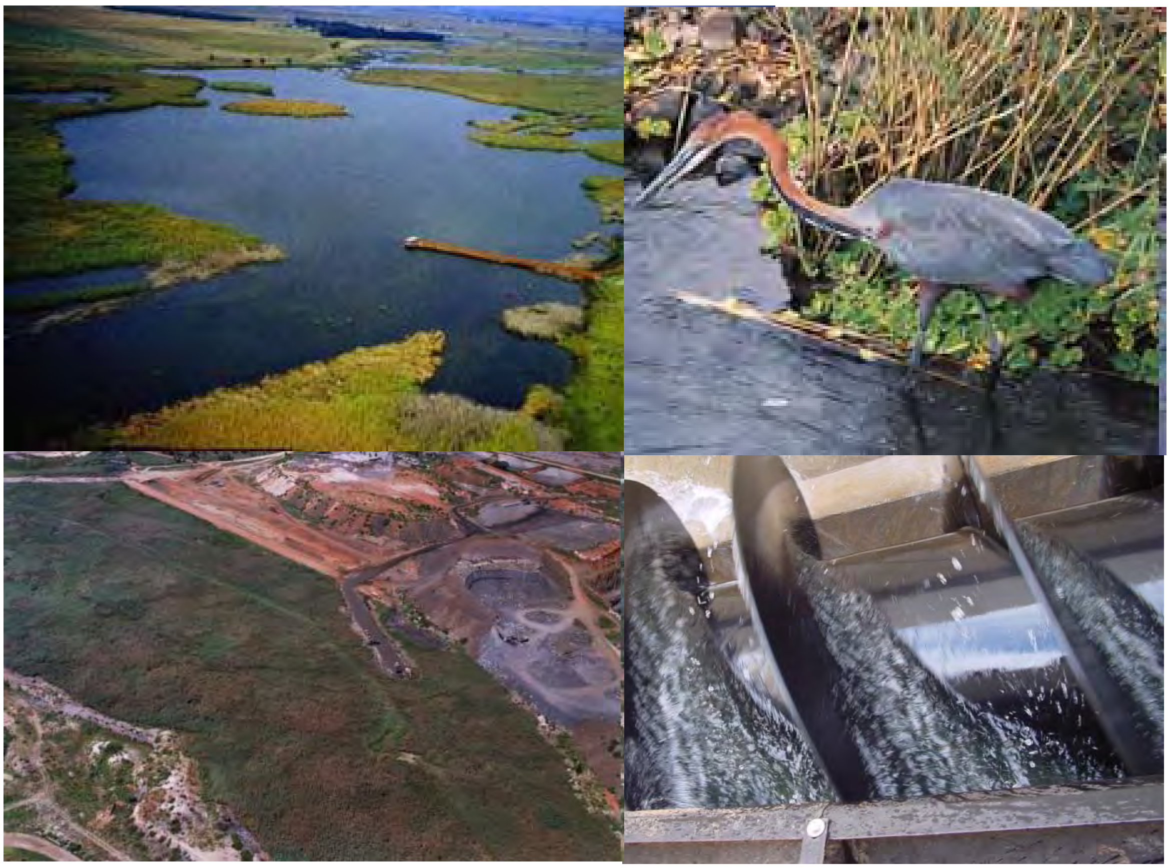
Final Report

WELGEDACHT WCW ALTERNATIVE DISCHARGE DESKTOP STUDY REV C



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WELGEDACHT WCW ALTERNATIVE DISCHARGE
DESK TOP STUDY REV B

EXECUTIVE SUMMARY

At a meeting held with the Department of Water Affairs (DWA) to discuss the proposed 50 Mℓ/d extension to the Welgedacht Water Care Works (WCW), ERWAT were informed that no additional effluent could be discharged at the plant into the Blesbokspruit upstream of the Ramsar Wetland Site. This prompted the need for a desk top study to be carried out, so as to assess the potential effects and impacts of increased hydraulic loads on the spruit as well as to identify alternative discharge options.

A desk top hydraulic study of the spruit concluded that by continuing to discharge at the plant, the median flow near the R555 crossing would increase by about 23% and at the Marievale Bird Sanctuary by 17%. The median water level near the R555 would increase by about 90 mm and at the Marievale Bird Sanctuary by 40 mm. The increasing dilution of the mine discharge would reduce the median salinity at the R555 by 7% and by 9% at the Marievale Bird Sanctuary and further downstream near the confluence with the Vaal River.

By bypassing the Ramsar Wetland Site, the median flow will reduce at the R555 by about 43% and at the Marievale Bird Sanctuary by 30%. The median water level at the R555 crossing would reduce by 200 mm and at the Marievale Bird Sanctuary the reduction in water level would be about 70 mm. A 12% increase in the median salinity at the R555 could be expected, with a 26% increase at the Marievale Bird Sanctuary. There would be no change in salinity downstream of the wetland. The median phosphate concentration in the Blesbokspruit near the R555 crossing would reduce by about 32%, with an 11% reduction at the Marievale Bird Sanctuary. However, the phosphate concentration below the wetland would be expected to more than treble and that near the mouth of the Suikerbosrand River increase by 50%. The phosphate load in the Blesbokspruit below the wetland would double, thereby increasing the nutrient load entering Vaal Barrage.

A number of alternative discharge options were considered including bypassing the Ramsar Wetland Site, distributing the flows to alternative catchment areas, treating the final effluent to potable standards for direct injection into the drinking water supply as well as alleviating the load on the spruit by treating the Grootvlei Mine drainage water to similar potable standards. A description of the various alternatives considered are presented below.

- *Option 1* Baseline option - Discharge into the Blesbokspruit at the Welgedacht WCW site upstream of the Ramsar Site, ie. status quo.

- *Option 2* – Pumping/gravity mains to the Blesbokspruit immediately downstream of the Ramsar Wetland Site at the R42 road crossing.

- *Option 2A* – A pressurised gravity main discharging into the Blesbokspruit immediately downstream of the Ramsar Wetland Site at the R42 road crossing.

- *Option 3* - A pumping/gravity main combination to carry raw sewage to the R42 road crossing and locating the WCW extension at that site.

- *Option 4* – Pumping and gravity mains bypassing the Ramsar Wetland Site to carry raw sewage to the existing Bickley WCW and constructing a new WCW at this site.

- *Option 5* – Pumping and gravity mains bypassing the Ramsar Wetland Site to the existing Heidelberg WCW site and constructing a new WCW at this site in Lesedi LM.

- *Option 6* - Pumping treated effluent to the Rietvlei (Crocodile River) catchment area to the north west of the Welgedacht WCW and near the Hartebessfontein WCW.

- *Option 7* and 7A – Pumping treated effluent to the Bronkhorstspruit catchment area to the north east of the Welgedacht WCW.

- *Option 8* – Pumping treated effluent to the Rietspruit (Vaal River) catchment situated south west of the Welgedacht WCW.

- *Option 9* – Pumping raw sewage to Vlakplaats and upgrading the Waterval WCW.

- *Option 10* - Treat final effluent further to a potable water standard at Welgedacht WCW and redistribute to Rand Water.

- *Option 11* - Treat Grootvlei Mine acid mine drainage (AMD) flow to potable standards and supply to Rand Water

All options investigated were found to add significant additional capital expenditure to the proposed extensions to the works. Options 10 and 11 could lead to generating income thus reducing the overall costs. Life cycle costs are summarised as follows:

		Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*			
Ranking	**Option**	**Capex**	**Pumping**	**NTC**	**Total Cost**
0	Option 1	0.00	0.00		0.00
1	Option 11	149.44	111.65		261.09
2	Option 7 A	169.86	284.68		454.55
3	Option 7	218.64	306.33		524.97
4	Option 2 A	629.46			629.46
5	Option 3	397.22	280.93		678.15
6	Option 2	414.14	325.88		740.02
7	Option 4	464.52	280.93		745.45
8	Option 6	402.95	422.31		825.26
9	Option 8	412.57	494.18		906.74
10	Option 5	652.60	280.93		933.53
11	Option 9	609.92	494.18		1,104.09
12	Option 10	1,035.39	373.87	3.87	1,413.13

Table 1 - Ranked life cycle option costs

Based on the limited potential hydraulic impact on the Blesbokspruit as well as the beneficial impact on the overall water quality of putting the effluent from Welgedacht WCW through the wetland, it is recommended that a relaxation of the restriction on further discharge into the Blesbokspruit from the Welgedacht WCW should be sought from the DWA.

It is further recommended that the effects of the additional flow on the downstream wetland site be separately investigated in more depth. The scoping study which is reported in full in Appendix A shows preliminary results based on a full study completed by SSI in the late 1990s. If these effects on the Ramsar Wetland, in terms of increased hydraulic loading and associated water quality factors, are better understood it may be possible to further mitigate the negative effects in a manner acceptable to all the stakeholders.

Similarly the findings from the reports commissioned by the DME must be obtained such that should the load on the Blesbokspruit be alleviated through undertakings by the WUC project, the Welgedacht WCW may be afforded the opportunity to make up this shortfall without negatively affecting operations at the mine.

WELGEDACHT WCW ALTERNATIVE DISCHARGE

DESK TOP STUDY REV B

TABLE OF CONTENTS

1. INTRODUCTION

At a meeting held on 13 November 2008 to discuss the possible extension of the Welgedacht Watercare Works (WCW), a representative from the Department of Water Affairs (DWA) noted that the Blesbokspruit Ramsar Wetland Site was hydraulically overloaded and that no further discharges of treated wastewater into the spruit upstream of the site would be allowed. Since the proposed 50 Mℓ/d extension to the Welgedacht WCW works will discharge final effluent upstream of the Ramsar Site, it was agreed that a desktop study needed to be completed into the options available, cost and other implications of the various means to divert water around or away from the Ramsar Site. ERWAT requested SSI to undertake this desktop study.

In addition to the possible diversion of wastewater around the Ramsar Wetland Site, DWA is also considering an option for treatment of dewatering water from the local mines to potable standards. If treatment of this mine water commences, then the discharge into the Blesbokspruit upstream of the Ramsar Site is likely to reduce significantly. For this reason, broad brush costs for treatment of mine dewatering water have also been investigated and reported on.

