Monitoring

Some degree of site monitoring was in place. This was limited, but did include a small-scale telemetry system, and the external sampling by East Rand Water.

7.4.1) Work Orders and Supervision

No evidence was found of any structured issuing of and monitoring of work instruction. Literacy levels were said to be low in a large proportion of the workforce, so issue of written instruction would not likely to have been effective. However, little or no supervision seemed to be taking place.

Discussions were held with management on this subject, and suggestions made as to how this could be improved in a simple and rapid manor. They were very open and receptive to these thoughts, but it was surprising that no structures were already in place.

Furthermore, no proper role structure and expectations were in place. It did seem that the role of the "Plant Operator" was not to operate, but merely to clean screens and watch pumps.

The lack of clear structure and role definition would almost certainly have been contributing towards the deterioration of the site.

7.4.2) Asset and Effluent Monitoring

A small-scale telemetry system was in place. This monitored basic items, albeit staff were unable to list which items were and were not being looked-at.

The functionality was basic, and relied on the interpretation of a small number of people. When an alarm was raised, this was sent to the security guard who then telephoned the on-duty superintendent, who then decided if it required a response. The technical knowledge of these people was not made clear.

Site management did inform us that a SCADA system was due to be installed, but could not give any expected timescales.

Other than the weekly sampling by East Rand Water, it was not clear if any real site monitoring was being done. The staffing structure implied that only a very small number of people did any real monitoring, with most only carrying basic tasks such as grass cutting. No facilities or capabilities for on site sample analysis were seen.

7.5) Staff

Staffing levels were very low. No evidence of direct mechanical and electrical support was observed. The site was being staffed 24/7, with a three-shift rota for a small number of people.

Position	Number in Post	Comments
Supervisor/superintendent	1	
Team Leader	1	On long term sick
Site plant operator	4	Limited role
General Workers	6	Day shift only
Security guards	Not quoted	

The supervisor and team leader were expected to take on the essential running of the works around the clock. They worked a regular day shift, but also had to perform a shared standby response. Furthermore, the team leader was on sick leave, so this was falling fully to the supervisor.

The plant operators worked a three-shift pattern, with one generally at work in each eight-hour shift.

Day shift 0600 – 1400hrs (1 person + general workers)
Late shift 1400 – 2200hrs (1 person)
Night shift 2200 – 0600hrs (1 person)

The general workers operated a 0730 – 1600hrs shift.

These staffing and skill levels would not be considered sufficient to reliably run this works, especially with the role structure, lack of skills, low level of monitoring and very poor current condition.

7.5.1) Mechanical and Electrical Maintenance

Maintenance of the plant was contracted out, but the quality and effectiveness of this process was very low. Contracts were said to be very vague, and did not contain any real incentive for quality work. This was borne out by the very poor condition of the assets, and the extremely slow response times. A particular example of this was the zone two aerator in the BNR plant.

At the time of inspection this unit had been out of action for two months. In this time the only response received from the contractor had been an initial visit. This visit had not resulted in any further response. The site supervisor reported that he had not even been told if what checks had been done, and if the issue was electrical or mechanical.

A contract arrangement was also in place for capital works, but management reported very little consultation took place. This was supported by the very poorly thought out construction of the lifting gantry for the balance pond aerators. The structure was considered unsafe, and incomplete. Removing and maintaining the aerators would have been very difficult and unsafe (and thus less likely to happen in a timely fashion).

Some discussion was held with site management over this issue. It would seem that some efforts had been made to set-up a monthly performance system, and for contractors to be paid only when they fixed a problem. However, only limited progress had been made.

7.6) Power and Standby Arrangements

Meyerton WWTW did have some provision for standby emergency power generation. The site had two units, one at the Rustevaal inlet (fig 59), and one at the end of the BNR reactor (fig 82).

Site management stated that they had been allocated R1m in the previous year to purchase generators. This was sufficient for these two units.

The Rustevaal inlet unit was close to the inlet, but did not appear to have a usable fuel supply nearby. There was an oil drum nearby, but this would not have provided for much running time. Hence, this generator equipment was of limited value.

The second unit did have a nearby fuel tank, but the siting of the exhaust had not been well thought out. As can be seen from the photo, the exhaust was very close to the nearby building, and had actually blown out the windows.

7.7) Health and Safety

Standards at Meyerton were not considered to be adequate. There were several examples of some issues including:

(i) Use of Chlorine: We were informed that chlorine had previously been used for disinfection. Chlorine is highly dangerous and difficult to manage. However, all of this equipment had been out of use for some time, and no gas was present on site. Fig 83 shows the dosing building in poor condition. A temporary unit had been set-up, but was also inoperative.

(ii) Use of personal protective equipment: A small number of site staff were present on the process site, but they did appear to be wearing suitable ppe.

(iii) Fall Protection: Very little evidence of protecting the workforce from falls from height or into chambers and channels was observed. Almost all of the "new" works structures were unprotected.

No barriers existed around the balance pond, or around the inlet screen and degritter units. Any staff taking grit or screenings away to the skip would have to risk balancing on small ledges (fig 62). The ramp to the skip, whilst rather ingenuous, did put the user at some risk (fig 64).

The aerator lifting frame was poorly designed, and did not allow for safe removal of the aerators (fig 84). When questioned, site management stated that this had not been certificated or tested in any way. Furthermore, once lifted, there was no safe means of lowering the unit onto any waiting vehicle. Immediately behind the frame was a steeply raked slope. This was clear evidence of poor design and lack of consultation and thought for the safety of the operator.

The long flow channel upstream of the BNR unit had no protection at all. Furthermore, the small metal plates across certain areas afforded no protection at all (fig 68). Several areas along this channel were also very boggy due to surcharging. The length of the grass hid this to a degree, but also hid the danger of slips and falls.

The inlet channels and the pumping station wells for the Rustevaal inlet were also totally unprotected (fig 61) In addition to this, any operative servicing the hand raked screens had only a very small ledge to stand on. Risk of falling in was high.

(iv) Electric Shock: Risk of shock was seen to be high. Fig 85 shows several panel doors open in the pumping station. The only protection offered was a small sign placed inside the panel cabinet (fig 86).

This represented a gross error in understanding of the risks. It is highly likely that these panels still contained high voltages. Furthermore, they did require the operative to be able to read. A slight irony was observed in that the only panel that was locked was the telemetry unit. This would have contained the lowest voltages of the entire panel!

A small hole near the pond pumping station contained a tail end of an electrical cable (fig 87). No attempts had been made to make this safe, nor could site staff demonstrate if this other end was or was not connected to anything.

(v) Biological: The practice of dumping rag and screening on the floor at the Rustevaal inlet represented a biohazard. It would also attract rats and other vermin.

7.8) Significant Observations and Conclusions - Meyerton WWTW

Meyerton was found to be in a very poor state, despite some recent (2008) capital investments. The site was scheduled to be closed in five years time as part of an overall re-think of strategy in the Mid Vaal area. (The Regional Sanitation Scheme plan for 2013).

1) Hydraulic Conditions

Very little if any of the available data for quoted hydraulic conditions allowed for a reliable judgement to be made. The site was said to have been designed for 5MLD, and then expanded to 10MLD. Site staff believed that flows were around 8MLD, but no reliable flow data was found. Site flow meters had not been calibrated for over a year. Generally, the other issues on site were clouding any real view on hydraulics.

2) Organic or Biological Loading

In summary, the entire site was a mess. The treatment process had virtually collapsed, and visually the effluent resembled a poorly operated septic tank. Several of the site processes were suffering from severe lack of attention or not functional at all.

The pst on the “new” works was taking flows, but not actually delivering any performance. Flow was not being measured, so no upward flow calculations were possible. Sludge production was doubtful, and the “settled” sewage very high in solids. The liquid phase was very septic and dark in colour. It was not clear if this was due to retention time, or the nature of the incoming sewage. Site staff did mention that the pst was designed with a flat base. The reasoning behind this construction was not understood or clear. In normal conventional pst design a sloped floor would be expected to assist the removal of sludge.

Aeration capability of the balance pond was doubtful. All but two of the floating aerators were out of action. Contractors were on site and talking of replacing them with jet aerators, but did not convince us of the full benefits of this. General calculations, assuming an oxygen capacity of 1Kg oxygen supplied per KWh of aerator did indicate that if all five units were functioning, then just about enough oxygen would be available to treat the received COD. (see appendix 2). The liquid body and effluent from this process was dark grey-black and septic in nature. It is highly unlikely that any realistic treatment was being achieved.

The process in the BNR reactor had also failed. One of the aerators had been out of action for some months, representing a loss of at least 25% treatment capacity. The liquid was also dark and clearly septic.

Recent samples taken by East Rand Water did show low levels of nitrates. This would have been due to the lack of nitrification rather than actual N removal. The high levels of ammonia in the effluent support this. Phosphates were mostly low, but no incoming levels were seen, so judgement as to removal was not possible.

The condition of the effluent passing out of the fst was poor, and directly impacting on subsequent stages. Disinfection was not being done, with the fixed and temporary equipment being out of use. The maturation pond had been filled by excess solids, so was also out of use.

In general, little or no control was being exerted over the process. None of the more normal conditions necessary for treatment were being met. Flows were passing through the works, receiving only minor attention and perhaps some degree of dilution effect.

3) BNR / Site Configuration

This was arranged in a modified Bardenpho configuration, but without the secondary anoxic zones for supported denitrification. This set-up is said to be good for nitrogen removal (Wastewater Handbook), but less good for P removal as nitrates are often recycled to the anaerobic zone.

At Meyerton the re-entry of nitrates to the anaerobic zone would not have been occurring, as nitrification was not being achieved in the aerobic zone. However, as the site had requirement to remove both N and P this configuration would not satisfy the need once nitrification of ammonia was restored.

Staff had stated that there was a high industrial loading to the site. It is possible that this was contributing a large COD loading, but with a high proportion of non-readily biodegradable COD. If this was so, then any aerobic treatment of COD in would have been altering the balance yet further and depriving the BNR reactor with the quantities of readily-biodegradable COD that it required to perform effective phosphorus removal.

It is likely that additions to the site would be necessary to achieve all of the required standard limits. These might include a further anoxic stage, or possibly chemical dosing to remove P.

4) Staffing Quantity and Quality

Numbers of competent staff were very low. Essential technical operational maintenance was left to just one person per shift. The site supervisor/ manager had to share a one-week in two standby rota that would not have been sustainable in the long term. Such arrangements would have been contributing to the poor state of the works, as the workload on these few people would have been high.

The attitude of site supervision /management was very willing and co-operative, but relatively inexperienced in the treatment process.

5) Site Maintenance and Monitoring

Mechanical maintenance had been outsourced. The contractors were providing a very poor service, and not keeping the site staff informed. A major example of this was the break-down of the aerator unit that had been left for two months with no site of any repair date (it was still in situ). The vague nature of the contracts was not assisting the site staff at all.

Liaison with capital engineers appeared to be poor, with limited opportunity for site staff to be consulted on operational matters relating to design.

Operational maintenance was not being actively planned or monitored. Discussions with management towards establishing some form of basic "tick-list" approach were positively received.

The site did possess a small-scale telemetry system. However, this was only monitored on site, and relied heavily on unskilled security staff to pass the alarms out. There was also only very limited resource available to respond.

6) Site Capacity

The initial observations did suggest that the site is severely lacking in capacity. However, due to many of the factors mentioned in the above sections, this can in no way be properly quantified. No reliable judgement can be made without a series of sustained and verified measurements being made on flows, actual unit capacities and biological factors.

It is possible that the site may be able to cater for its flows if all equipment and plant is restored to full function.