The existing Welgedacht WCW site located north of the Welgedacht / Cloverfield area and the R555 is approximately 36 ha in size. (At coordinates -26.192470°S, 28.473652°E – See Figure 1 in Appendix C). The existing WCW discharge is into the Blesbokspruit which is located on the eastern boundary of the WCW site. The current works are rated to treat a flow of 35 Mℓ/day but are currently receiving a flow of approximately 59 Mℓ/day. This means that a decision on this issue needs to be made as soon as possible and any option that will allow the construction of a plant to address this immediate need would be preferred.

This report comments on various discharge alternatives, capital and life cycle costs for each option and offers recommendations on a way forward. It also briefly considers the effects of the diversion of the Welgedacht WCW flow on the water levels in the Blesbokspruit wetland and some key water quality parameters.

2. OPTIONS IDENTIFIED

This study includes an investigation into the possible discharge alternatives of the Welgedacht Water Care Works as follows:-

- *Option 1* Baseline option - Discharge into the Blesbokspruit at the Welgedacht WCW site upstream of the Ramsar Wetland Site, ie. status quo.
- *Option 2* – Pumping/Gravity mains to the Blesbokspruit immediately downstream of the Ramsar Site at the R42 road crossing.
- *Option 2A* – A pressurised gravity main discharging into the Blesbokspruit immediately downstream of the Ramsar site at the R42 road crossing.
- *Option 3* - A pumping/gravity main combination to carry sewage to the R42 road crossing and re-locating the WCW to the same site.

- *Option 4* – Pumping and gravity mains bypassing the Ramsar site to carry raw sewage to the existing Bickley WCW and constructing a new WCW at this site.

- *Option 5* – Pumping and gravity mains bypassing the Ramsar Site to the existing Heidelberg WCW and constructing a new WCW at this site.

- *Option 6* - Pumping treated effluent to the Rietvlei (Crocodile) catchment area to the north west of the Welgedacht WCW.

- *Option 7 and 7A* – Pumping treated effluent to the Bronkhorstspruit (Olifants) catchment area to the north east of the Welgedacht WCW.

- *Option 8* – Pumping treated effluent to the Rietspruit situated south west of the Welgedacht WCW.

- *Option 9* – Pumping raw sewage to Vlakplaats and upgrading the Waterval WCW.

- *Option 10* - Treat final effluent further to a potable water standard at Welgedacht WCW and redistribute to Rand Water.

- *Option 11* - Treat Grootvlei Mine AMD flow to potable standards and supply to Rand Water

3. METHODOLOGY

3.1 Key steps

The methodology for the study included the following key steps:

- The identification of catchment boundaries for the alternatives (see quaternary catchments shown on Figure 1 in Appendix C).

- Desktop determination of possible pipe routes for all alternatives including the likely grades.

- Establishing pumping main and gravity main lengths and the static heads for the selected route alignments.

- Preparing capital and life cycle cost estimates.

- Review of main advantages and disadvantages of each option

Information for the above was based on data on 1:50 000 maps for the area. A summary of the options and pipe routes reviewed is included in Figure 1 of Appendix C.

3.2 Design assumptions and criteria

The work summarised in this report is based on the following assumptions:

- Generally, pipeline preliminary routes have been selected to follow an existing service (road, powerline, railway line). If this is not possible, the pipeline has been routed along a property boundary line. The selected routes would need to be confirmed with the relevant property or servitude owner.

- Pumping mains have been sized using the same peak factor (2.2 x average dry weather flow) as is proposed for the Welgedacht WCW extension. Although this peak factor is higher than normally used, it allows for a number of uncertainties. The resulting design flow rates are as follows:

Criteria	**Stage 1 (50 Mℓ/d)**	**Total Stage 2 (including an additional 50 Mℓ/d)**
Design Flow (Mℓ/d)	50	100
Design Flow (m^3/s)	0.58	1.16
Peak Factor (design peak for plant)	2.2	2.2
Pipeline Design Flow (m^3/s)	1.28	2.56

Table 3.2.1: Design flow rates

- Pumping mains have been sized on an initial flow velocity of 1.0 m/s at the end of Stage 1, ie. for the first 50 Mℓ/d module extension. This velocity would increase to 2.0 m/s after the full flow of the additional 50 Mℓ/d module is added.

- Gravity (unpressurised) mains have been sized using available orthophoto mapping with 5 m contour information. Pipe routes and grades would need to be investigated in detail to confirm that these grades and routes are acceptable.

- No pipeline optimisations have been undertaken and costs for pumping and pressurised gravity mains have been based on steel pipes with a cement mortar lining.

- Costs for unpressurised gravity mains have been based on concrete pipes

- Where pressure mains cross ephemeral streams, it has been assumed that the pipe would be excavated into the riverbed and encased in a concrete surround (preferably in a rocky area). In other areas where gravity unpressurised mains cross streams, a pipe bridge would be required.

- In estimating flows, it has been assumed that the Grootvlei Gold Mine would continue to operate for the next 50 years with no reduction of treated acid mine drainage (AMD) discharging into the Blesbokspruit.

4. DESCRIPTION OF ALTERNATIVE DISCHARGE OPTIONS

4.1 Option 1 Baseline - New WCW extension at the existing Welgedacht WCW and discharge at source

This is the baseline case with discharge of treated wastewater into the Blesbokspruit at the Welgedacht site upstream of the Ramsar Wetland. Attached in Appendix C is a layout plan of the proposed new WCW at the existing Welgedacht site. No additional pumpstations or pipelines are required for this option and the additional costs are thus zero.

The discharge of treated effluent into the Blesbokspruit upstream of the Ramsar Site is expected to result in a rise in water levels in the Blesbokspruit and potentially increase water seepage into the mine. This option would also see an increase in the levels of phosphates and other pollutants entering the wetland. It would, however, not require any additional capital expenditure for the discharge of final effluent from the WCW but may be required at the mine should the increase in seepage at Grootvlei require additional pumping capacity or other measures. This increase in cost cannot be easily quantified and due to the certainty has not been included in this report.

4.2 Option 2 – Pumping/gravity main to discharge at the R42 road crossing

This option consists of a pipeline from the Welgedacht WCW that discharges into the Blesbokspruit immediately downstream of the Ramsar Site at the R42 road crossing (see Figure 1 Appendix C). The terrain that the pipeline is to cross on the left bank of the Blesbokspruit is very flat (average slope 1:2000 with some sections even flatter). Depending on the exact route selected, a number of obstacles need to be negotiated by the pipeline including:

- Three slimes dams (two part of the Grootvlei Gold Mine)
- Three major road crossings (R555, R24 and the R42)
- Two incoming streams
- Various power lines
- A number of operating and closed gold mines, shafts and diggings.
- The Ramsar Wetland Site

Three different basic pipeline configurations were investigated to traverse this route as follows:

- Pumping for 24 km in a steel pipeline to a point approximately 3 km from the Blesbokspruit/R42 junction and then flowing in an unpressurised gravity sewer (concrete pipe) to a discharge point downstream of the R42/Blesbokspruit crossing (Option 2).
- A pressurised gravity main from the Welgedacht WCW to the Blesbokspruit/R42 junction (Option 2A – see section 4.3)

- An unpressurised gravity outfall sewer. Because of difficulty of both construction and operation of a pipeline with an extremely flat grade and the fact that the pipe would need to run adjacent to or in the wetland reserve for most of the way to keep the required grade, this option has been considered as not feasible and subsequently abandoned.

For Option 2 some flexibility with regard to routing is possible because a large portion of the main will be pressurised. A preliminary pipe route is shown on Figure 1 in Appendix C. The pumping main route would follow the left bank of Blesbokspruit initially rising to a head of 1600 m amsl and then follow one of the various available gravity routes to a discharge point. Over the first section of this route, the main is to cross railway lines, existing mines, old diggings/excavations, Eskom power lines and industrial/residential properties.

In addition to the main route shown, two alternative routes are presented in Figure 1 with cadastral boundaries, railway line servitudes, power line servitudes and road reserves shown. It would be necessary to obtain permission from the servitude owners before any of the pipe routes could be selected.

This option may allow the construction of the wastewater plant to proceed while the pipeline routing is being finalised and the necessary approvals received. Because the pipeline will handle treated wastewater, all the issues associated with constructing and operating a wastewater pumping main (eg air valves, scour pipes) need to be carefully planned.

A disadvantage of this and Options 2A, 3, 4 and 5 is that treated effluent discharged downstream of the Blesbokspruit Ramsar Wetland would not benefit from the positive polishing effect of the wetland on the water quality (See EIA Scoping Document on Hydrological and Water Quality Impacts in Appendix A). The water quality with these options is thus lower at any downstream position.

From a cost perspective this option is ranked third with a total nett present replacement (NPV) cost of R539.1 million over a 50 year life.

Pumping Main	**Option 2 – Bypass Wetland to R42**	**Gravity Main**	**Option 2 – Bypass Wetland to R42**
Start Invert (m)	1560	Start Invert (m)	1580
High Point (m)	1600	End Invert (m)	1560
End Invert (m)	1580	Static Head (m)	20
Static Head (m)	40	Pipeline Length (km)	3.0
Pipeline Length (km)	24	Average Slope (1:)	150
Pipeline Dia (mm)	1300	Stage 1 Dia (1.3 m^3/s)	1050
		Stage 2 Dia (2.6m^3/s)	1200
		Stage 1 Velocity (m/s)	1.7
		Stage 2 Velocity (m/s)	1.9

Table 4.2.1: Pipeline data

The comparable life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 2	414.14	325.88	740.02

Table 4.2.2: Cost estimate

See section 4.13 for full details of the life cycle cost estimate.

4.3 Option 2A – Pressurised gravity main to discharge at the R42

Option 2A is a pressurised gravity main from the Welgedacht WCW site to the Blesbokspruit/R42 junction carrying treated wastewater effluent. Unlike Option 2, this option does not have a pumping main. The average grade of the pipeline is very flat and the pipe size is correspondingly larger at 1950 mm dia. The pipeline would be constructed in steel and carry the treated wastewater under pressure. Using a pressure main allows limited flexibility in routing, for example the main would be able to cross under streams rather than flowing in a pipe bridge or inverted siphon.