7) Standby Power Generation

In contrast to other sites, this site did have some generation capability. This was limited to two units, one powering the inlet, and one parts of the BNR plant. The presence of these units was found to be very positive, but their configuration fell short of ideal. For example, the inlet unit did not have any fuel storage tank so would not have been much use in extended power outs.

8) Health and Safety

This area has been detailed previously, but the overall attention to safety was considered to be inadequate. Several areas were noted that were presenting threats to the overall safety and well being of staff. Some of these were due to the staff themselves (e.g. no gloves being worn), and some more by design (e.g. unprotected drinking water taps very close to contamination sources and major lack of fall protection on new construction).

7.9) Meyerton – Ways Forward.

This section contains a brief outline of the suggested early ways to make progress on this site. It is not exhaustive, nor necessarily in chronological order.

- Set-up and implement localised monitoring and supervisory regime across the whole site.
- Implement "technical" and "people" based training for supervisory and leading-hand personnel, in conjunction with WSSCU programme.
- Formally assess all site staff against structured guidelines linked to WSSCU.
- Implement plan of immediate calibration of flow meters, followed by regular (at least twice yearly) programme of repeat calibrations. This may also require the installation of some new ones to measure flows not currently measured.
- Devise and implement programme of sampling across the site. This to determine the actual flows and loads being received and dealt with at different stages of the site, compared with design capacities.
- Implement programme of immediate repairs to all aerators to fully restore site treatment capacity.
- Critically examine the configuration of the BNR plant in relation to full treatment of COD, ammonia and nutrients.
- Examine the rationale and outputs of the recent consultant report, to ascertain if best value for capital investment is likely to be achieved.
- Re-negotiate service contracts to ensure they deliver value to site operations and performance.

8) Funding Arrangements

Whilst the common factor for all three sites was that they were owned and primarily funded from the Municipality, several variations were observed. This section is not included in any great detail, as it was not the primary focus of the project.

8.1) Rooiwal WWTW

Owned, wholly funded and operated by Tshwane Metro. Financial information provided on site was scarce. Site management quoted that the opex budget was 70c/Kl, but stated that a figure of between 80-120c/Kl was more applicable for a works of this nature.

It was claimed that the expenditure in the last financial year was R102/ML treated. Power estimates were 22c/KWh on average three years ago. Average across the site was said to be R97/MLD.

Constraints on purchasing were viewed as being restrictive towards effective running of the site. All items above R30, 000 had to be put to tender, with full tenders if above R200, 000.

A summary of 2007/08 costs was provided, which showed comparative costs against other sites in the municipality. However, its use a unit cost tool was limited by the lack of accurate flow measurement observed on site.

Site staff did make mention of the SAP computer system, but said that it was not very accessible to them. No evidence of access to it was observed.

8.2) Northern Works

Owned by Johannesburg City Council, but operated by a semi-private Johannesburg Water (JW). This arrangement has existed since 2000. As the sole shareholder, the City Council effectively funds the operation, but JW are able to borrow money on the strength of the assets. JW also cater for collection of charges from the public.

Site managers had the authorisation to purchase to the value of R200, 000 on opex budgets (albeit with localised controls). All purchasing is done via the SAP system.

Emergency capital repair monies were accessible, and more planned items are requisitioned via a separate capex department. Any decisions made by the capex department are then put into a consortium of retained consulting engineers prior to design and tender. Site managers did get involved in the details when the tender process begins.

Staff quoted an approximate opex cost of 37 to 45c/Kl. Whilst no evidence was seen to substantiate this, it compared very favourably with the budgeted figures quoted at Rooiwal.

8.3) Meyerton

Owned and operated by Mid Vaal Local Municipality, but with maintenance out to contract.

Site management could purchase up to only R2000 directly on opex, needing to go to three quotes between R2000 and R10000. Anything above R10000 had to go to tender. This represented a very restrictive process. The cost of the time and downtime whilst waiting for such quotes and tenders would have been high.

Total opex budget said to be a mere R500,000 a year.

8.4) Financial Evaluation

A more detailed financial evaluation of these three sites was performed by others during the project. This was done for all three of these sites, and two others (Brits and Zeerust WWTWs). Much of the financial assessment was carried-out during the site visits made to Rooiwal, Northern Works and Meyerton, so the all of the assessors took the opportunity to discuss the relationship between the two types of assessments.

This document is presented separately in Appendix 4.

9) Young Professionals (YPs)

A major part of this project was the enhancement of capacity within the country to carry out site assessments. The candidates were selected by and drawn from DWAF and DBSA.

The original plan was to take the four candidates and instruct them directly on assessments. However, it became clear early on that a change of plan was required. The level of basic treatment process knowledge was judged as falling short of that required to assess such large and complex works.

The revised approach taken was to take the YPs out with us on the assessments, and use the visits as a means of assessing them and instructing them simultaneously. This approach also allowed for progressively increasing the level of challenge to them. Furthermore, opportunities were taken to directly involve them as we did the inspections, and to ask questions and coach them into coming up with their own answers based on the evidence available to them.

As the time in country passed, the level of involvement and the will for the YPs to work together and learn from each other grew. This allowed for further and increasingly difficult challenges to be set. By the end of the first week it was decided that we would set them the challenge of actually delivering a presentation at the feedback meeting session. The intention here was to focus their minds and encourage them to prepare materials based on their findings. This skill would be very necessary if they were to continue to perform assessments on a larger scale.

Ultimately, different exercises were carried out at all three locations inspected.

9.1) Rooiwal WWTW

9.1.1) Root Cause Analysis

One useful approach when inspecting a site is to look beyond the surface issues, and try to determine the actual root causes. There is no prescribed perfect method for this, so a simplistic issues/potential reasons table was compiled. This is laid out below in fig 88.

This exercise was initially carried out at Rooiwal WWTW after the YPs had experienced several aspects of the site. This session was conducted by facilitating the YPs, having given them some ideas to start, and listing some potential causes.

The YPs actively engaged in this session, albeit needing a small amount of initial encouragement. By the end of the exercise it was clear that they had gained some knowledge in interpreting their findings. They did also seem to enjoy it.

Rooiwal Waste Water Treatment Works
YPs Root Cause Analysis (Fig. 88)

	Items spotted by YPs	Area of Site			
		West	East	North	Sludge
1	Biofilter not working	√			
2	Digesters working	√			
3	Clarifiers used as thickeners	√			
4	Inlet works not functioning	√			
5	Some biofilters not working		√		
6	Ponding on filters		√		
7	Blocked sparge holes		√		
8	Overlflow screens not clear		√		
9	Dam overflowing –too small				√
10	Why is the dam there?				√
11	Floating sludge on clarifiers			√	
12	Some clarifiers not working			√	
13	One screen not working			√	
14	Screenings passing screens			√	
15	Grass on digesters			√	
16	Corrosion on degritter pipes			√	
17	Broken gate on reactors			√	
18	Told site up to capacity			√	
19	Permit for irrigation of FE?			√	
20	Safety not as good as could	√	√	√	√
21	Auto analysers not working			√	

Rooiwal Waste Water Treatment Works
YPs Root Cause Analysis

		Flow	Organic Load	Maintenance	Capital Investment	Skills/workfce
1	Biofilter not working			√	√	√
2	Digesters working			√		√
3	Clarifiers used as thickeners			√	√	√
4	Inlet works not functioning			√	√	√
5	Some biofilters not working	√	√		√	√
6	Ponding on filters		√			
7	Blocked sparge holes			√		
8	Overlflow screens not clear	√		√		
9	Dam overflowing – too small	√			√	
10	Why is the dam there?					
11	Floating sludge on clarifiers	√	√	√		
12	Some clarifiers not working	√	√	√		
13	One screen not working			√		
14	Screenings passing screens	√		√		√
15	Grass on digesters			√		
16	Corrosion on degritter pipes			√	√	
17	Broken gate on reactors			√	√	
18	Told site up to capacity	√				
19	Permit for irrigation of FE?					
20	Safety not as good as could			√	√	
21	Autoanalysers not working					

9.1.2) Basic Treatment Biology and Process Exercise

The next step was to enhance their level of understanding towards the basic biology of the treatment process, and how this fits into the overall process flow on a treatment works. This again was done by means of a facilitated classroom exercise.

Techniques used included drawing out the basic process flow options, including preliminary, primary, secondary etc. Then they were taken through which type of biology fitted-in where. For example, the different types of bacteria responsible for treatment of COD and ammonia, and the different population styles found in aeration plants to those in filter works. Attention was also drawn to then what could go wrong and how this related to some of the issues they had found (e.g. organic overloading causing excessive film growth in filter beds and then ponding on the surfaces). Figure 89 and 90 are photos taken at the time.

9.1.3) Calculation Exercise

A third exercise then followed to encourage further exploration of the findings. This time it was a quantitative session, taking the YPs through some basic calculations looking at the flow characteristics of the primary tanks. It had been observed that the flow being put through the tanks on the north works was very high.

As the performance of the primary tanks influences the load being put on later stages, it is important for anyone doing an assessment to understand what it happening from the first stages. This was achieved by taking the data for flow and for tank sizes, and then taking the YPs through worked examples to derive the upward flow rate (or surface loading rate). This value is representative of the hydraulic loading on the tank, and should be within a tight band.

To calculate upward flow they first determined the surface area of the tank, and then used both average and maximum flow rates.

Upward flow (m/hr) = tank surface area (m2) / flow rate (m3/hr)

By repeating these calculations at different quoted flow rates the YPs determined that the upward flow rates were well in excess of the recommended rate of 1.2m/hr. Consequently, they were able to see that this hydraulic loading was excessive and would have adverse affects downstream. Examples of such affects witnessed were sludge that was too thin, and needed further settlement in the West works, and high loadings on the secondary treatment phases.

9.2) Northern Works WWTW

It was originally intended to carryout similar exercises at Northern Works. However, after the initial findings, it was decided to amend this approach. After the first day it was found that this site had many good areas and practices. Hence, we decided to carryout a “What is good comparison” exercise to illustrate how things can and were being achieved. Figure 91 below details this work.

9.2.1) Northern Works WWTW "What is Good?" YP Exercise

	Good Finding or Observation by YPs
1	Final Effluent quality good
2	Optimisation – attitude of "not waste" (i.e. produce compost from sludge)
3	Plant has more advanced technology
4	Evidence of maintenance
5	Knowledge of staff
6	More organised
7	Staff more active
8	Managers organised and understood their roles
9	Managers had good working relationship
10	Better housekeeping
11	Small, but important workshop and spares holdings
12	Maintenance contract for instrumentation
13	Active and planned expansion programme
14	Active and planned refurbishment programme
15	Process easy to follow
16	Procedure in place for emergencies (incl high value critical items)
17	No flies!
18	Contact tank for chlorine disinfection
19	On-line monitors working
20	Standby and call-out system
21	SCADA unit monitoring the site
22	Screenings dewatering – and taken to off-site controlled landfill.

	Potential Reasons Why (or Root Causes) Considered
1	JW are separate business entity (albeit wholly owned by Job. City)
2	Level of expertise is high
3	Focus is wastewater treatment
4	JW benefit directly from the collection of revenues
5	JW allowed to borrow money on their own
6	Able to attract higher quality staff – better pay and conditions
7	Assumed greater flexibility

9.3) Meyerton WWTW

As the group of YPs were beginning to function more as a team and learning from each other, it was decided that they should be asked to prepare a presentation for the final feedback day in the second week.