In addition, because the pipeline would carry treated wastewater the issues associated with constructing a wastewater pressure main (eg air valves, scour pipes) need to be carefully planned.

Because of the extremely flat grade, choosing a final route for this option would be challenging. The pipe would need to run adjacent to or even within the Ramsar Wetland for a significant portion, including passing between the Grootvlei Mine slimes dams and the wetland. Construction of the pipeline would in most instances be required in the waterlogged area adjacent to the wetland.

Gravity Main	**Option 2A**
Start Invert (m)	1572
End Invert (m)	1560
Static Head (m)	12
Pipeline Length (km)	28.0
Average Slope (1:)	2333
Stage 1 Dia (1.3 m^3/s)	1500
Stage 2 Dia (2.6m^3/s)	1950
Stage 1 Velocity (m/s)	0.9
Stage 2 Velocity (m/s)	1.0

Table 4.3.1: Pipeline data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil) (Ranked in order of Cost)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 2 A	629.46	-	629.46

Table 4.3.2: Cost estimate

The difference in costs between Option 2 and 2 A is as a result of the larger diameter steel pipeline that is required for much of the route. Capex costs for Option 2A may be further escalated because of the difficulties of construction in or adjacent to the Ramsar Site. See Section 4.13 for full details of the life cycle cost estimate.

4.4 Option 3 - New WCW near the R42 – downstream of the Ramsar Site

Option 3 is a combination of either of the pipelines discussed for Option 2 and a new WCW in proximity to the point where the R42 crosses the Blesbokspruit. Under this option, raw sewage would be pumped in the main under pressure to a point about 3 km from the R42/Blesbokspruit crossing. The final length of pipe would be a 3 km unpressurised gravity main to a new wastewater plant near to the R42/Blesbokspruit crossing. Sewage would be treated at the new site and discharged downstream of the Ramsar Site.

An additional cost in this option is the sourcing of a new WCW site in this area. This would include costs such as for land acquisition as well as undertaking the necessary environmental and technical investigations to obtain permission to construct a new plant at the site. This permission in particular may result in a considerable delay to the project.

A major disadvantage of this option is that the long distance pumping/gravity main would need to carry raw untreated wastewater. Issues that require special attention with such a pipeline are the the location of air release and scour (line emptying) valves and that it is more difficult to obtain permission to use servitudes because of the medium being pumped. The environmental risks associated with this pipeline will be greater than those associated with a similar pipeline pumping treated wastewater effluent and will thus take longer to resolve.

Selection of this option may also result in delays and costs in obtaining the new WCW site because the work could not commence until the pipeline route is finalised and permission obtained to commence construction. In addition the WCW could not commence operation until the new pipeline is complete. The construction of the 30 km long pipeline that would feed this plant could be delayed given the number of obstructions that it needs to pass and the technical difficulties that would need to be overcome to construct the pipeline.

In addition, when the pipeline is operating and there is a blockage, raw sewage would spill directly into the Ramsar Wetland. If the wastewater is treated at the Welgedacht WCW (Option 2) a spillage would be of treated wastewater which would not be as detrimental to the wetland. The operational costs, logistics and staffing of 2 separate rather than a combined plant is also higher and has little advantages.

Pumping Main	Option 3	Gravity Main	Option 3
Start Invert (m)	1560	Start Invert (m)	1580
High Point (m)	1600	End Invert (m)	1560
End Invert (m)	1580	Static Head (m)	20
Static Head (m)	40	Pipeline Length (km)	3.0
Pipeline Length (km)	24	Average Slope (1:)	150
Pipeline Dia (mm)	1300	Stg 1 Dia (1.3 m^3/s)	1050
		Stg 2 Dia (2.6 m^3/s)	1200
		Stg 1 Velocity (m/s)	1.7
		Stg 2 Velocity (m/s)	1.9

Table 4.4.1: Pipeline data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 3	397.22	280.93	678.15

Table 4.4.2: Cost estimate

This option cost is marginally higher than that of Option 2 above but has no advantages. See Section 4.13 for full details of the life cycle cost estimate.

4.5 Option 4 - New WCW at the existing Bickley WCW Site

Option 4 includes the construction of a new WCW at the existing Bickley WCW site. The Bickley WCW treats a flow of 16 Mℓ/day and is located on the right bank of the Blesbokspruit, to the south of Nigel and downstream of the Ramsar Site. As per Option 3, raw sewage would be pumped from the existing Welgedacht site to a discharge point about 3 km upstream of the R42/Blesbokspruit crossing. The wastewater would then gravitate in a concrete outfall sewer to the new WCW at Bickley. This 14 km gravity pipeline would cross the Blesbokspruit along the R42 and past the outskirts of Nigel along the river following various existing service corridors.

A major restriction of this option is the additional cost of an even longer outfall sewer that would need to be constructed to carry raw sewage to the new WCW. Construction of this pipeline would present the same challenges as stated for Option 3 with the further obstacle of Nigel. The average slope of the gravity outfall sewer is flat at 1:300 but is considered feasible for this flow.

Pumping Main	Option 4	Gravity Main	Option 4
Start Invert (m)	1560	Start Invert (m)	1580
High Point (m)	1600	End Invert (m)	1535
End Invert (m)	1580	Static Head (m)	45
Static Head (m)	40	Pipeline Length (km)	14.0
Pipeline Length (km)	24	Average Slope (1:)	311
Pipeline Dia (mm)	1300	Stg 1 Dia (1.3 m^3/s)	1200
		Stg 2 Dia (2.6 m^3/s)	1350
		Stg 1 Velocity (m/s)	1.4
		Stg 2 Velocity (m/s)	1.6

Table 4.5.1: Pipeline data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 4	464.52	280.93	745.45

Table 4.5.2: Cost estimate

See Section 4.13 for full details of the life cycle cost estimate.

4.6 Option 5 - New WCW at the existing Heidelberg WCW site

Option 5 includes the construction of a new WCW at the existing 8 Ml/day Heidelberg WCW downstream from the existing Bickley WCW site. This option is similar to Option 4 to Bickley WCW but would include a further 26 km (40 km total) of gravity outfall sewer running adjacent to the Blesbokspruit. The route to the new site is obstructed by many properties and would need to follow various service corridors and also pass through Heidelberg CBD to the existing Heidelberg site.

Judging from aerial photos, the existing services servitude will not allow working space for the new pipeline. These issues and the cost of construction of such a pipeline make this option not feasible.

This option has all the disadvantages of Option 4 at a significantly higher cost but no identified advantages and is therefore not favoured.

Pumping Main	Option 5	Gravity Main	Option 5
Start Invert	1560	Start Invert (m)	1580
High Point	1600	End Invert (m)	1490
End Invert	1580	Static Head (m)	90
Static Head (m)	40	Pipeline Length (km)	40.0
Pipeline Length (km)	24	Average Slope (1:)	444
Pipeline Dia (mm)	1300	Stg 1 Dia (1.3 m^3/s)	1200
		Stg 2 Dia (2.6 m^3/s)	1500
		Stg 1 Velocity (m/s)	1.3
		Stg 2 Velocity (m/s)	1.5

Table 4.6.1: Pipeline Data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 5	652.60	280.93	933.53

Table 4.6.2: Cost Estimate

This option has a total life cycle cost of R933 million which is excessive and for this reason alone can be disregarded; see Section 4.13 for full details of the life cycle cost estimate.

4.7 Option 6 – Pumping treated effluent to the Crocodile River catchment

This option follows a cross catchment route and will not discharge into the Blesbokspruit but into the Crocodile River catchment to the north of Welgedacht WCW, near the Hartebeestfontein WCW.

The raw sewage will be treated at an upgraded Welgedacht WCW and be pumped to the Crocodile River catchment area discharging via a steel pumping main into a concrete outfall sewer. The route for the pipelines is dependant on existing service corridors and permission from their owners to allow the new service to be installed within the existing service boundaries. Both routes investigated discharge into the Rietvlei River, a tributary of the Hennops River, in the Crocodile River catchment area.

This option is sixth lowest in cost. The main advantages is that treated effluent is transferred from the Vaal River to the Crocodile River catchment where there are shortages.

Pumping Main	Option 6 - Crocodile	Gravity Main	Option 6 - Crocodile
Start Invert (m)	1560	Start Invert (m)	1640
High Point (m)	1640	End Invert (m)	1555
End Invert (m)	1640	Static Head (m)	85
Static Head (m)	80	Pipeline Length (km)	9.6
Pipeline Length (km)	19.7	Average Slope (1:)	113
Pipeline Dia (mm)	1300	Stage 1 Dia (1.3 m^3/s)	800
		Stage 2 Dia (2.6 m^3/s)	1050
		Stage 1 Velocity (m/s)	2.7
		Stage 2 Velocity (m/s)	3.2

Table 4.7.1: Pipeline Data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil)		
Option	**Capex**	**Pumping**	**Total Cost**
Option 6	402.95	422.31	825.26

Table 4.7.2: Cost estimate

See section 4.13 for full details of the life cycle cost estimate.

4.8 Option 7 and Option 7A – Discharge of treated effluent into the Bronkhorstspruit catchment

In Option 7, treated effluent is pumped from an upgraded Welgedacht WCW to the Bronkhorstspruit catchment area to the north east of the plant (figure7). The treated effluent would be discharged in to the Koffiespruit or one of its tributaries.

Various routes are available following existing service corridors. Two routes (Options 7 and 7A) have been considered. These represent the shortest length of pipeline of all the alternative discharge points investigated. The effluent would be pumped via a (steel) pipeline from the Welgedacht WCW and gravitated from a high point through a (concrete) pipe to a suitable discharge point into the nearest watercourse within the Bronkhorstspruit catchment.

From a cost perspective these options (7 and 7A) are preferred to the others investigated. As per Option 6, treated effluent would be transferred to another catchment (Bronkhorstspruit). However, concerns have been raised that the volumes transferred could be lost through illegal abstractions before these reach the intended water use points.