This was perhaps a bit of a surprise to them initially, but they soon rose to the challenge. The inspection at Meyerton allowed them to further consider the classroom exercises and to begin to use the learning. Subsequently, the classroom time in the second week was spent with them preparing and then giving the presentation. This was done firstly internally to us, and then to the wider audience on the final day.

10) Significant Observations and Conclusions

Due to the size and nature of this assessment exercise, the main observations and conclusions have been presented as chapters associated with the site details (Rooiwal 5.8, Northern Works 6.8, and Meyerton 7.8). Each observation is discussed and conclusions drawn. In some cases these are individual to each site, and in others they are relevant across one or more areas. The table below in 10.1 summarises the generic areas as they applied to each of the three sites. The following sections comment on some more generic areas.

10.1) Summary of Overall Issues

Issue	Rooiwal	Northern	Meyerton
Hydraulic loads received against designs	√	√	√
Biological loads received & handling of	√		√
Insufficient treatment capacity (flow)		√	√
Insufficient treatment capacity (load)	√		
Poorly set-up processes	√		√
Poor BNR configurations	√		√
Inadequate internal management of flows	√		√
Major equipment out of service	√		√
Poor operational maintenance	√		√
Poor mech/elec maintenance	√		√
Insufficient monitoring/supervision	√		√
Poor quality or inexperienced staff	√		√
Lack competent staff numbers	√		√
Complex & constraining funding arrangements	√		√
Low quality of contracts			√
Inadequate health and safety arrangements	√	√	√
Lack of standby power capacity	√	√	

This list is not exhaustive and the details are discussed in sections 5.8, 6.8 and 7.8.

10.2) Flow Management Decision Making

One factor noted was the tendency for many South African parties to refer to site capacity in terms of “MLD”. That is, in all cases, site capacity was quoted in terms of design capacity measured in megalitres per day (MLD). Subsequently, it did appear that further design decisions about treatment processes were being made on hydraulics alone. In addition to this, it did appear that insufficient attention was being paid to actual received flows, most thought being about design levels.

In the UK and other areas of Europe it is common practice to consider the size of treatment plants in terms of “population equivalent”. This is a general parameter which allows comparison of works using a common factor which relates to the actual loading applied to them. Population equivalent (PE) considers the “loading” on a process or plant, which is a product of both hydraulic and biological factors. It is considered appropriate to use PE as merely considering the hydraulics is not enough.

For example, a plant may have the physical nature to cater for some hydraulic flows, but not enough biological capacity to actually treat the material. This may be particularly apparent when sites receive high strength influents from food industries.

Purcell (2003) defined PE as follows:

"*The quantity and strength of a wastewater source can be more meaningfully presented by equating it to a number of persons that would be required to contribute an equivalent wastewater load, generally referred to as the population equivalent (PE), 1 PE is generally considered to be equal to 60g of BOD_5 / day. Therefore, BOD_5 load may be converted to its population equivalent as follows*:"

$$\text{Population equivalent} = \frac{\text{daily } BOD_5 \text{ load (kg/day)}}{0.06}$$

BOD_5 is the measure of the biochemical demand measured over a five day laboratory period. It is realised that in South Africa COD is used primarily to represent organic loading rather than BOD. Some limited research suggests that the generally regarded relationship between PE and COD is 110g COD per person (Mosai, 2007).

10.3) BNR Configuration

The details of site BNR configuration are discussed in the relevant site chapters, but one common factor observed was apparently incorrect layouts. Some of these were apparent from the original design-construction and some by modification. No obvious reasons for these errors were discovered.

It is considered possible that this had resulted from a combination of changes in demand (e.g. tightening of consent standards to include nutrients), lack of understanding and the number of potential options available. Insufficient time was available to examine this thoroughly during this assessment phase. Further research is required to discover the underlying reasons.

10.4) Risk Scores

The DWAF (DWEA) approach of overall risk scoring was seen to be a sound basis as it attempted to include a variety of factors to derive a "level playing field" for assessment of the sites. This can be compared (in principal) to the "Overall Performance (OPA) Score" system used in the UK. This system is used by Ofwat, the UK water industry regulator to judge the companies performance against each other. The parameters used are different, but the principals very similar. As discussed elsewhere the actual factors used and their weightings do need to be reconsidered, but the process should be retained.

10.5) General

In general, all of the sites had significant issues to be dealt with. Rooiwal and Meyerton had several pieces of critical plant out of service. Restoration of some of these units would significantly enhance overall treatment capacity and performance. Northern did not have as much, but definitely suffered hydraulically.

Staff at both Rooiwal and Meyerton were generally willing, but often lacked the knowledge and experience necessary to operate and run such works. At both of these sites some staff were seen to be standing around doing very little. This did imply a lack of work arrangements and supervisory capability. The quality of management at Northern did appear much higher and more effective.

Funding arrangements at Northern were much more flexible than at the other two sites.

The initial significant findings and conclusions were presented at the feedback meeting in Meyerton on the 18th March.

11) Recommendations

There were very many issues and factors observed during this project. The initial feedback meeting discussed several of these. This section attempts to summarise into a series of recommendations:

11.1) Short Term (within the next six months)

1) Refurbish/restore essential plant

Both Rooiwal and Meyerton were missing large parts of their essential treatment process train.

The biological filters on the Rooiwal east works should be refurbished and restored to full function. This would enable loads to be removed from the north works. Serious consideration should be given to doing the same at the west works. The west may require a cost-benefit analysis against installing further treatment capacity in the north works due to the large amount of work required. However, as the civil structures are largely intact, the metal-work element should be achievable quickly.

The anaerobic digestion process at Rooiwal was not functioning fully. Civil and mechanical repairs should be carried-out to restore effective production of methane. This methane can then be used to heat the process to ensure it stays mesophilic. Some degree of start-up heating may be necessary to initiate the digestion process.

Meyerton had only limited aeration capacity. Repairs should be made to the aerator equipment immediately to restore treatment. The work required did appear to be relatively straight-forward mechanical refurbishment of motors and gearboxes. Full restoration of the BNR treatment phase would require some re-seeding with healthy activated sludge from a similar plant elsewhere.

On both sites there were several pumps and smaller equipment left lying around in pieces. These should be restored to full function or replaced.

2) Restore/ install flow adequate flow measurement

Flow is clearly an issue at all of the sites. However, until it is being measured accurately it will be impossible to correctly analyse and decide on any control strategy. Any existing devices need to be calibrated and trended over a period of time to precisely determine the patterns of flow. In some cases this may require installation of new devices to determine flows not currently measured.

Accurate flow measurement is essential to calculate and assess loadings being applied to any part of a works. Calibration should be part of normal routines, and performed at six monthly intervals.

3) Devise and implement maintenance programme

It is essential to have a programme of routine maintenance activities for any site. This is relevant to both operational and mechanical activities. Absence of any obvious planned programme at both Rooiwal and Meyerton was not enabling essential works to be done.

The SAP computer programme does have this functionality, but a programme can be based on a simple spreadsheet style (i.e. "tick-sheet"). This should start by identifying the daily routine tasks, and then move up to the less frequent ones. The small table below is an example of how this might look:

Example "tick-sheet" for maintenance.

Area of works	Action	Frequency	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Inlet screens	Clear rag blockages	Daily							
	Check operation	Daily							
	Lubricate drive motor	Monthly							
Biofilter	Clear sparge holes	Daily							
	Check dosing syphon	Daily							
BNR	Check gearbox oil levels	Weekly							
	Sample oils	Yearly							

Use of such sheets would enable considered planning of work, simple instruction to the workforce, a method of recording work done/not done, and it is a tool for supervision and management.

Where there are cases of low literacy this could be supplemented to include simplified sketches and drawings of the tasks.

Part of this area would be the examination and renegotiation of the some of the contracts. Meyerton reported that they do have contracts let for mechanical maintenance, but they were vague and did not contain any real incentives for contractor performance. Northern Works did have a team of semi-permanent contractors, as well as a small essential spares and repair workshop. Rooiwal had a large new workshop, but site staff did not seem to have ready access to it. Furthermore, site management at both Rooiwal and Meyerton need to have direct managerial control over any maintenance staff.

4) Devise and Implement Sampling Programme

As with flow, very little was known about the actual characteristics of the wastewater arriving or as it passed through the works. Rooiwal did have some auto-analysers on the north works effluent, but it was not clear if this was being trended anywhere. The analysers at Northern were being fed-back to the SCADA system. Meyerton did have monthly samples taken by East Rand Water, but these did not go far enough.

The management of any treatment process requires a variety of information about how each part of the plant is performing. The more complex the process, the more necessary it is to have detailed information. Such data can be derived from on-site manual testing, auto-analysers, or samples sent to a laboratory.

Parameters such as ammonia, nitrates, phosphates, mlss / ras solids, turbidity, temperature and pH can all be measured on-site, using basic equipment. All of these tests are simple, and generally reliable. Furthermore, all can be taught to people with low literacy levels quite easily.

Any programme should include for daily monitoring of items such as ammonia, turbidity, pH, nitrates and phosphates. Parameters such as mlss and ras concentrations should be done at least weekly. COD should be done at least weekly, but would generally require laboratory analysis.

As the understanding of the plant performance appeared rather low, it is recommended that a series of samples be analysed over a period to enable trending and measurement of actual loadings across the various stages of the process. Without at least two months worth of data, it is difficult to suggest what process changes may be needed.

5) Establish Good Practice Sharing

Whilst not perfect, Northern Works clearly had a lot of good practice in operation. Moves towards sharing this experience need to be made. Managers for both Rooiwal and Meyerton would benefit from having regular contact with their Joburg counterparts.

6) General Governance

Vast differences existed between the sites in terms of levels of flexibility and levels of controls for managers. This needs to be re-examined and ways of improving this sought. It is understood that a large number of laws exist at Municipality level, but all are meant to be operating within the same basic financial and legal regulations. Some of the constraints placed on funding and procurement where seen to be impeding quick and decisive action at site level.

7) Health and Safety

Very many examples of poor practice were witnessed. These have already been detailed, but all three sites visited need to improve in this area. Particular examples were lack of protection for drinking water (all sites); use of gaseous chlorine; and lack of fall prevention (Rooiwal and Meyerton).

Attention should be paid to these areas and funds made available locally to prevent harm and lower risks on site. As several areas were found to be commonplace across sites, it may be appropriate to do this on a regional basis.

Contracts and contractor standards should be included in this work to ensure that safety is included within the design and construction of new works. For example, to avoid the issues at Meyerton around the aerated balance pond. It is difficult to expect operatives to maintain safe standards if construction leaves several high-risk hazards from new!

11.2) Medium Term (over next 12 months)

8) Training of Young Professionals

The group of YPs selected to be part of this project did show some progression and improvement throughout. However, it was necessary to spend a proportion of the time going over the basic elements of wastewater treatment. Regretfully, insufficient time was available in country to fully explore this topic.

Candidates would need to spend some time on sites actually learning how to operate the processes so they fully understand the problems, and what actions work and those that may not.

It is recommended that the YP programme be continued, but subdivided to ensure the candidates have the opportunity to learn and demonstrate knowledge of the basic processes before they are tasked with actually assessing them. This could be achieved starting off with smaller, less complex sites and building to larger ones. Built-in to such a programme should be assessments including presenting their findings (verbal and written) to demonstrate learning and observations. The ultimate aim would be for a team of candidates to take this through to writing a report for themselves.

The overall training programme for the YPs would take several months, but it is envisaged that an assessment-capacitating phase would take between three to eight weeks, depending on the complexity and number of sites to be inspected.

9) Review Overall Risk Score Process

The overall risk score process placed Northern Works high on the list. This occurred due to past issues with site compliance, and the flow issues. However, it failed to account for more recent improvements in treatment and capital investment. The inspection visit did not find any major issues with staff or treatment quality.

It is recommended that the scoring process be reviewed in light of the findings of these inspections. Further study is required on the nature of any failures, and the elimination of isolated "spikes" in compliance from average and overall trends. Flow is indeed an issue at this site, but investment is being put-in to tackle the issue.

10) Review Licensing Processes

The inspections did not focus on the issue site licensing, but the impression was that several sites did not hold a current one, and some of the standards were more general, rather than site specific. Some mention was made of the municipalities not making applications.

The purpose of a license should be to control the discharge from a treatment plant, relating it to the ability of the receiving watercourse to deal with the loading; the nature of downstream use of the water; and the ability of the site to sustain treatment to those standards.

Consequently, it would be expected that the entire catchment characteristics be examined and a set of standards be derived from that. For example, a sea discharge would not need to be as strictly controlled for nutrients as an inland water with potable abstraction points downstream. Conversely, there would be little point in setting limits on a works that clearly cannot meet them with its existing treatment processes. In such cases, the risk score should be elevated.

When these levels are established, then they should be proactively applied to the treatment process. In many cases this would likely lead to the need to invest more in the treatment process.

11) Critically Examine Site Configurations

This applies particularly to the BNR plants. Northern Works have examined their configurations in some detail in the past, and converted to ensure effective levels of treatment. There is much published material on these past projects. One such example is an article by Dr. A.R. Pitman entitled “Process Design of New Biological Nutrient Removal Extensions to Northern Works, Johannesburg”. This can be found as chapter four in “Nutrient Removal from Wastewaters”, edited by Nigel J Horan, Paul Lowe and Ed. I. Stentiford (1994).

The configuration of the BNR at Rooiwal did not seem to meet any of the “normal” expected patterns for nutrient removal. The consultant report did mention the possibility of modifying to the Johannesburg configuration. It is not possible to suggest which configuration to change to currently without the availability of some sustained loading and flow information. A simple internet search did discover a large number of publications on process designs for BNR configurations. These could be used a source of reference once the pattern of flows and loads was available.

Meyerton has two different treatment stages. The BNR unit comes after an aerobic oxidation phase. It was possible that dentrification was occurring in the long channel upstream of the BNR, but only accidentally. Conditions were not appropriate to reliably remove both N and P. As the site is due to be decommissioned in five years, the recommendation would be to fully restore the aerobic phases to ensure proper COD and ammonia treatment. This would increase nitrates, which would then need to be dealt with by the addition of an anoxic tank. It may be possible to create this by sectioning off part of the front of the anaerobic zones. If the anoxic zone was successful this should facilitate P removal in the anaerobic zone, but it may be necessary to supplement this with chemical dosing. Ferric sulphate or ferrous chloride could be used for this, but should be done upstream of the BNR to encourage precipitation in a settling stage whilst aerobic conditions still existed.

Further work is needed to examine the Unit one biofilter plant at Northern works. It is currently operating under capacity, and may prove cost-effective to bring it back up to specification.

12) Carry-out Formal Assessment of Staff

All staff, including management and supervision should be formally assessed against some standardised criterion. This needs to include the ability to demonstrate the ability (or not) to operate plant and make necessary adjustments on a day-to-day basis.

These assessments should link closely with the WSSCU benchmarking project currently underway. The main purpose of this would be to establish a starting point for constructing any training and development programmes. It is recommended that initial assessments should be done on the basic elements of wastewater treatment, and then move onto the more specialised topics on specific works.

Staff at Meyerton did make mention of some previous assessment having been done, but could not provide details, and had not received any feedback.

13) Invest in Supervisory Training and Coaching Programme

This is particularly recommended for site supervisors and senior operators. Levels of supervision where seen to be very low and ineffective at both Rooiwal and Meyerton. Site managers were exerting some degree of supervision at Northern Works.

In general, the supervisors at Rooiwal and Meyerton were willing and wanted to be able to do a good job. What they lacked was experience and the ongoing training. This was both from a process knowledge and coaching ability perspective. Large sites can be run with smaller numbers of staff if the expected tasks are clearly laid out and then work quality closely supervised.

If possible, it is recommended that supervisors spend some time with their counterparts in Johannesburg to see such techniques put into action.

Supervisors should also be taught how to coach their staff. This may include using visual aids. The DWAF have produced an illustrated document for this purpose. "An Illustrated Guide to Basic Sewage Purification Operations" (2002).

A further document obtained during the visit was "Introduction to Wastewater Treatment Principles and Practice". This is a technical guide written in some detail by Dikubu Water and Environmental Services, PO Box 6001, Halfway House 1685, South Africa. dikubu@mweb.co.za . This is a well written document giving advice across many processes and is recommended reading for site supervisors and managers. Also cited in this document were:
"Manual on the Design of Small Sewage Works", First Edition 1988, WISA
"Handbook for Operation of Wastewater Treatment Works", First Published 2002, WISA.
"Theory, Design and Operation of Nutrient Removal Activated Sludge Processes", WRC Report No. TT16/84.
"Operational Manual for Biological Nutrient Removal at Wastewater Treatment Works", WRC Report No. TT83/97.

11.3) Longer Term (over next 1 – 3 years)

12) Introduce "Licence to Operate" scheme

Each individual within the process, from General Worker, right up to Site Managers should hold a licence to operate at that level.

The general principal is that roles and generic responsibilities are defined at each level in the structure. Assessments are then made against these criteria. These can be practical competency demonstrations for site personnel, and more knowledge based for supervisors and managers. This type of scheme would assist the process of consistency across any one or more municipalities.

It is envisaged that this could be built into the current WSSCU programme for development scales.

13) Install Automated Site Monitoring

Rooiwal does not have any form of automated monitoring. Staff did talk of a possible SCADA system, but with no timescales. On a site of this size it is not practicable to maintain visual checks on the critical elements. An automated system of telemetry or SCADA should be installed. Either system would provide early warning of plant breakdowns and issues, but SCADA would provide more localised controls, and would be easier to manage. It would require personnel on site trained to suitable standards to interpret and manage the information. Such expertise has been achieved at Northern Works.

Meyerton has a small-scale telemetry system. Staff talked of installing a SCADA system, but with no timescales. As the site is due to be decommissioned in five years, it may not be economic to fit a SCADA. A cost-benefit analysis should be carried-out against improvements to the existing telemetry equipment to cover all critical equipment. It would require personnel on site trained to suitable standards to interpret and manage the information. Such expertise has been achieved at Northern Works.

Northern Works has an existing SCADA system. Care should be exercised to ensure that this remains current and covers all new critical plant.

Investigations should be carried-out to providing key personnel (e.g. site managers / supervisors and key standby staff) with laptops or other IT to enable them to remotely interrogate any site monitoring systems. This could have the benefit of managing costs by controlling call-out attendance.

14) Install Sludge Liquor Pre-Treatment

The ability to install this would largely depend on what type of sludge processes are on site. Joburg Water have previously reported experience of nutrients being re-released from sludge during dewatering stages. They have dealt with this by applying slaked lime dosing to filtrate liquors.

This adjusts the pH above 9.2 and encourages precipitation of P in the primary tanks. They also utilise composting to stabilise sludges.

No such systems exist at Rooiwal or Meyerton. A treatment system is required at Rooiwal as the filtrate loading back to the north works must be high.

For Meyerton a full system is unlikely to be economic in the time before closure, so it may be more appropriate to consider some form of chemical dosing (which can then be relocated to another site).

15) Standby Power Generation

Rooiwal had none, Northern Works only one unit at the inlet, and Meyerton had two units. Large sites do need to have standby facilities as significant environmental damage can occur in less than a day without power. Furthermore, biological processes take time to recover once power is restored. Funding should be made available to install more units at strategic locations.

12) Next Steps

Although this project was only short, a great deal was gained from the experience. The initial intent was to carry-out assessments based on cumulative risk scoring and to enhance capacity within some young professionals.

It became clear from early on that the task of carrying out the assessments was very much a "learn and adapt as you go" process. The capacitating of the young professionals tended to be a very similar process.

General conclusions arrived at from this project:

1) There is still a lot of work to do to identify and quantify the characteristics and issues on the various WWTWs.

2) Whilst a growing level of excitement was observed in the YPs, their level of process knowledge needs to be raised for them to be effective in their assessment role.

3) There are some common themes (e.g. cumulative risk scoring criteria) which need to be considered both at Provincial and National levels for the overall project to succeed.

4) The approach to the inspections should change. On reflection, it would have been more beneficial to have visited these sites over a three to four week period, with a time in the middle (still in country) to begin to evaluate initial findings. This evaluation would then generate questions and requests that would have been far easier to answer closer to the time.

It was felt that the following course of action be pursued:

1) Submit this report to various interested parties as included in the original project briefing. Discussion and review to follow between all parties.

2) Continue the project of selecting groups of sites for inspection, but with a revised approach. If possible, it would be useful to compare sites and municipalities across more than region.

3) Select more YPs for this project, but to first spend some time expanding their treatment process knowledge without the pressure to actually assess.

4) Integrate the findings of the project inspections into discussions relating to the overall catchment management.

5) Use the above to devise a rolling programme to gradually pass-on the responsibility to local resources within municipalities and regulatory resources.

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14) Appendices

1) Appendix 1 – Photograph gallery, containing selection of pictures taken during the inspections. Many are labelled “figure..”, referring back to the text.

Rooiwal WWTW East Works March 2009

Fig 1: Mechanical Screen out of use and under repair. Also shows limited ppe

Fig.2 East Works PSTs out of use – mechanical failures

Fig.3: East works PST short-circuiting

Fig. 4: East works biofilters ponding due to overloading

Fig 5: East works filters out of use due to mechanical issues.

Fig. 6 Humus tanks overloaded

Fig. 7: Ferrous chemical dosing plant out of use.

Fig. 8: Leaking digesters east works

Fig. 9: Empty gas holder east works

Fig. 10: Boiler out of use due to lack of gas.

Rooiwal WWTW West Works March 2009

Fig. 11: Inlet works abandoned and unused.

Fig.12: Inlet works abandoned

Fig. 13: PSTs being used to re-settle sludge from north works

Fig.14: Biofilters totally out of use, mechanical plant missing

Fig. 15: Biofilters out of action due to mechanical issues, excessive vegetative growth.

Fig. 15: Biofilters out of action, missing mechanical plant.

Fig.16: West works leaking digesters

Fig.17: Gas holder empty, with perished internal gas bag.

Rooiwal WWTW North Works March 2009.

Fig. 18: Flooded inlet flumes

Fig. 19: BNR Reactors

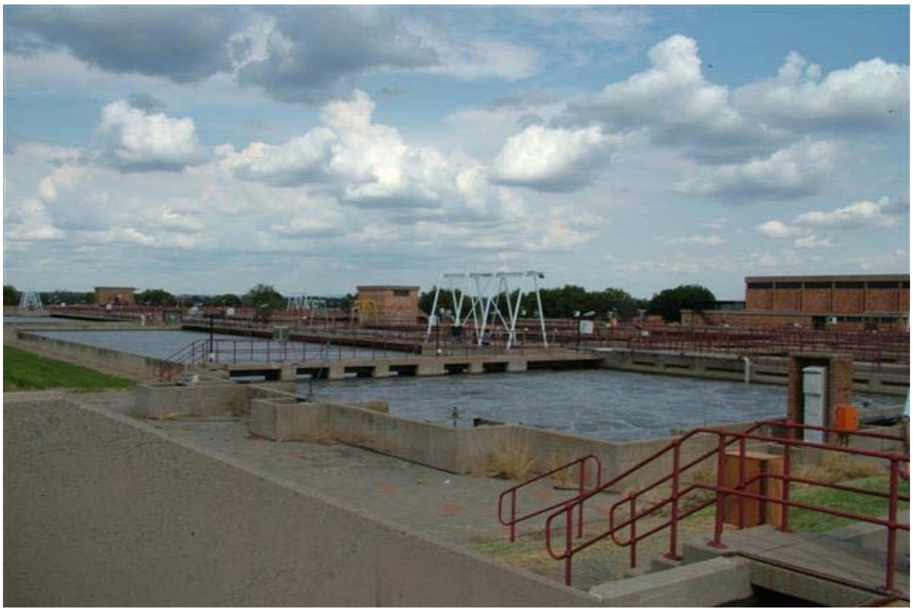

Fig.22: RAS screws taken out of action, pumps partially dismantled.