Pumping Main	Option 7	Option 7A	Gravity Main	Option 7	Option 7A
Start Invert	1560	1560	Start Invert	1630	1630
High Point	1630	1630	End Invert	1590	1600
End Invert	1630	1630	Static Head (m)	40	30
Static Head (m)	70	70	Pipeline Length (km)	3.6	2.4
Pipeline Length (km)	9.6	6.6	Average Slope (1:)	90	80
Pipeline Dia (mm)	1300	1300	Stg 1 Dia (1.3 m^3/s)	800	800
			Stg 2 Dia (2.6 m^3/s)	1050	1050
			Stg 1 Velocity (m/s)	2.7	2.7
			Stg 2 Velocity (m/s)	3.2	3.2

Table 4.8.1: Pipeline data

The life cycle costs for these options are summarised below:

	Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*		
Option	**Capex**	**Pumping**	**Total Cost**
Option 7 A	169.86	284.68	454.55
Option 7	218.64	306.33	524.97

Table 4.8.2: Cost estimate

Options 7 and 7A are ranked as first and second respectively from a cost perspective, because of the short pipeline lengths. They are still, however, over R300 million higher in cost when compared to the baseline, Option 1. See Section 4.13 for full details of the life cycle cost estimate. The issues involved with pumping relative large volumes into small streams need to be carefully considered, especially for treated effluent, and would need extensive environmental and specialist studies.

4.9 Option 8 - Effluent discharge to the Rietspruit catchment

Option 8 covers the pumping of treated effluent to the Rietspruit catchment to the south west of Welgedacht WCW and a gravity outfall sewer to the Rietspruit. The most practical routing for this pumping main / gravity main combination is through the built up area of Springs. The routing would need to be investigated very carefully before this option is chosen. A service corridor that might be followed is a railway line reserve that passes near Welgedacht WCW and through Springs. Looking at aerial photos it can be assumed that the working space would be very limited and that construction would be time consuming and expensive and may be interrupted by passing rail traffic.

This option is relatively expensive and is ranked eighth overall from a cost perspective.

Pumping Main	Option 8	Gravity Main	Option 8
Start Invert (m)	1560	Start Invert (m)	1655
High Point (m)	1655	End Invert (m)	1590
End Invert (m)	1655	Static Head (m)	65
Static Head (m)	95	Pipeline Length (km)	4.5
Pipeline Length (km)	20.7	Average Slope (1:)	69
Pipeline Dia (mm)	1300	Stage 1 Dia (1.3 m^3/s)	800
		Stage 2 Dia (2.6 m^3/s)	1050
		Stage 1 Velocity (m/s)	2.7
		Stage 2 Velocity (m/s)	3.2

Table 4.9.1: Pipeline data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*		
Option	**Capex**	**Pumping**	**Total Cost**
Option 8	412.57	494.18	906.74

Table 4.9.2: Cost estimate

See section 4.13 for full details of the life cycle cost estimate.

4.10 Option 9 – Pump/gravitate effluent to Waterfal WCW

Option 9 is the pumping raw sewage similar to Option 8, described in 4.9 above, through Springs. The difference, however, is that under Option 8 this main would pump raw sewage to a new gravity sewer to be built from Vlakplaats to Waterval adjacent to the existing main. Raw sewage would either be treated at the Vlakplaats works in periods of low flow, or at the Waterval works downstream. The Vlakplaats works bypass would divert any in excess of the works' capacity to Waterval. An additional capacity of 50 Mℓ/d and later 100 Mℓ/d would need to be installed at either the Vlakplaats works, or at the Waterval works.

This option is however extremely expensive and is ranked tenth overall from a cost perspective.

Pumping Main	Option 9 - Waterfal Works Diversion	Gravity Main	Option 9 - Waterfal Works Diversion
Start Invert (m)	1560	Start Invert (m)	1655
High Point (m)	1655	End Invert (m)	1480
End Invert (m)	1655	Static Head (m)	175
Static Head (m)	95	Pipeline Length (km)	42.0
Pipeline Length (km)	20.7	Average Slope (1:)	240
Pipeline Dia (mm)	1300	Stage 1 Dia (1.3 m^3/s)	1050
		Stage 2 Dia (2.6 m^3/s)	1200
		Stage 1 Velocity (m/s)	1.5
		Stage 2 Velocity (m/s)	1.9

Table 4.10.1: Pipeline data

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*		
Option	**Capex**	**Pumping**	**Total Cost**
Option 9	609.92	494.18	1,104.09

Table 4.10.2: Cost estimate

See Section 4.13 for full details of the life cycle cost estimate.

4.11 Option 10 – Treating wastewater effluent to potable standard

This option considers treating wastewater from the Welgedacht WCW to a potable standard. The ideal situation would be for water to be treated to a standard which is high enough for the Ekurhuleni Metropolitan Municipality or Rand Water to accept it into their system. This would minimise any additional costs required for construction of reticulation systems to distribute water to users, or storage facilities, because the water could potentially be injected directly into the existing water supply system. A number of fail-safe mechanisms would have to be provided to ensure that the risks with this direct re-use are covered. These measures will be costly.

However, the key issue that needs to be addressed before this option can proceed further is would users accept wastewater treated by this system injected directly into the potable water supply system? Until Gauteng's water supply is stressed to a point where there is no other option, it will be difficult to gain public support for this proposal.

Based on the extremely high cost and the technical and social issues associated with this option, it is not recommended at present.

The water treated to potable standards would have a resale value. A revenue of R4/m^3 has been included in the life cycle costing based on the installed capacity of the upgraded Welgedacht WCW over the 50 year life cycle cost period. In preparing these costs an amount of R9 million per Mℓ has been assumed for the capital cost of the plant that would treat the treated effluent to potable standards. A further R7 per kℓ has been assumed for operating this plant.

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*			
Option	**Capex**	**Pumping**	**NTC***	**Total Cost**
Option 10	1,035.39	373.87	3.87	1,413.13

Table 4.11.1: Cost estimate

The above table shows that this is the most expensive of all options considered. See Section 4.13 for full details of the life cycle cost estimate.

* Net Treatment Costs (NTC) to potable standards i.e. cost of treatment less revenue from the sale of water

4.12 Option 11 - Grootvlei Mine water (Re-use)

Due to the complex environmental issues around acid mine drainage (AMD) of old gold mines or shafts, a group of active mines operating around the Johannesburg gold fields formed the Western Basin Environmental Company. The latter, tasked with finding solutions to the issues on a sustainable and cost effective basis, formed the Western Utilities Corporation (WUC), an Article 21 company. WUC has been in the process of planning and designing systems to drain mine shafts at various locations from Randfontein to Springs and to treat the AMD to either industrial or potable standards. The treated water would be sold to existing mines to recover capital and operational costs. The WUC initiative has, however, been put on hold pending the outcome of the report commissioned by the National Government's Inter-Ministerial Committee on Acid Mine Drainage.

In the Welgedacht WCW area, WUC had planned to abstract 82 Mℓ/d from shafts at or near Grootvlei Mine and treat the same quantity to potable standards for sales of this water to the local mines. At present, this volume is abstracted but released into the Blesbokspruit and thus forms a component of the daily river flows. The 82 Mℓ/d is based on long term flow records of underground water infiltrations and the pumping system is designed for this volume with little spare capacity. The pumping cost is presently not recovered and thus not sustainable if mining activities were to stop. The planning was for the maximum volume abstracted to be made available for on-sales to the mines after treatment, ideally the full volume. The planning had allowed for 10 Mℓ/d of the treated water to be released for base flow discharge into the Blesbokspruit if so required.

The abstraction and treatment system would be negatively affected if the infiltration into the shafts were to increase as a result of volume of larger upstream flow releases.

The Welgedacht WCW is about 7 km upstream of the Grootvlei Gold Mine situated immediately north west of the Marievale Ramsar Wetlands Site. A preliminary meeting was held with WUC to discuss various options and potential synergy between the two projects. A possibility which would be looked at by WUC if agreement could be reached would be to lay a pipeline from the Welgedacht WCW towards Grootvlei Gold Mine and to convey 20Ml/d of treated wastewater effluent towards the latter for further processing and/or blending with AMD, for on selling to the mines as industrial water. This would require some modifications to the existing planning and acceptance by the end users of this option, ie. use of treated wastewater. The quality of the treated wastewater would need to be at least as for the minimum standard as imposed under the license conditions for the Welgedacht WCW. This option is similar to Option 1, the baseline option and would carry no additional costs for Erwat.

If the WUC project were to be implemented, flow from the upgraded WCW would in essence replaces the volumes previously discharged by the mine, resulting in no net change to the flows in the spruit. A key issues which is yet to be considered Is that of increased infiltration into the mine. WUC have indicated that a hydraulic study has been completed by Golder on behalf of the DME to ascertain the critical points of infiltration to the Grootvlei mine. In the absence of this apparently confidential data it has been assumed that these critical points are all located upstream of the mine's current discharge point.

This option therefore allows for a 9.5 km pipeline with associated pumping infrastructure at the Welgedacht WCW to convey the treated effluent (less the 20 Ml/d contribution directly to WUC's treatment works in the central basin) to the point where the mine currently discharges into the Blesbokspruit.

The life cycle costs for this option are summarised below:

	Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*		
Option	**Capex**	**Pumping**	**Total Cost**
Option 11	149.44	111.65	261.09

Table 4.12.1: Cost estimate

The possibility of discharging the effluent closer to the WCW without adversely impacting on the volume of infiltration needs to be investigated further.

4.13 Life cycle cost analysis

A life cycle cost analysis was completed for all options discussed above. Net present value has been calculated using the following figures:

- Escalation rate 10.00%
- Discount rate 16.00%

The costs have been calculated over a period of 50 years assuming that the plant would be upgraded in 2020 to a full capacity of 135 Mℓ/day by adding a further 50 Mℓ/day upgrade.

The two tables below summarise the net present value costs for the options investigated. Table 4.13.1 shows the cost for each option sorted on option number and Table 4.13.2 is sorted on the Total NPV cost.

	Net Present Value Accumulated Costs (R mil)			
Option	**Capex**	**Pumping**	**NTC**	**Total Cost**
Option 1	0.00	0.00		0.00
Option 2	414.14	325.88		740.02
Option 2 A	629.46			629.46
Option 3	397.22	280.93		678.15
Option 4	464.52	280.93		745.45
Option 5	652.60	280.93		933.53
Option 6	402.95	422.31		825.26
Option 7	218.64	306.33		524.97
Option 7 A	169.86	284.68		454.55
Option 8	412.57	494.18		906.74
Option 9	609.92	494.18		1104.09
Option 10	1,035.39	373.87	3.87	1,413.13
Option 11	149.44	111.65		261.09

Table 4.13.1: Life cycle cost summary

* Net Treatment Costs (NTC) to potable standards

		Net Present Value Accumulated Costs (R mil) *(Ranked in order of cost)*			
Ranking	**Option**	**Capex**	**Pumping**	**NTC**	**Total Cost**
0	Option 1	0.00	0.00		0.00
1	Option 11	149.44	111.65		261.09
2	Option 7 A	169.86	284.68		454.55
3	Option 7	218.64	306.33		524.97
4	Option 2 A	629.46			629.46
5	Option 3	397.22	280.93		678.15
6	Option 2	414.14	325.88		740.02
7	Option 4	464.52	280.93		745.45
8	Option 6	402.95	422.31		825.26
9	Option 8	412.57	494.18		906.74
10	Option 5	652.60	280.93		933.53
11	Option 9	609.92	494.18		1,104.09
12	Option 10	1,035.39	373.87	3.87	1,413.13

Table 4.13.2: Ranked life cycle cost summary

* Net Treatment Costs (NTC) to potable standards

5. HYDRAULIC AND WATER QUALITY SCOPING STUDY

The purpose of the scoping study was to overview the potential effects of the proposed extension of the Welgedacht WCW on hydrological and water quality systems taking particular account of the main effluent disposal options.

The hydrological and water quality scoping has been confined to an overview of the potential effects of the proposed extension of the Welgedacht WCW taking particular account of two main effluent disposal options:

- Baseline option - Discharging to the Blesbokspruit above the R555 road crossing and,

- Bypass option - Diverting the discharge to below the Blesbokspruit wetland.

The full report is attached as Appendix A. The main findings are summarised as follows in an extract from the executive summary:

- **Effect on flow rate:** By 2020 for the Baseline Option development growth would increase the median flow near the R555 by about 23% and at the Marievale Bird Sanctuary by 17%. The Bypass Option would reduce the median flow at the R555 by 43% and at the Marievale Bird Sanctuary by 30%.

- **Effect on water levels and inundated width:** The Baseline Option would increase the 2020 median water level near the R555 by about 90 mm and at the Marievale Bird Sanctuary by 40 mm. The very roughly determined corresponding increases in the inundated widths at these two sections would be 28 m (14 m on either bank) and 4 m (2 m on either bank). The Bypass Option would reduce the 2020 median water level at the R555 by 200 mm with a corresponding reduction in surface width of 64 m, again very roughly determined. At the Marievale Bird Sanctuary the reduction in water level would be about 70 mm and the inundated width would reduce by 9 m.

- **Effect on salt concentrations:** For the Baseline Option increasing dilution of the mine discharge would reduce the 2020 median salinity at the R555 by 7%, and by 9% at the Marievale Bird Sanctuary and further downstream near the confluence with the Vaal River. The Bypass Option would cause a 12% increase in the median 2020 salinity at the R555, with 26% at the Marievale Bird Sanctuary. There would be no change in salinity downstream of the wetland.

- **Effect on phosphate:** The Bypass Option would reduce the median phosphate concentration in the Blesbokspruit near the R555 by about 32%, with an 11% reduction at the Marievale Bird Sanctuary. However, the phosphate concentration below the wetland is expected to more than treble and that near the mouth of the Suikerbosrand River increase by 50%. The phosphate load in the Blesbokspruit below the wetland would double, thereby increasing the nutrient load entering the Vaal Barrage.

- **Other water quality effects:** The two options can also be expected to affect other water quality variables, such as E-coli counts, COD and ammonia levels. These effects have not been considered in the scoping evaluation.

- **Effect of other Welgedacht WCW effluent disposal options:** The main variants include the option of pumping the effluent to another catchment and direct reclamation. The effect of both on the Blesbokspruit wetland would be similar to that for the Bypass Option. However, the effect below the Wetland and on the downstream Vaal River would be very different. In the case of direct reclamation, the salt feedback effect would elevate total dissolved solids (TDS) concentrations in supply, thereby increasing the cost to consumers and would also increase the salinity of the remaining effluent discharges to the Blesbokspruit.

- **Effect of Grootvlei Gold Mine closure:** The Baseline and Bypass Options that were considered in the scoping study are both based on the assumption that Grootvlei Gold Mine will continue to discharge to the Blesbokspruit. However, it must be recognised that both the flow rate and the salinity of this source have reduced over the last 11 years. Complete closure would have even more pronounced effects on water levels and salinity.

Please see the full report in Appendix A for details and background to the above.

6. CONCLUSIONS

There are two underlying issues that must be considered and mitigated against before further development at the Welgedacht WCW may be realised. These are:-

- According to the DWA the RAMSAR site is hydraulically overloaded and cannot cater for any additional flows into the Blesbokspruit upstream of this reserve.

- Additional loads on the Blesbokspruit upstream of the Grootvlei Mine may result in additional seepage into the mine which places strain on pumping activities required to dewater the mine.

Preliminary hydraulic analysis carried out to date shows a small increase in water levels in the Blesbokspruit for the base case scenario. This increase is largest (90 mm deeper) at the upstream end of the catchment near to the R555. This hydraulic effect is reduced further down the Blesbokspruit (to approximately 40 mm deeper) at the Marievale Bird Sanctuary.

Preliminary findings from a water quality perspective show that the Bypass Option would more than treble the phosphate concentration at the downstream end of the Ramsar Site. Salt concentrations would not be affected downstream of the Ramsar Site for the Bypass Option. However, they could be significantly affected if the treated wastewater is pumped into another catchment. It may be possible to reduce water levels in the spruit by reducing restrictions to the flow in the wetland for example by widening culverts etc.

The net increase in seepage into the mine under the base case scenario is unknown at this stage. Hydraulic studies in this regard have apparently been undertaken through the DME in determining the key infiltration points into the mine. These reports are apparently subject to confidentiality requirements and were not available at the time this investigation was concluded. For the purpose of this study however it was assumed that all key infiltration points occur upstream of the mines current discharge point and details of these exact positions may yield more economical options.

The various options considered for preventing any additional hydraulic loading on the Blesbokspruit and Grootvlei mine due to the discharge from the Welgedacht WCW, requires a minimum additional capital expenditure (Option 11) in the order of R150m and a minimum of R58m additional life cycle costs over a 50 year period. The minimum additional amount required increases the cost of wastewater treatment by an additional R2.1m/Mℓ/d for this project. This is a 30% increase if compared to the average cost of between R6m to R7m/Mℓ/d for a conventional wastewater treatment plant.

The alternative to treat the effluent on site to a potable water standard is costly and it will be difficult to gain public support for this option because of the perception that albeit treated, wastewater is being pumped directly into the treated water system.

The key issues with regard to this additional cost is who would be responsible for the financing the additional infrastructure required and who would benefit from the reduction of water in the Blesbokspruit. The Welgedacht WCW receives and treats sewage received from an extensive low income area and the additional capital required for the infrastructure necessary to alleviate hydraulic loads on the mine and the spruit cannot be carried by way of tariff charges through the

Ekurhuleni Metropolitan Municipality. This could severely affect and or suspend further development initiatives in this area.

7. RECOMMENDATIONS

Based on the limited potential hydraulic impact on the Blesbokspruit, the beneficial impact on the overall water quality of putting the effluent from Welgedacht WCW through the wetland and significant effect on project costs serving an extensive low income earning area, it is recommended that a relaxation of the restriction on further discharge into the Blesbokspruit from the Welgedacht WCW should be sought from the DWA.

It is further recommended that the effects of the additional flow on the downstream wetland site be further investigated in more depth. The scoping study which is reported in full in Appendix A shows preliminary results based on a full study completed by SSI in the late 1990s. If these effects on the Ramsar Wetland, in terms of increased hydraulic loading and associated water quality factors, are better understood it may be possible to mitigate these effects in some manner that may be acceptable to all the stakeholders.

Similarly the findings from the reports commissioned by the DME must be obtained such that should the load on the Blesbokspruit be alleviated through undertakings by the WUC project, the Welgedacht WCW may be afforded the opportunity to make up this shortfall without negatively affecting operations at the mine.

None of the alternative discharge options considered in this report appear to present a particularly cost effective solution, with the additional capex required increasing the project costs significantly.

APPENDIX A

EIA SCOPING AND HYDROLOGICAL AND WATER QUALITY IMPACTS

ERWAT

WELGEDACHT WATER CARE WORKS 50 Ml/d EXTENSION

EIA SCOPING

HYRDROLOGICAL AND WATER QUALITY IMPACTS

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EXECUTIVE SUMMARY

The hydrological and water quality scoping has been confined to an overview of the potential effects of the proposed extension of the Welgedacht Water Care Works taking particular account of two main effluent disposal options, namely the options of discharging to the Blesbokspruit above the R555 road crossing (Baseline Option) and diverting the discharge to below the Blesbokspruit wetland (Bypass Option). The time periods considered include present day and after the proposed extensions at Welgedacht have reached capacity in about 2020. Grootvlei Gold Mine has been assumed to continue discharging effluent to the wetland. The scoping analyses exclude modelling but are rather based on the results of earlier investigations carried out in 1998.

The main findings are as follows:

- **Effect on flow rate:** By 2020 for the Baseline Option development growth would increase the median flow near the R555 by about 23% and at the Marivale Bird Sanctuary by 17%. The Bypass Option would reduce the median flow at the R555 by 43% and at the Marivale Bird Sanctuary by 30%.

- **Effect on water levels and inundated width:** The Baseline Option would increase the 2020 median water level near the R555 by about 9 cm and at the Marivale Bird Sanctuary by 4 cm. The corresponding increases in the inundated widths at these two sections would be 28 m (14 m on either bank) and 4 m (2 m on either bank). The Bypass Option would reduce the 2020 median water level at the R555 by 20 cm with a corresponding reduction in surface width of 64 m. At the Marivale Bird Sanctuary the reduction in water level would be about 7 cm and the inundated width would reduce by 9 m.