Fig.23: Above ground RAS pipelines feeding back to BNRs

Fig. 24: Overflows from sludge transfer ps, around water (non potable) tap

Fig. 25: General view of aerobic digester

Fig. 26: Drum thickeners not being used.

Rooiwal WWTW sludge dewatering plant March 2009.

Fig. 27: Sludge holding dam, with floating aerators.

Fig. 28: Sludge dam inlet flows, shows close proximity of inlet pipes to banking.

Fig. 29: Unfinished maintenance around sludge dam.

Fig. 30: Sludge overflows from holding dam.

Fig. 31: Lack of maintenance sludge dam plant.

Fig. 32: Security issues with damaged fence left un-repaired at sludge dam.

Fig. 33: Sludge dewatering press belts inside building

Fig. 34: Finished dewatered cake product on conveyor belt.

Fig. 35: Redundant polymer dosing equipment.

Fig. 36: Polymer dosing plant in use.

Fig. 37: Inclined cake conveyor transporting cake into elevated hopper.

Fig. 38: Cake spreader, re-used silage spreader with wheel missing.

Fig. 39: Redundant flow measuring devices at west works

Fig. 40: Potable water tap, labelled but in very vulnerable position.

Fig. 41: Safety warning on blowers on north works.

Northern Works WWTW March 2009

Fig. 43: Grit and screenings properly collected in skips prior to off site disposal.

Fig. 44: Inlet channel very close to overflowing

Fig. 45: PST Launder channel flooded due to hydraulic overloading

Fig. 46: Bank of 6 digesters, some in need of refurbishment.

Fig. 47: Sludge dewatering filter presses.

Fig 48: Sludge composted and placed into windrows.

Fig. 49: Wood chippings being sorted for re-use after composting.

Fig. 50: Slaked lime pH adjustment plant.

Fig. 51: Spillages around lime dosing plant not cleaned-up.

Fig. 52: Auto analysers monitoring various fe components.

Fig. 53: Sludge spills following power cut, not yet cleared-up.

Fig. 54: PST out of action, showing crust formation, awaiting repairs.

Fig. 55: Small essential spares stores.

Fig. 56: Small maintenance workshops and spares.

Fig. 57: Hypochlorite disinfection equipment.

Fig. 58: Drinking water tap – signed, but very close to inlet works channels.

Meyerton WWTW March 2009

Fig. 59: New standby generator at inlet works

Fig. 60: Rough and uneven ground around inlet works, also shows rag being dumped.

Fig. 61: Inlet screens channels with no fall protection provided.

Fig. 62: Mechanical and hand rake screens, also with no fall protection provided.

Fig. 63: Screenings removal, showing wheelbarrows.

Fig. 64: Unsafe access to skip for rag and grit disposal.

Fig. 65: New PST heavily overloaded, with thick scum of solids on surface.

Fig. 66: New aerated balance pond with highly septic contents, showing aerators out of use

Fig. 67: Joining channel for flows from both inlet works.

Fig. 68: Disused parallel grit removal channels.

Fig. 69: Flow meter flume and instrument – not set-up or calibrated.

Fig. 70: Poor condition of BNR inlet zones.

Fig. 71: Poor condition of BNR zone 2 shows septicity attack on bridge.

Fig. 72: Mixer leaking oil.

Fig. 73: BNR Zone 2 aerator out of action and heavy crust forming.

Fig. 74: FST Structure cracked and damaged.

Fig. 75: FST Surface showing grey-black poor quality contents.

Fig. 76: Temporary Fix Chlorination unit, fixed but not functioning.

Fig. 77:Lagoon and contact tank, full of sludge and being bypassed.

Fig. 78: New sludge digester, open topped.

Fig. 79: Sludge drying beds with vegetative growth and algae on surface.

Fig. 80: Sludge storage area inlet chamber, clearly not been used for some months.

Fig. 81: BNR RAS pumps with interesting additions.

Fig. 82: Standby generator at BNR unit, showing ill thought out placement.

Fig. 83: Dosing building in poor condition and unused.

Fig. 84: Poorly designed and fitted lifting beams for floating aerators.

Fig. 85: Transfer ps with panel doors open, posing high risk of electric shock.

Fig. 86: Inadequate warning or protection against electric shock.

Fig. 87: Electric cable cut off and not protected in any way.

Fig. 89: Classroom Session at Rooiwal

Fig. 90: Assessment Team at Rooiwal.

Fig 91: Assessment Team at Northern Works

2) Appendix 2: Meyerton WWTW process Calculations

VGC report (September 2006) predicts a COD load of 9500 kg COD/day (2015)

Aeration capacities: -

Assuming 1 kWh = 1kg oxygen/hour (a conservative estimate)

Existing BNR :	2 x 75 kW + 1 x 30 kW	= 4320 kg O2/day
Additional Reactor pond:	5 x 45 kW	= 5400 kg O2/day
	Total Oxygen capacity	**= 9720 kg O2/day**

Therefore there is more than sufficient aeration capacity to treat 100% of the COD load assuming that **all aerators are functioning**

Organic loading (f/m ratio): -

Assuming MLSS of 4500 mg/l (stated as the norm)

Existing BNR (aerobic zones) total volume 4342 m3	= 19539 kg TDS
Additional Reactor pond operating volume 5000 m3	= 22500 kg TDS
Total mass of MLSS	**= 42039 kg TDS**

Using 9500 kg/d COD* loading: -

f/m = 9500/42039 kg/kg/d
= **0.226 kg/kg/d**

Conventionally f/m ratios are calculated using Biochemical Oxygen Demand (BOD) rather than COD (Chemical Oxygen Demand); there is a ratio range of about 1.5 – 2/1 COD/BOD (depending on the composition of the sewage)

A realistic calculation of f/m using a derived BOD load (from the predicted COD loading of 9500 kg/d) would be: -

(9500/1.5) / 42039 = **0.15kgBOD/kg MLSS/d**

The latter f/m is in the middle of the ratio required to achieve 100% nitrification in a conventional activated sludge plant.
VGC report (September 2006) predicts a COD load of 9500 kg COD/day (2015)

3) Appendix 3: Recommended Basic Monitoring on Sites

There is a vast array of parameters that need to be fully understood on complex BNR sites. The advice on which and how often to monitor for them varies, and would be largely dependent on circumstances. However, the table below provides some basic recommendations for day to day understanding and process control.

Primary, Secondary & Tertiary Treatment Phases

Item	Crude	Settled	2^o effluent	3^o effluent	MLSS	RAS	WAS	Daily on site
Flow	√			√	√	√	√	√
Total COD	√	√	√	√				
Rb COD	√	√	√	√				
TSS	√	√	√	√				√
Alkalinity	√	√						√
Phosphate	√	√	√	√				√
Nitrate	√	√	√	√	√	√		√
Ammonia	√	√	√	√				√
TN	√		√	√				
Free Chlorine				√				√
Coliforms			√	√				
E Coli			√	√				
SSVI					√			√
% DS					√	√	√	√
DO					√			√

Key:

Rb COD: Readily biodegradable COD, the proportion of the organic load that is likely to be degraded in the process (important in BNR design considerations).
TSS: Total suspended solids
Nitrate: Oxidised nitrogen, a measure of the levels of ammonia degradation.
TN : Total Nitrogen, a measure of inorganic and organic nitrogen compounds , both soluble and particulate (reduced by efficient sludge removal and/or denitrification in the BNR reactors)
MLSS: Mixed liquor suspended solids. This is a measure of the active microbiological levels within the aeration process, and will be specific to particular sites and processes.
SSVI: Stirred sludge volume index. A measure of the settlability of the MLSS in the post aeration settlement phase.
%DS: percent dry solids. An important measure of the solid content of the sludge
DO : Dissolved Oxygen content important to monitor and control in the 2^o Treatment stage
2^o effluent: Effluent from the secondary phases. This will typically be the individual BNR reactors.
3^o effluent: Effluent from any tertiary phases such as settlement ponds.

It should be noted that this table is not exhaustive, and frequencies of sampling would need to be greater initially to allow an understanding of plant performance to be gained. After this is achieved, then frequencies could be reduced.

Sludge Treatment

Item	Primary Sludge	Digested sludge	Digester Gas	Thickened sludge	Filtrate/ Centrate	Sludge cake	Daily on site
Flow	√	√	√	√	√	√	√
Total COD					√		
Rb COD					√		
TSS					√		√
Ammonia					√		
pH		√					√
VFA		√					
Alkalinity	√	√					
% DS	√	√		√		√	
%VM	√	√					
Temp		√					√
NPK						√	
Metals	√	√		√		√	
Gas comp			√				√
Coliforms	√			√		√	
E Coli	√			√		√	

Key:

pH, VFA (Volatile Fatty Acids), Alkalinity & Temperature : all important parameters to maintain in correct mesophylic anaerobic digestion
%DM (Dry solids) & % VM (Volatile matter): important to measure in/out of digestion to assess effectiveness of digestion
NPK: Nitrogen/Phosphorous & Potassium content – important if being used on agricultural land
Metals: e.g. As.Cu,CrHg,,Ni,.Pb,Zn, - concentrations limit volumetric loading to land disposal.
Gas composition : should be approx 70% Methane: 30% Carbon Dioxide
Coliforms & E coli : can limit amount and specific usage of sludge to land

4) Appendix 4 Financial Evaluation Document

A FINANCIAL EVALUATION OF THE STATUS OF MUNICIPAL WASTEWATER TREATMENT WORKS IN SOUTH AFRICA

-a case study based 'snap shot' view-

This Report represents a review of the financial aspects of Municipal Waste Water Treatment Works (WWTWs), as a complimentary report to the First Order Assessment of Municipal Wastewater Treatment Works (April 2008 – July 2009), as well as the field (technical) assessments conducted by the PAWS team led by UK specialists Messers Rob Smith and Tom Wayling in March 2009. In addition to the site assessments the authors incorporated learning from two further WWTW reviews conducted namely Brits WWTWs and Zeerust WWTWs. Discussions held with Mr Sean Deacon (Best Practices Manager of Johannesburg Water,) and Mr Max Pawandiwa, Water and Sanitation Manager at UGU District Municipality were also helpful in compiling this review.

Context

The technical assessments of WWTWs that are conducted by a DWAE-WISA specialist team cover many aspects including plant loading and design issues, the condition of the works, staff capacity, environmental (discharge standards) issues regulatory matters and operational issues. The operational issues include a comparison of the works budget to the national norm of between R0.8 to R 1.3 to treat a cubic meter (m^3) of influent. The higher costs being applicable to high-end technology WWTWs.

From the assessments, it was clear that at some of the works, assistance with respect to access to technical skills, materials, resources, service providers, training or finance should be facilitated by DWAE; yet at other works the best course of action would be emergency procedures as outlined in the enforcement protocol.