- **Effect on salt concentrations:** For the Baseline Option increasing dilution of the mine discharge would reduce the 2020 median salinity at the R555 by 7% and by 9% at the Marivale Bird Sanctuary and further downstream near the confluence with the Vaal River. The Bypass Option would cause a 12% increase in the median 2020 salinity at the R555, with a 26% increase at the Marivale Bird Sanctuary. There would be no change in salinity downstream of the wetland.

- **Effect on phosphate:** The Bypass Option would reduce the median phosphate concentration in the Blesbokspruit near the R555 by about 32%, with an 11% reduction at the Marivale Bird Sanctuary. However, the phosphate concentration below the wetland is expected to more than treble and that near the mouth of the Suikerbosrand River increase by 50%. The phosphate load in the Blesbokspruit below the wetland would double, thereby increasing the nutrient load entering Vaal Barrage.

- **Other water quality effects:** The two options can also be expected to affect other water quality variables, such as E-coli counts, COD and ammonia levels. These effects have not been considered in the scoping evaluation.

- **Effect of other Welgedacht WCW effluent disposal options:** The main variants include the option of pumping the effluent to another catchment and direct reclamation. The effect of both on the Blesbokspruit wetland would be similar to that for the Bypass Option. However, the effect below the Wetland and

on the downstream Vaal River would be very different. In the case of direct reclamation the salt feedback effect would elevate TDS concentrations in supply, thereby increasing the cost to consumers and would also increase the salinity of the remaining effluent discharges to the Blesbokspruit.

- **Effect of Grootvlei Gold Mine closure:** The Baseline and Bypass Options that were considered in the scoping study are both based on the assumption that Grootvlei Gold mine will continue to discharge to the Blesbokspruit. However, it must be recognised that both the flow rate and the salinity of this source have reduced over the last 11 years. Complete closure would have even more pronounced effects on water levels and salinity.

Recommendations

In view of the wide ranging implications on flow rate, water depth, inundated depth, salinity and nutrient concentrations and export, it is prudent to carry out a more rigorous evaluation making full use of the data that has been collected over the last 11 years and the modelling tools that were developed during the previous investigation. Changes that have taken place during this period also need to be considered. Other effluent disposal options also need to be evaluated with and without the influence of continued discharge by Grootvlei Gold Mine.

The recommendations are as follows:

- **Flow and salinity modelling:** Use the NACL daily time step hydro-salinity model to simulate flow and TDS concentrations for a wide range of historical meteorological conditions and provide vital information at key points in the Blesbokspruit / Suikerbosrand rivers for present day and projected future time horizons for each of the main options.

- **Backwater modelling:** Use the HEC-RAS backwater model to determine the effect of the basic Welgedacht extension option and the major ameliorative options on water levels in the Blesbokspruit wetland, taking due account of changes in channel cross-sections and the expected discharges from Grootvlei Gold Mine.

- **Non-conservative pollutant modelling:** Use the DECAY model and the longer records of water quality data now available to estimate the impact of the options on key non-conservative pollutants (phosphate, ammonia, COD and E-coli).

- **Estimation of impact of phosphate breakthrough:** Assess the likelihood and consequences of phosphate breakthrough from the Blesbokspruit wetland. An approach similar to that used in the previous study is proposed.

- **Vaal Barrage impact assessment:** Estimate the impact of phosphate export from the Suikerbosrand River on Vaal Barrage for the main Welgedacht WCW effluent disposal options. An approach similar to that used in the previous study is envisaged, except that the phosphate load to Vaal Barrage will be compared to that from other major sources.

- **Siting of point of discharge:** From an engineering perspective the benefit in terms of reduced water level of diverting the effluent to below the Blesbokspruit wetland appears to be outweighed by the large associated cost and the increased phosphate loading on Vaal Barrage. However, broader environmental and socio-economic factors also need to be taken into consideration.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

1. INTRODUCTION

The purpose of the scoping is to overview the potential effects of the proposed extension of the Welgedacht Water Care Works on hydrological and water quality systems taking particular account of the main effluent disposal options. The time periods considered include present day and after the proposed development at Welgedacht. The analyses exclude modelling.

1.1 Background

The increased effluent flow associated with extension of the of the Welgedacht Water Care Works would, if discharged to stream, increase water levels in the downstream river system. The impact would be greatest in the Blesbokspruit wetland area down to the R42 road crossing near Nigel. Land slopes are at their flattest adjacent to the wetland area resulting in the most pronounced inundation of riparian land. The impact of water level on open water surfaces and reed beds is also of concern, particularly since it can affect bird life in the sensitive RAMSAR site.

At present the high nutrient concentrations in various point discharges to the upper Blesbokspruit are reduced by the wetland to near background levels at its outlet. There is concern that the assimilative capacity of the wetland may be nearing exhaustion with the subsequent break-through of phosphate. The main concern is a potential rise in the phosphate load entering the Vaal Barrage, leading to increased eutrophication problems in this RW water supply source. Elevated concentrations of other pollutants could occur closer to the point of discharge, but high decay rates in the wetland should confine such impact to a relatively short reach of the Blesbokspruit.

1.2 Ameliorative options

A number of ameliorative options have been suggested. The main variants of options include the following:

- **Baseline**: Discharge the treated effluent from Welgedacht to the Blesbokspruit at the upstream end of the wetland.
- **Bypass**: Discharge the Welgedacht treated effluent downstream of the Blesbokspruit wetland.
- **Effluent export**: Convey the Welgedacht treated effluent to another catchment.
- **Direct reclamation**: Reclaim the Welgedacht effluent for direct re-use.

In effect the last two options have identical effect on the Blesbokspruit / Suikerbosrand river system. However, their economic implications and impact on adjacent river systems differ widely. The initial scoping investigation has been confined to investigation of the first two options, although all four are described in the following section.

2. DESCRIPTION OF OPTIONS

The main options are discussed in the following sections.

2.1 Baseline option

The Baseline Option is the status quo, which implies that increasing discharge from the Welgedacht Water Care Works (WCW) will continue to be discharged to the Blesbokspruit at or near to the present point of discharge. The effluent will be treated to meet discharge quality requirements. Discharges to the Blesbokspruit from other WCWs and industries will continue to grow as projected.

Expected discharges from Grootvlei Gold Mine need to be taken into account, since cessation of this inflow will have a significant impact on water levels in the Blesbokspruit.

The assumption is made that the discharge from Grootvlei Gold Mine will continue at a constant rate until after the point at which the extensions at Welgedacht reach capacity. (The alternatives, that the Grootvlei Gold Mine discharge changes with time or ceases before the Welgedacht extensions reach full capacity, due to the implementation of direct reclamation or decanting downstream of the wetland at Nigel have not been considered in the initial scoping.) The most likely scenario of Grootvlei gold mine discharges will need to be investigated further after the scoping phase.

2.2 Bypass Option

This option involves the construction of a pipeline or canal to convey treated sewage effluent discharge around the Blesbokspruit wetland. This would serve to alleviate water levels in the Blesbokspruit wetland and reduce the possible onset of phosphate breakthrough from the wetland. However, it would also make the adverse effects on Vaal Barrage of a possible future phosphate break-though an immediate certainty since there are no significant downstream wetlands or other storage units that could remove the phosphate load that would be discharged below the wetland.

Conjunctive use of this long distance outfall with Grootvlei Gold Mine needs to be considered. However, since the option of a regional mine water reclamation plant is receiving serious consideration, it is unlikely that Grootvlei Gold Mine would consider participation in the building and operating an expensive outfall sewer for an uneconomically short time, only to replace it with an even more expensive demineralisation plant. Hence the assumption used in the scoping is that only Welgedacht WCW would discharge to the bypass canal or pipeline.

Other sub-sets of this option include conjunctive use with Sappi and / or with one or more of the WCWs that currently discharge effluent upstream of or to the Blesbokspruit wetland.

This option would reduce flows, and hence water levels in the Blesbokspruit wetland, but would be similar to the Baseline Option below the R42 road crossing.

2.3 Effluent export

This would involve pumping the Welgedacht effluent to an adjacent water-scarce catchment. Possible donor catchments include the upper Olifants or Crocodile West catchments. The pressure to build new power stations in both of these catchments could be relevant, especially since the Waterberg area will require interbasin water transfer from the Crocodile West catchment, which is already dependent on effluent return flows and plans are already under consideration to supplement this with effluent transfer from the upper Klip River to sustain the additional power station requirements.

The quantity of water pumped could be confined to just the incremental flow from the Welgedacht WCW extensions, but if built would almost certainly require inclusion of other effluent discharges to improve the economic viability. It is also unlikely that if DWAF implements an effluent transfer scheme from the Klip River, that they will also want to transfer effluent from another smaller source. This is because they may not need so much effluent in the Crocodile catchment and it would be economically unviable to implement two small transfer schemes instead of one large one.

This option would reduce flows and water levels in the Blesbokspruit wetland and in the downstream reaches of the Blesbokspruit and Suikerbosrand River.

The initial scoping does not cover this option.

2.4 Direct reclamation

This option would involve further treatment of the Welgedacht effluent to potable or industrial standard prior to pumping it back into the supply system.

In terms of water quantity the effect on the Blesbokspruit / Suikerbosrand River system would be identical to that for the Effluent Export Option (see Section 2.3). (Although the costs of implementing it would differ.) However, the effect on water quality would differ. This is because direct reclamation would introduce a feedback cycle that would elevate the salt concentration of the water in supply, and hence, in the effluent to the remaining regional effluent sources.

The initial scoping does not cover this option.

3. EFFECT ON FLOW AND WATER LEVEL

3.1 Point inflows

The effluent point discharges to the Blesbokspruit system are described in Table 3.1.

Table 3.1: Effluent point sources to the Blesbokspruit system

Source	Discharged to
Benoni WCW	Benoni canal
Rynfield WCW	Rynfield Dam (tributary of Benoni canal)
Jan Smuts WCW	Jan Smuts Lake (tributary of Benoni canal)

Source	Discharged to
J P Marais WCW	Tributary of Benoni canal
Sappi	Cowles Dam (Benoni canal)
Daveyton WCW	Blesbokspruit (above wetland)
Welgedacht WCW	Blesbokspruit (above wetland)
Grootvlei Gold Mine	Blesbokspruit (wetland)
Ancor WCW	Klein Blesbokspruit (into wetland)
Grundlingh WCW	Tributary of Blesbokspruit (below wetland)
Bickley WCW	Blesbokspruit (below wetland)
Tsakane WCW	Kaydalespruit (below wetland)
Heidelberg WCW	Blesbokspruit (below wetland)
Ratanda WCW	Blesbokspruit (below wetland)

The locations of the effluent sources are shown in Figure 3.1.

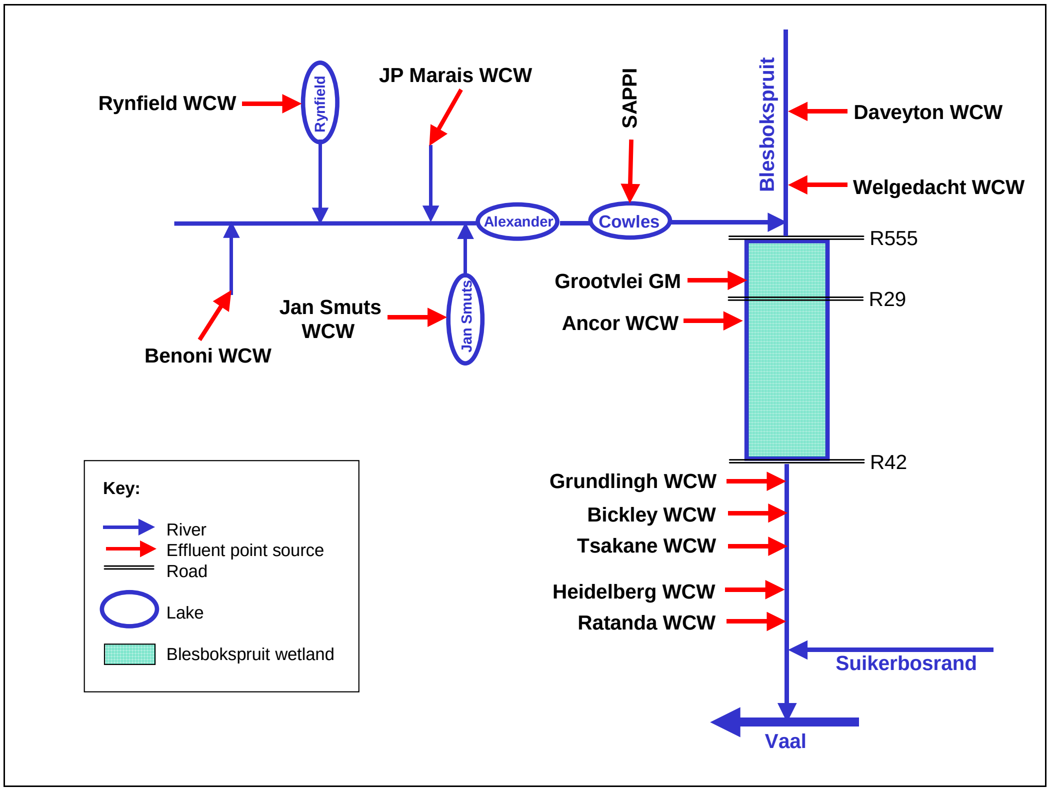

Figure 3.1: Locations of effluent point sources

The present day and projected point source flows up to the time when the extensions to the Welgedacht WCW reach capacity are as shown in Table 3.2.

Table 3.2: Projected discharges to the Blesbokspruit

Source	Discharge (Ml/d)	
	2009	2020

Source	Discharge (Ml/d)	
	2009	2020
Above Blesbokspruit wetland		
Benoni WCW	9.0	11.2
Rynfield WCW	7.0	8.8
Jan Smuts WCW	8.2	10.1
J P Marais WCW	14.0	14.0
Sappi (1)	22.7	22.7
Daveyton WCW (2)	16.0	16.0
Welgedacht WCW	54.0	85.0
Total above wetland	**130.9**	**167.8**
Into Blesbokspruit wetland (3)		
Grootvlei Gold Mine (1)	61.0	61.0
Ancor WCW	27.5	30.9
Total into wetland	**88.5**	**91.9**
Below Blesbokspruit wetland (3)		
Grundlingh WCW	2.2	2.4
Bickley WCW	15.6	17.6
Tsakane WCW	12.3	13.8
Heidelberg WCW	7.4	8.3
Ratanda WCW	2.8	3.2
Total below wetland	**40.3**	**45.3**
TOTAL POINT SOURCE FLOW	**259.7**	**305.0**

Note: (1) Discharge from Sappi and Grootvlei Gold Mine are assumed to remain constant.
(2) Inlet works at Daveyton WCW assumed repaired to allow it to run at capacity.
(3) WCWs discharging into and below the Blesbokspruit wetland are assumed to grow at 1%.

3.2 Interpolated flows

Median flow estimates have been made at the points shown in Figure 3.2 and described in Table 3.3.

Table 3.3: Description of key points where flows have been estimated

Key point	Description
R555	Top of Blesbokspruit wetland at R555 road crossing
R29	Blesbokspruit wetland below Grootvlei Gold Mine
MBS	Blesbokspruit wetland at Marivale Bird sanctuary
B10	Blesbokspruit at Heidelberg
S2	Blesbokspruit above confluence with Vaal

The estimated median flows at each key monitoring point are given in Table 3.4 for the Baseline and Bypass Options. These estimates are not based on model simulations, but are instead coarse approximations inferred from the effluent flow projections for 2015 given in Table 3.2 and the simulated flows obtained from Teurlings *et al* (1998) and the original computer files. The interpolation takes account of changes in point source discharges, but does not account for changes in urban areas and other land use changes.

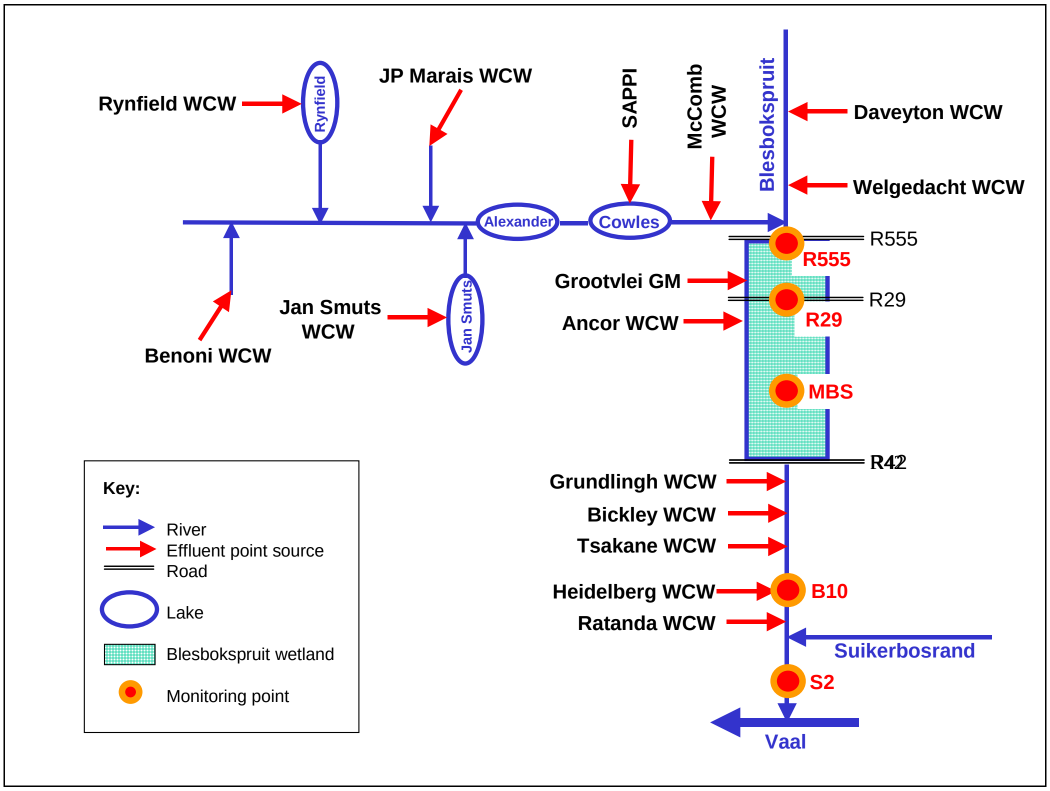

Figure 3.2: Locations of key monitoring points

Table 3.4: Interpolated median flows at key points in the river system (m^3/s)

Option	Baseline Option		Bypass Option	
	2009	2020	2009	2020
R555	1.86	2.29 (+23%)	1.24 (-33%)	1.31 (-43%)
R29	2.52	2.95 (+17%)	1.90 (-25%)	1.97 (-33%)
MBS	2.83	3.30 (+17%)	2.20 (-22%)	2.31 (-30%)
B10	3.26	3.77 (+16%)	3.26 (0%)	3.77 (0%)
S2	2.81	3.34 (+19%)	2.81 (0%)	3.34 (0%)

Development growth is expected to increase the median flow in the Blesbokspruit at the R555 road crossing by 23% by the time the Welgedacht extensions reach capacity in about 2030, with a 17% increase in the median flow in the wetland below Grootdraai Gold Mine. The median flow represents low flow conditions when flow in the river is dominated by point sources.

The option to bypass the Welgedacht treated effluent below the wetland would reduce the present day median flow at the R555 by 38%, growing to 43% by 2020. At the Marivale Bird Sanctuary causeway the flow would be reduced by 22% to 30%. In the lower Blesbokspruit and Suikerbosrand Rivers there would be virtually no change in flow, since for this option the treated effluent from the Welgedacht WCW would re-enter the Blesbokspruit near Nigel.

The Welgedacht effluent Bypass Option does not alter the inflow from the Suikerbosrand River to Vaal Barrage.

3.3 Interpolated water levels

The relative effect on flood discharges and the associated flood levels is small (Teurlings *et a*l, 1998) and therefore the scoping has focused on those associated with median flow conditions when the impact is more pronounced.

Stewart Scott (1998) carried out backwater analyses for projected 2015 conditions for the following four scenarios:

1. Welgedacht WCW discharges upstream of the Blesbokspruit wetland and Grootvlei Gold Mine continues discharging to the wetland.