It should be noted at this point that some caution needs to be extended as the accuracy of the base data. That is, in the derivation of per capita costs it is necessary to have reliable flow measurement. The on –site assessments did reveal some issues with this process. For example, on one site the flow meters were said to have been calibrated every two years, and on another the measurement devices where not being used in a way that would provide reliable data. Whilst this was only observed on the 3 sites visited, it is reasonable to assume that the general issue is perhaps more widespread. As this factor is a basic building block to financial assessment of works and Municipality performance, an assessment of flow measurement data and practice across the country would be necessary to provide greater confidence going forward.

From the assessments conducted and further research, **several areas of potential improvement in the financial assessments are suggested.** It was found that a comparison between the budgeted costs and the national norm is not sufficient to determine whether a WWTW has sufficient funds available for its duty. Furthermore it is believed that the suggestions will help **distinguish between where a works suffers from inadequate finances and where finances are not a constraint to the functioning of the works and other factors require attention**. This will then aid the assessor in making a recommendation on the course of remedial action where there is non-compliance.

Reviewing the total allocations towards sanitation services provides some insight into the challenges that face municipalities responsible for the works, but it does not reveal much about the efficiency or effectiveness of the works. Higher expenditures at a particular treatment works may reflect difficult technical conditions, such as a dispersed population or a municipality reaching a specific stage in the life-cycle of its assets. But it may also reflect higher than average personnel costs, weak O&M practices or expenditure control systems. Or in extreme cases it may reflect intentional inappropriate or misleading budgeting.

Inefficiencies in operational aspects such as maintenance will quickly translate into increased expenditures and perhaps even reduce the availability of resources available to the works.

At many municipalities, budgeted revenues are seldom achieved due to the culture of non-payment that persists well into SA's democratic era. In fact the ***2008 Local Government Expenditure and Budget*** review highlights consumer debt as one of four key area of concern. Unlike the water boards and national utilities the municipalities are not shielded from non-paying consumers. Other areas of concern highlighted in the review are:

- **Growing grant dependence**

'The growth in government transfers has occurred at a faster pace than the increase in own revenue generated by municipalities. This has created a situation where municipalities are increasingly dependent on grants to fund their operating costs. This is creating a dependency syndrome, which in future might be unsustainable. The equitable share constituted 8.6 per cent of the total operating revenue in 2003/04. This has risen to an estimated 17.5 per cent in 2007/08.'

- **Inadequate maintenance expenditure**

'Among the reasons for the low expenditure on repairs and maintenance is the ease with which these expenditures can be deferred in favour of new capital projects or other operating costs. This results in the degradation of the value of assets and the need for their replacement earlier than might otherwise be the case. Two factors appear to underlie this problem. First, the under-pricing of municipal services relative to their true cost of delivery, including maintenance costs. Second, poor management practices in municipalities, particularly the absence of up to date asset registers, often result in maintenance schedules either not being set or being ignored.'

A further important consideration is the apparent lack of will to involve operational staff (particularly management) in the capital design process. It was found that little or no input was going on and this is thought to have contributed to the delivery of some less than suitable capex solutions. In general, it is thought likely that seeking to utilise any knowledge of operational staff may have been able to reduce overall expenditure. This could be through more suitable (and therefore more useful) capex investment that would directly enhance the operating process. By doing so longer term costs may actually be reduced.

One particular example of this was found at Rooiwal. Here the proposal was to increase the storm water balancing facilities. This work may well have been necessary, but placing it downstream of the primary treatment phase meant that it did nothing to protect them. Consequently, extra costs would be incurred in operating the primary stages overloaded, and having to re-treat the sludge elsewhere.

- **Under-pricing of services**

'The over reliance by municipalities on national grants points to the possibility of under-pricing of services. This is more so even in services that have the potential to finance themselves. This practice has the potential to negatively affect investments in repairs and maintenance of existing municipal infrastructure.'

There is also a huge disparity in the ability of rural municipalities to generate income versus their urban peers. Further to their ability to raise taxes from industries, the Metros and urban municipalities also have a century old legacy of cross subsidisation amongst customers and services, which can't be changed overnight.

Municipalities have full discretion over how their operational budgets are spent. Even the equitable share contributions from central government may be spent as they see for with no (other than moral) obligation to provide equally for all services. If one looks at the services offered by the municipalities waste water treatment - sanitation - is the 'least visible.' Water, electricity, roads and solid waste handling would have immediate consumer protests should these services fail. Sewage treatment does not enjoy this visibility and where municipalities under financial pressure the service may receive lower prioritisation.

To the municipality discharge into a receiving body ends their ownership of the sewage they treat, yet problems and disease may be created for downstream users of the receiving body. From a financial perspective there is therefore a structural flaw in how the treatment of wastewaters is incentivised for municipalities. The monitoring role of the Department of Water and the Environment is not yet able to fully counter-balance this structural flaw. It is also resulting in two organs of state having a potential for a legal conflict.

It may be possible to incentivise the Municipalities by creating a methodology to recharge downstream costs for further treatment or pollution clean-ups. Such a financial penalty based process may be more politically successful than a direct legal conflict?

The following **five areas** where found to be lacking in the current assessment formats relating to financial issues. Where the spirit of co-operative governance can be established, these additions may also assist the Water and Sanitation departments in their quest to receive the appropriate prioritisation in the municipal budget allocation process.

1. **Allocation of Capital Costs**

The first aspect that requires addressing in the current assessment format is the fact that little attention is drawn to the Annualised Capital Costs (Capex) of the works being assessed. Based on replacement costs ranging from R3million to R9 million per (10^6 litres per day – MLD) and assuming an economic life expectancy of 30 years, Capex costs are between R0.77/kl (for large works) and R2.32/kl for small works. The calculations were based on the prevailing SA Govt bond yields at 8.6%. In reality only part of the Capex is financed through the Municipal Infrastructure Grant (MIG,) and the actual costs may be up to 30% higher as municipalities raise their funding at a premium to National Government.

Why is Capex an important consideration? Municipalities are measured on their operating budgets and not on their capital efficiencies. National government makes Municipal Infrastructure Grant (MIG) financing available to the municipalities free of charge. Yet annualised capital costs are between 150% and 200% higher than operating budgets for sanitation services.

Municipalities are prioritising the rollout of sanitation infrastructure. Any saving that can be made through process enhancements can free this capital, and it can be applied to other aspects of sanitation or other service areas. The planned capital expenditure in the water and sanitation sector over the next few years shows that to expand the service to unserved communities and to revamp existing treatment works the annual capital funding required will exceed R8billion in the medium term.

Municipal sanitation expenditure more than doubled between 2003/04 and 2006/07. Most of the sanitation budget is directed towards infrastructure expenditure: 72 per cent for metros (R996 million), 91 per cent for local municipalities (R1.6 billion) and 95 per cent for district municipalities (R322 million) for 2006/07.

Long run sanitation tariffs need to reflect the capital costs to prevent a shortfall in coming years or the prevailing trends will lock in a dependency on National Government.

M**unicipal capital expenditure, 2003/04 – 2009/10 (R million)**

	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10
Water and sanitation	**1,839**	**2,925**	**4,014**	**4,957**	**10,397**	**9,434**	**8,664**
Electricity	**1,267**	**1,599**	**2,295**	**2,725**	**4,426**	**4,255**	**4,063**
Housing	**658**	**718**	**658**	**1,269**	**3,893**	**4,586**	**4,221**
Road and storm water	**1,775**	**1,751**	**2,517**	**3,222**	**5,536**	**6,466**	**5,013**
Other	**5,157**	**6,329**	**7,747**	**8,718**	**15,484**	**14,510**	**8,376**
Total	**10,696**	**13,323**	**17,232**	**20,891**	**39,736**	**39,252**	**30,337**

Source: National Treasury local government database

The minimisation of capital expenditure is not expected to be an overriding consideration in an environment where plant upgrades being undertaken are being funded through a combination of MIG and DFI funding. Financial evaluation should be done combining Opex and Capex cost. This is the how large projects in the water and energy sectors are evaluated and will avoid a skewing of budgeting and expenditure in favour of that which does not cost the municipality money in the short term, but which has a long run cost to National Treasury and the country. A combination of Capex and Opex costs should also be the basis for sewerage tariff structures. It may be possible to introduce a modification to the risk-scoring process by adding a factor based on the ratios of opex-capex, or proportion of MIG funding required.

From the evaluations it was apparent that some municipalities such as Zeerust require external assistance in accessing adequate MIG or other discounted sources of funding, whereas others like certain of JHB waters works did not qualify as they service more affluent communities. The WWTW assessor can play a role in studying the medium term Capital Expenditure plans of the municipality along with the Water Development Plan to see that it ties into the needs of the community and whether it is technically appropriate. There are many opportunities to defray Capex costs through process adjustments. These should be studied with the technical and human resource review to see if they are appropriate for the works being studied. Some of these changes will lead to higher Opex costs, but may result in an overall lower treatment cost.

At JHB northern Works, the Capex cost was estimated to be R1.00/ kl as they do not qualify for MIG financing and borrow at a premium of around 3% to the State in the capital markets. Their Capex costs are twice that of the Opex costs.

2. **Benchmarking of cost drivers**

Whereas the total O&M costs per kl influent treated ranges between R0.48/kl and R1.30/kl of influent treated, the effectiveness of the spend will vary depending on how it is spread. From the plants visited, maintenance was found to be a key driver of the other Opex costs. This is because plant availability drives process control and a process that is in control requires less expensive interventions.

In the 2008 local government budgets and review the following conclusion was made after comparing two WSAs maintenance expenditures.

'The scale at which Maluti-A-Phufong Water invests in repairs and maintenance is substantially higher than that of Joburg Water. This could be because of a number of factors, including possible underinvestment in repairs and maintenance by Joburg Water and older water services infrastructure in the Maluti-A-Phufong area, which requires more maintenance and refurbishment.'

Without having the opportunity to visit Maluti-A-Phufong's works, but having compared the situation **at Rooiwal, Meyerton, Brits and Zeerust to Northern Works** there is evidence to the **contrary** of the explanation above. A plant that attempts to minimise maintenance costs can successfully achieve this through a preventative maintenance program.

Whereas a plant that is caught in a breakdown-repair-repair-replace cycle will require higher maintenance costs. The quality of maintenance expenditure needs to be evaluated. JHB Water spends R0.08/kl influent on maintenance. This is because they have an effective preventative maintenance program in place. Even at Northern Works which stood out as performing hugely better in almost all aspects than the other works reviewed, after they abandoned oil and vibration tests on some of the plant a few years back, they now have to replace the gearboxes that previously had a 20 year life after 14 years, showing that reducing preventative maintenance can increase life-cycle costs considerably.

The irony on maintenance expenditure is that **planned maintenance actually costs less than breakdown maintenance.** It's clearly cheaper to replace a bearing or seal than a whole gearbox that fails due the catastrophic failure of the bearing or seal.

Alarmingly a basic lubrication program was not in place at 2 of the works visited and not surprisingly they were suffering from a high rate of breakdown of aerators. Failure to lubricate machinery would nullify any warranties that the suppliers may have provided. Imagine driving ones car for a year without adding/ changing the oil.

A lubrication program is inexpensive and should be conducted by general worker or plant operators as is the case at Zeerust, yet the lack thereof was seen at the Madibeng District Municipality where the 18month old Hartebeespoort plant has crumbled into disrepair due to the failure of several aerators. The lack of effective maintenance at Rooiwal though not to the same extent has had serious implications on chemical dosing costs and effluent quality.

The table below compares maintenance and other operating costs amongst some of the works reviewed.

	Northern Works	Rooiwal	Sunderland Ridge	Dasport
Total costs R/kl	0.52	0.96	0.64	0.84
Salaries	0.15	0.24	0.23	0.44
Electricity	0.11	0.13	0.01	0.15
Chemicals	0.08	0.19	0.16	0.05
Maintenance	0.08	0.17	0.24	0.20

Where gaps exist in preventative maintenance, the actual maintenance spend is twice. The data is not directly comparable as the treatment processes and accounting standards were found to differ across the plants. But what was observed was that a plant which has a high mechanical availability such as Northern Works also has lower (64%) overall treatment costs than works that relied on breakdown maintenance. Maintenance costs under a preventative maintenance program were 50% less than were ad-hoc breakdown maintenance is practiced. These works also had lower chemical costs. Electricity usage seemed on par. (The electricity used at Sunderland Ridge is estimated be R0.14/kl for this analysis. The current management accounting system is allocating the electricity used there to another user.)

Where basic lubrication is not practiced maintenance expenditure will be even higher than at the Tshwane works. The life expectancy of aerators is around 20 years but they failed after just 18 months at Hartebeesport WWTW due to the lack of basic lubrication. Determining an appropriate maintenance budget under those circumstances would be very difficult, but provisions should be made for at least twice the unit cost as at Tshwane. I.e. around R0.5/kl. It may be necessary to budget for extra-ordinary maintenance. **Lifecycle costing can also assist in determining whether a plant should be replaced or repaired.**

Once basic maintenance activities are in place the maintenance spend can be lowered to around R0.3/kl and once preventative maintenance programs are in place the maintenance budgets can be reduced to around R0.1/kl. This is not something that happens overnight though and requires two to three years of senior management support and focus.

Process control is achieved when plant availability permits. A BNR process is compromised within hours of the failure of a single aerator. **Plant availability is driven by maintenance.** Chemical costs at the Tshwane works where twice that of Northern Works. And they were not achieving discharge standards either. Based on the above table, smaller works should be budgeting around R0.2 to R0.3/kl for chemical costs depending on the processes they are using. An observation at Zeerust was that the budget for chemicals was insufficient and was depleted early in the financial year and requests for chemical purchases had to be directed to the municipal manager for approval. This then became a time-consuming process for all involved.

If Phosphate standards are to be met and biological P removal is not catered for in the plant design, dosing with iron salts may be necessary, this will add to chemical costs. A first order estimate can be made for this and added to the above amounts to ensure that sufficient funds are available for chemicals throughout the year. Sludge conditioning may also require expensive polyelectrolyte dosing which should be budgeted for.

When considering chemical costs, the actual processes available (and how they were being used) need to be taken into account. Whilst Rooiwal chemical costs where high, two significant factors where observed: The sludge treatment process was totally physio-chemical, and so used more polymer, compared to Northern works which had the use of composting. Secondly, the digestion process was not being operated properly. Consequently, Rooiwal were missing-out on the benefit of pre-treating the sludge which would have facilitated more effective sludge dewatering. Hence, before budgeting for sludge conditioning the condition of any pre-treatment stage needs to be accounted for. (Note: A cost benefit analysis may be appropriate to determine if expenditure on the digestion process was going to be more cost effective than providing more funds for the dewatering.)

Electricity costs seem to be consistent across most of the works visited. Electricity costs may double over the next 3 to 5 years, so additional funds should be budgeted for this line item going forward. A concern at several of the works visited was that they were not able to determine their electricity use as the SAP system does not allow them access to this info.

At a small treatment works salaries can make up the bulk of the budgeted treatment costs (up to 85% vs. 30% at large works). When up to 85% of the sanitation budget is soaked up by staffing costs, very little remains for the other major cost drivers that were identified.

<u>Example: Using benchmarking to enhance the financial assessment at Zeerust WWTWs:</u>

A first order assessment can be made on the following basis. The budget assessment should first deduct all staff costs from the available sanitation budget. Thereafter based on the existing maintenance practices and plans going forward, an estimate should be made for maintenance costs, chemicals and electricity based on the above discussion. The minimum allocation for maintenance should be R0.3/kl for works with an effective lubrication program in place and extra-ordinary maintenance for works where this is not in place.

The Zeerust works treats approximately 7MLD of influent and has an annual budget of R3.153 million. This translates to a budget of R1.23/kl, which under simplistic benchmarking would be deemed adequate as it is at the higher end of the average range of treatment costs for similar size treatment works (R0.8/kl to R1.3/kl.)

Expense category	Actual 2006/2007	Current year 2007/2008	Budget 2008/2009
Employee direct salaries	1,400,204	1,452,241	1,953,231
Total staff including overtime and incentives	1,647,169	1,696,099	2,620,219
Total maintenance	164,112	117,310	166,647
Chemicals	14,728	50,000	100,000
Total general expenses	150,962	175,265	366.219
TOTAL EXPENDITURE	1,962,243	1,988,674	3,153,085
Equitable share Allocation	1,434,985	3,605,303	4,500,000
Levies	1,822,590	1,454,055	1,587,700
TOTAL INCOME	3,257,575	5,059,358	6,087,700
SURPLUS/ (DEFECIT)	1,295,332	3,070,684	2,934,615

However after one deducts staff costs the balance remaining is only R532, 863 or R0.21/ kl. The current state of the plant indicates that maintenance expenditure should be around R0.3/kl. Electricity usage is not budgeted for by the treatment works and is paid for directly by the municipality.

Chemical costs now seem more appropriate (R0.04/kl - R100k vs. R15k in 2006/2007.) The low chemicals budget reflects the fact that no sludge treatment or iron salts are dosed and chlorination is the major chemical used. Insufficient maintenance budget is clear despite there being a surplus of R3million in the municipality's sewerage treatment net budget. The allocation to staff expenditure is 84% of the total budget. The medium term maintenance budget should be increased to R800, 000 p/a.

The actual budget can be compared to the maintenance practices at the works and the state of the works being evaluated. A move towards preventative maintenance will allow for the costs to be reduced over time, but may call for higher maintenance budgets for 2 to 3 years.

On a similar basis, chemical budgets (especially when BNR without biological P removal is practiced) should be around R0.2/kl. Electricity consumption can be calculated from the aeration capacity and based on the sludge handling practices. Electricity consumption at small to medium works will be higher than that at the large works, so a minimum budget there should be around R0.25/kl.

Total budgeted expenditure based on the above estimates will be around R0.70/kl plus the staff and extra-ordinary maintenance components budgeted for.

3. Budgeted vs. Actual Expenditure

Where municipalities are pressed for finance, they can re-allocate funds from one budget to another or just spend it on the external cost centre. It was observed at the Brits WWTW that certain items where budgeted for and were then used for activities outside the WWTW. This indicates that the financial assessment needs to be tightened to verify that actual expenditure matches that which was budgeted for. This can be achieved by conducting an interview with the responsible financial officer for the works.

4. Tariff collection, Equitable share vs. budgeted expenditure

To fund their operating expenses, municipalities collect effluent tariffs from their constituencies and equitable share contributions from national treasury. They have discretion on how the revenue is spent. It was observed that at certain works which were not performing to standard, the sewerage treatment department was actually a source of a financial surplus for the municipalities and was used to subsidise other services. This is clearly not an acceptable situation.

Government's objective is to ensure that all South Africans have access to basic water supply and sanitation services. Government has prioritised not only the rollout of infrastructure necessary for the rendering of services but also the provision of free basic services to the poor.

A basic water supply facility refers to the infrastructure necessary to supply 25 litres of potable water per person per day supplied within 200m of a household and with a minimum flow of 10 litres per minute (in the case of communal water points) or 6 000 litres of potable water supplied per formal connection per month (in the case of house connections).

A basic sanitation service refers to the provision of a basic sanitation facility which is easily accessible to a household and the sustainable operation of the facility. This includes the safe removal of human waste and wastewater from the premises where this is appropriate and necessary and the communication of good sanitation, hygiene and related practices.

While there has been substantial improvements in the rollout of water services infrastructure and the rendering of free basic water and sanitation, the sector does face challenges in the period ahead as implementation capacity remains a constraint. Furthermore, the financial sustainability of existing and new infrastructure cannot be neglected and is requiring more and more funding as infrastructure ages, advanced technology gets applied making bigger demands on the available funds for the provision of new infrastructure to communities. The following excerpts from the 2008/2009 Local Government Financing review describes the funding sources available to local municipalities.

Equitable share, is a constitutional entitlement of municipalities of part of the revenue collected by National Treasury. Municipalities are largely free to allocate the equitable share as they see fit after taking account of national priorities that underpin the vertical division of revenue. It was first introduced in 1998/99. The main purpose of this programme is to address the gap between the revenues and expenditures of municipalities. In the South African context, the main cause of this gap is high levels of poverty. The equitable share thus allocates resources between municipalities largely on the basis of the proportion of poor households in their jurisdiction.

The formula does, however, have five variable components: basic services (BS); development (D), institutional (I); revenue-raising capacity (RRC); and correction and stabilisation (R) components.

The equitable share is intended to fund a range of municipal activities, although national free service levels are the main purpose. Most importantly, government uses this mechanism to support municipalities in providing free basic services to poor households. Municipalities have discretion in designing the actual subsidy mechanism that channels these resources to intended beneficiaries, as there is no single subsidy mechanism that is appropriate across all services and municipalities in South Africa. The equitable share also supports the general expenditures of municipalities, including specific items such as councillor remuneration.

Many smaller municipalities use their equitable share to pay basic operating expenditures such as salaries, due to their limited capacity to raise their own revenue. Since 2006/07, part of the equitable share has been used to temporarily channel funding to replace revenues lost to municipalities as a result of the withdrawal of RSC levies on the payroll and turnover of businesses.

The equitable share is the largest single transfer programme, accounting for an average of 56.7 per cent of all transfers between 2003/04 and 2009/10. It has also experienced strong real growth of 31.4 per cent between 2003/04 and 2005/06. Real growth of 12.8 per cent is projected over the medium-term as government continues to prioritise universal access to basic municipal services.

The equitable share is generally classified together with the direct transfer component of the water service operating subsidy, managed by the Department of Water Affairs and Forestry. This grant funds the operating costs of water services schemes that have been transferred to municipalities. It is complemented by an indirect transfer, through an augmentation to the water services trading account on the Department of Water Affairs and Forestry's budget vote. This funds the costs of schemes that have not yet been transferred to municipalities. The direct transfer component of this programme is thus projected to rise over time, as more scheme transfers take place. Ultimately, these resources will be consolidated into the equitable share once the transfer of schemes has been accomplished. This programme makes up a small and declining proportion of total transfers to local government, although it has shown real growth as the costs of operating these water services schemes have increased.

The total number of households receiving basic sewerage and sanitation increased by 6.8 per cent between 2005 and 2006, while the number of households receiving free basic sewerage and sanitation increased by 7.4 per cent of households over the same period. Of the 7.7 million households receiving basic sewerage and sanitation from municipalities, 3.8 million (49.7 per cent) had access to free basic sewerage and sanitation.

Municipalities with a high percentage of rural population will not be in a position to provide free basic sanitation as they still lack the necessary equipment and other resources to empty ventilated pit latrines.

In the poorest local authorities, equitable share revenue dominates the budget, while this revenue was relatively trivial in the wealthier local governments it has been on the increase. Thus, there is some genuine redistribution occurring. If own-source revenues cannot be substantially increased, however, there will be growing dependence on grant financing for both urban and rural works.

Infrastructure transfers collectively make up an average of 40.2 per cent of all conditional transfers to municipalities between 2003/04 and 2009/10. Infrastructure transfers have also experienced strong real growth, averaging 17.8 per cent over the period.

Government has a distinct policy preference for direct (cash) transfers. These make up an average of 81 per cent of all infrastructure transfers. The largest infrastructure transfer programme is the municipal infrastructure grant (MIG), currently administered by the Department of Provincial and Local Government. It accounts for an average of 54.1 per cent of all infrastructure transfers between 2003/04 and 2009/10. The MIG has shown strong real growth over the period, averaging 6.4 per cent between 2004/05 and 2006/07. Real growth is projected to accelerate to an average of 21.4 per cent over the medium-term.

The MIG was introduced in 2004/05 through consolidating various sector infrastructure grants, each administered by different departments, into a single programme. This was intended to make the system of transfers to municipalities simpler, more certain and more supportive of municipal infrastructure priorities. The programme is designed to supplement the capital budgets of municipalities, with a focus on providing basic infrastructure services to the poor, while stimulating local economic development and job creation over the medium-term.

MIG funds are distributed to all municipalities based on a formula that accounts for existing backlogs in service delivery as well as the functions assigned to individual municipalities. In some instances, portions of MIG allocations are earmarked for specific expenditures by municipalities, although on the whole they have the flexibility to determine their own expenditure priorities.

Indirect infrastructure transfers make up an average of 24 per cent of infrastructure transfers between 2003/04 and 2009/10. This declines rapidly from 57.2 per cent of infrastructure transfers in 2003/04 to a projected 14.9 per cent in 2009/10. The declining trends of the indirect grants are because the implementation of the water services projects was phased out from 2004/05. The trend starts to rise again from 2007/08 due to the introduction of more indirect grants in the local government sphere. The major programmes here focus on electrification and water services.

Conditional transfers make up the remainder of the resources transferred by national government to municipalities. These transfers are provided to support municipal infrastructure investment and to strengthen municipal capacity. In both cases, transfers are made directly, in the form of cash and indirectly, in the form of assets or support services provided to a municipality. The specific conditions and procedures associated with individual programmes are provided in annexures to the annual Division of Revenue Act.

Infrastructure transfers collectively make up an average of 40.2 per cent of all conditional transfers to municipalities between 2003/04 and 2009/10. Infrastructure transfers have also experienced strong real growth, averaging 17.8 per cent over the period.

Capacity building transfers account for only an average of 2 per cent of all transfers to municipalities between 2003/04 and 2009/10. This share declines over the medium term due to the ending of some programmes and strong growth in other categories of transfers. These transfers support municipalities in introducing reforms to management practices associated with the Municipal Systems Act (2000) and the Municipal Finance Management Act (2003). The financial management grant (FMG) has replaced the restructuring grant as the largest single transfer to municipalities in this category. The restructuring grant supported large cities with the transition costs of adjusting their fiscal positions to better support growth and poverty alleviation and has been phased out.

Different kinds of capacity building support are also provided to municipalities, most often through direct hands on assistance (such as the deployment of technical advisors). The Siyenza Manje programme, managed by the DBSA, is one such example. The lack of standardised information on these indirect transfers prevents accurate analysis of their contribution to the overall system of transfers. This matter is being addressed by National Treasury, with the intention of introducing more rigorous monitoring and evaluation of expenditure and output performance of all capacity building programmes.

Furthermore, the municipalities are receiving transfers from provinces in the form of a direct transfer. This is mainly from programmes that are administered at the provincial level, but have local government related programmes. Programmes such as ambulance services and primary health clinics are administered at the local level, though they are partly funded by the provincial departments of health.

Municipalities are required to provide a service on behalf of the province for these programmes. Provinces should therefore provide municipalities with a clear indication of the exact amounts to be transferred to them during the course of the financial year. This will assist municipalities in planning.

Returning to the Budget of Zeerust WWTWs, the effect of National transfers to municipalities can be seen. Firstly equitable share allocations have increased to 300% in nominal terms to R4.5 million whereas revenue collection has declined 13% in nominal terms over the 3 years reviewed. Or around 30% in real terms. Approximately half of the influent at Zeerust includes discharges from a 100 head a day beef abattoir. At present this is the biggest treatment challenge for the municipality, yet they do not use the opportunity to levy trade tariffs. This effectively results in subsidisation of the abattoir by National Treasury and the taxpayer.

Whilst this financing is sufficient to meet both the Capital and Operational needs of the Sanitation Department, it will not lead to a sustainable solution as the funds are not applied appropriately. Maintenance provisions are not sufficient and the new plant will deteriorate rapidly. Also the planned process changes will require additions to the Chemicals Budget.

The declining real tariff and continued funding through Equitable Share will trap Zeerust into a financial dependency on this allocation for years to come.

Zeerust is also in the process of applying for MIG financing of approximately R40 million for their sanitation services. They require assistance with this as they are relying on a report which is not reflecting the loadings from the abattoir.

The issues raised in this chapter have to be interpreted individually for each community visited as local issues will override any possible generalisations. The horizontal sharing of revenue across services talks to the intentions of the municipality. Whilst they face many challenges in their finances, it would seem as though there is sufficient support from National Treasury to address this and finance in general should not be a constraint to the proper operation of WWTWs in South Africa.

In the past, grants were earmarked for specific sectors and specific amounts allocated to municipalities, but with only limited information on their relative needs and priorities. Now national departments must engage with municipalities on sectoral priorities to influence local decision-making processes. This requires significantly more information and a different approach to co-ordination with municipalities. On the one hand, national departments have found it considerably more challenging to engage with municipalities on their sect oral spending priorities.

The spirit of co-operative governance will not always prevail. Where it does the works assessor will be in a position to assist the Sanitation Department motivate for sufficient funding for their operations. Where there is a lack of co-operation from the works, the framework for redressing non-compliance should be used. It does create an unfortunate end state though which is legal action between two organs of state, but this should only be used when other means of redressing the problems have failed or urgency demands that this route is taken.

5. Procurement Procedures

It was observed that different municipalities apply different thresholds and timeframes in their procurement procedures. This has the potential to frustrate the maintenance process or may result in delays in obtaining chemicals.

Of the sites visited only JHB water carried spares on site and were in a position to repair equipment timorously. It is not practical to keep all spares on site, but it is of concern that Municipalities are not allowed to keep any spares.

Time consuming procurement and payment procedures also result in unfavourable pricing and terms from suppliers. The works visited had difficulties in attracting and retaining suppliers.

It’s not possible to obtain three quotes for items such as pump overhauls as part of the work is disassembly and investigative inspection. Zeerust has adopted a rotational policy which is equally flawed in that a piece of equipment gets serviced by a different company every time it goes in for repairs. This results in a lack of accountability for the reliability of the repaired item. Imagine servicing your car with 5 different mechanics.

Conclusions

The assessor of WWTWs in South Africa can add a lot of value to the process by expanding on the financial assessment of the WWTWs. In line with the **technical assessment**, the assessor should *verify the appropriateness of any capital expenditure, unpack the operating budgets, check that budgets match historical expenditure, ensure that the revenue and grants collected match the needs of the works and by ensure that the procurement processes is not a bottleneck in the smooth operation of the works.*

Further areas of improvement and focus should be discussed with DWAE and financing institutions such as the DBSA. One possible area would be the engagement of the private sector and creation of Special Purpose Delivery Vehicles (SPV) in the management, operation and maintenance of WWTWs through public-private partnerships.

These assessments have demonstrated that changes in the way finances are structured have to go in conjunction with real improvements to processes on the ground. Any such improvements would be inextricably linked to enhancement in the overall competency and quality of operating staff. In many cases it is suspected that overall expenditure could be reduced in the long term by concentrating initial investment in enhancing the "people" element of the industry.

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5) Appendix 5 Glossary of terms.

This section attempts to outline a brief explanation for some of the more frequently used terms in the text (where not already explained). Terms are defined in relation to the wastewater treatment process, but are not exhaustive.

DWAF – Department of Water Affairs and Forestry. Government body responsible for control and regulation of wastewater treatment in South Africa. (Note: Recently merged with the Department of Environment and Tourism, to become the Department of Water and Environmental Affairs – DWEA. This change effected after the drafting of this report.

Regulation 2834 – Part of the national government regulation and legislative package relating to staffing numbers and educational requirements in the South African water industry.

BNR – Biological Nutrient Removal. Type of wastewater treatment process designed to remove nutrients using biological techniques. Primarily focused on nitrogen and phosphorus.

Nutrients – Biological compounds found in wastewater that are used by microorganisms. Primarily nitrogen and phosphorus, commonly found in the form of nitrates and phosphates. These are important growth factors and can lead to significant pollution and harmful affects in watercourses.

Eutrophication – Enrichment of water bodies with nutrients, which promotes rapid and extensive growth of algae. This impacts directly on water quality, often leading to reduced dissolved oxygen levels and difficulty with downstream treatment for potable purposes.

COD – Chemical Oxygen Demand. An expression of the polluting capacity of a substance. COD measures the amount of oxygen consumed by the breakdown of the substance into simpler, stable and less harmful products.

MLD – Mega litre per day. A common expression of flow. One MLD = one million litres. Flow is often expressed as litres / second, but MLD is more convenient when dealing with much larger values.

PST – Primary sedimentation or settlement tank. A process unit commonly used at wastewater treatment works to settle out heavy organic solids under gravity. The resulting solids are known as *sludge* or sometimes as *biosolids*.

FST – Final settlement tank. Very similar to PSTs, but used to settle finer solids produced by the treatment process.

Activated Sludge – A form of wastewater treatment process. It works by "suspending" microorganisms within the body of wastewater that they are treating. Activated sludge has the appearance of a light brown semi-solid "soup".

WAS or SAS – Waste, or surplus activated sludge. The treatment process is biological, and results in the rapid growth of microorganisms. There is always more produced than is required, so control is exerted by wasting or surplussing the excess. WAS then requires further treatment and disposal.

Digestion – A process of breaking down the structure of the sludge. This converts the complex compounds into simpler and less harmful products. These can then be further treated, or in some cases (e.g. methane), drawn-off for useful purposes.

Aerobic – Process using elemental or molecular oxygen, usually sourced direct from the atmosphere.

Anaerobic – Process in the absence of oxygen.

Anoxic – Process of no molecular oxygen, but with other forms of “bound” oxygen. Typically this will be nitrates and phosphates that contain oxygen molecules as part of their structure. Within aeration plants these compounds are then utilised for energy and as an oxygen source, depending on the stage of treatment.

MLSS – Mixed liquor suspended solids. A measurement of the amount of microorganisms contained within the secondary treatment phases. The mixed liquor is the brown, semi-solid mass present in the reactors. The mixed liquor normally refers to the live organisms carrying out the actual treatment, but the mix will also contain a certain amount of inert matter (e.g. grit). Usually expressed in mg/l.

Cake – A form of sludge solids after it has been subjected to removal of water (dewatering). The term cake comes from the largely solid nature and appearance. Sludge will become a cake when dewatered to around 15% dry solids.

Dry Solids – The measurement of the actual solid content within a sludge. Applicable to either liquid or cake forms. The “% ds” expresses the actual percentage of solids, and is equivalent to mg/l. That is, 1% ds is equivalent to approximately 10,000mg/l.

SCADA – A system of remote sensors and computers that can be used to monitor and control any number of treatment processes. Usually confined and monitored on a single site.

Telemetry – Similar to scada, but tends to be used more for monitoring rather than control. Also, these systems usually monitor a number of remote sites, which then communicate with a centralised control and monitoring centre.