2. Welgedacht WCW discharges downstream of the Blesbokspruit wetland and Grootvlei Gold Mine continues discharging to the Blesbokspruit wetland.

3. Welgedacht WCW discharges upstream of the Blesbokspruit wetland and Grootvlei Gold Mine discharge ceases.

4. Welgedacht WCW discharges downstream of the Blesbokspruit wetland and Grootvlei Gold Mine discharge ceases.

These earlier backwater results were used to interpolate the water levels associated with the current flow estimates. The resulting scenarios of coarse water level estimates are given in Table 3.5.

A similar process was used to interpolate the widths of land inundated at the three wetland sections. These are shown in Table 3.6.

Table 3.5: Interpolated median flow depths in the wetland (m)

Option	Baseline Option		Bypass Option	
	2009	2020	2009	2020
R555	1.31	1.39 (+9 cm)	1.18 (-13 cm)	1.20 (-20 cm)
R29	1.38	1.40 (+1 cm)	1.23 (-15 cm)	1.24 (-15 cm)
MBS	0.65	0.68 (+4 cm)	0.60 (-5 cm)	0.61 (-7 cm)

Table 3.6: Interpolated inundation widths in the wetland (m)

Option	Baseline Option		Bypass Option	
	2009	2020	2009	2020
R555	160	188 (+28 m)	119 (-41 m)	124 (-64 m)
R29	1406	1408 (+2 m)	1324 (-82 m)	1341 (-68 m)
MBS	795	799 (+4 m)	781 (-14 m)	790 (-9 m)

Comparing tables 3.5 and 3.4 shows that the percentage change in water depth due to the Bypass Option is only about a third of the percentage change in flow rate. This is attributable to the non-linear relation ship between flow depth and discharge. Comparison of tables 3.6 and 3.4 shows that near the R555 the proportional change in surface width corresponds much more closely to the change in flow rate, whereas deeper into the wetland the change in surface width is an order of magnitude lower than the change in flow rate. This complex relationship is attributable to changes in the valley shape and backwater effects caused by causeways and bridge openings.

For the baseline scenario development growth over the next 11 years is expected to raise water depths by 3% to 6%, i.e. 9 cm near the R555 road crossing and between 1 and 3 cm deeper further downstream into the wetland. During this period the greatest increase (17%) in the associated width of land inundated would occur near the R555. In this area the surface width would increase by about 18 m (or an extra 9 m on either bank of the wetland. Further downstream where the wetland is considerably wider and the water level at the more steeply sloping sides of the wide U-shaped valley, the surface width would only increase by about 2 m to 4 m (1 m to 2 m on each bank).

Since the median flow condition corresponds with low flow conditions, the changes in water surface width represent near perennial inundation. A small drop in water level would occur during exceptionally dry conditions. Flood levels would be little affected since then the point source inflow would be only a small proportion of the total flood discharge, and under such conditions the flow cross-sectional area would be large and the slight change in flow caused by changes in the point source flows would have very little effect on water levels.

Implementation of the Bypass Option would result in larger reductions in the median flow depth of 13 cm (2009) to 20 cm (2020) below the R555 road crossing. It is interesting to observe that near the R29 road crossing the reduction in flow depth would be about 15 cm, compared with only a 1 cm increase for the Baseline Option from 2009 to 2020, even though the change in flow rate is comparable. This is attributable to the fact that for the baseline condition the water level is finely poised above the flat bed of the U-shaped valley, with the result that an increase in flow results in little change in water level, whereas a reduction in flow drops the water level into the flat valley bottom. This effect is not evident further downstream near the Marivale Bird Sanctuary where the water level remains largely above the valley floor even after the Welgedacht effluent is diverted.

The reduction in water levels after bypass of the Welgedacht effluent would reduce the median inundated width by 41 m (1990) to 64 m (2020) below the R555 road crossing, 82 m to 67 m near the R29 crossing and 14 m to 9 m near the Marivale Bird sanctuary.

It should be noted, however, that the four different flow conditions given in Stewart Scott (1998) are for different options, all of which have different effects on the backwater levels. This is particularly so for the upper reaches of the wetland above the point of discharge of Grootvlei Gold Mine. For example, Scenarios 1 and 3 both have identical flows at the top end of the wetland, but Scenario 3 has a lower water level at this same point due to backwater effects. This effectively reduces the usable number of scenarios for each option to just two interpolation points. (Only Scenarios 1 and 2 can be used for the upstream cross sections, i.e. for the wetland near the R555). Moreover, the Grootvlei Gold Mine discharge rate is now significantly lower than the 125 Ml/d used in the backwater analysis. Hence the interpolated values for reaches above Grootvlei Gold mine are extremely coarse.

The interpolation process becomes firmer further downstream of the point of discharge from Grootvlei Gold Mine, since then the changes in flow for all four scenarios occur far upstream and lose the identity of the nuances of each option. Hence all four points can be used in the interpolation process with greater confidence.

It is important to observe that even while the surveys were being carried out for the 1998 backwater analysis, construction work was underway to raise the causeway at the Marivale Bird Sanctuary. This would have altered the present day backwater at this important site. Hence this section at least needs to be re-surveyed.

Since the Blesbokspruit wetland has grown over the years to its present size and accumulated a considerable amount of sediment over that period, it is likely that since 1998 it has continued to trap sediment in the dominant slow moving areas that are often also covered by reed-beds. Conversely, flood events may also have scoured some channel sections. It is therefore possible that some of the cross-sections may have changed over the last 11 years.

4. EFFECT ON SALT CONCENTRATIONS

Earlier 1988 reports and the original computer files provide information on the median flows and total dissolved solids (TDS) concentrations at key points in the wetland for simulation of the then projected 2015 conditions. The corresponding projected effluent point source flows and TDS concentrations are also available. From this information a spreadsheet was set up to calculate the incremental catchment runoffs and washoff loads, and river losses between the five key points in the main river system shown in Figure 3.2 and described in Table 3.3.

The Effluent point source discharges for present day and for projected 2020 conditions were then used in conjunction with the calculated median incremental catchment inflows and river losses to calculate the flows, TDS loads and, finally, TDS concentrations at each of the key points.

The observed effluent point source TDS concentrations for 2008 were assumed to represent present day conditions and were also assumed to remain unchanged until 2020. Effluent flow and water quality data was derived from the following sources:

- ERWAT provided daily flow records for 2008 and electrical conductivity and phosphate data.

- Grootvlei Gold Mine provided monthly data for 2008 for the final discharge from their HDS plant to the Blesbokspruit.

- Sappi provided 2008 daily flows, phosphate and electrical conductivity data for their final discharge to Cowles Dam.

- The DWAF's WMS database was a source of phosphate, electrical conductivity, and dissolved mineral salts (DMS) data for most of the point sources based on compliance sampling carried out by the DWAF. The latter is a good measure of TDS based on summation of the most significant ions comprising the TDS.

The DWAF data was used to calculate the average 2008 TDS and phosphate concentrations for Grootvlei Gold Mine. Since there are more electrical conductivity (EC) analyses than TDS, the TDS/EC ratio for the last thee years was calculated and applied to the 2008 EC data to obtain a firmer estimate of the 2008 average TDS. The last thee years were used to increase the sample size, since there were too few TDS analyses during 2008. The full historical record was not used since the TDS/EC ratio may have shifted over time (although this made little difference because TDS was not analysed for most of the period prior to 2006). Care was taken to identify and eliminate outliers from all of the databases before carrying out this process. The TDS/EC ratios for the ERWAT stations and for Sappi were also calulated from the WMS database.

The TDS/EC ratios were applied to the ERWAT stations and Sappi to calculate the appropriate average TDS concentrations for 2008.

Table 3.7 shows the ensuing coarse calculated TDS concentrations at the five key points in the Blesbokspruit and lower Suikerbosrand River.

Table 3.7: Calculated TDS concentrations for median flow conditions at key points (mg/l)

Option	Baseline Option		Bypass Option	
	2009	2020	2009	2020
R555	669	624 (-7%)	795 (+19%)	776 (+12%)
R29	1247	1128 (-10%)	1519 (+22%)	1481 (+31%)
MBS	1198	1092 (-9%)	1419 (+18%)	1378 (+26%)
B10	1085	999 (-8%)	1085 (0%)	999 (0%)
S2	983	899 (-9%)	983 (0%)	899 (0%)

For the baseline scenario, increasing treated sewage effluent discharges, combined with constant outputs form Grootvlei Gold Mine and Sappi would result in a 7% to 10% reduction in TDS concentrations at all five points by 2020.

Under present day conditions the Bypass Option is expected to increase the TDS concentration at the R555 road crossing by about 19% due to the reduced dilution of upstream industrial sources, declining to 12% by 2020. Bigger increases of between 22% (2009) and 31% (2020) are expected at the R29 road crossing due to the reduction in the dilution of the Grootvlei Gold Mine effluent. Slightly smaller, but still substantial, increases in TDS concentration are expected further downstream at the Marivale Bird sanctuary. No change is anticipated below the wetland at B10 (Heidelberg) and S2 (near Suikerbosrand River confluence with the Vaal River).

It must be cautioned, however, that the coarse method of calculation assumes no change in the catchment runoff quality or in the urban runoff, which will grow as the urban area increases.

The Welgedacht effluent Bypass Option does not alter the salt load or the salt concentration of the flow entering Vaal Barrage from the Suikerbosrand River.

5. EFFECT ON NUTRIENTS

5.1 General considerations

The phosphate dynamics differ markedly from those for TDS since phosphate behaves in a distinctly non-conservative fashion. (Although phosphorous is a conservative constituent, it's presence in the water column exhibits distinctive decay characteristics since it adheres to sediment particles that are removed by deposition and is taken up by organic matter that is also subject to sedimentation. These processes are particularly pronounced in slow moving water bodies, such as lakes and wetlands. Much of the sediment appears to be semi-permanently trapped under successive layers of sediment, especially in lakes and wetlands. Biological processes can slowly re-introduce phosphate into the water column, but these processes are very slow compared with sedimentation and are therefore not noticeable except at quite low concentrations.

Large wetlands such as the Blesbokspruit are likely to keep on trapping phosphate in their flat reed-covered flood plains, where flow velocities seldom rise high enough to mobilise sediments. Here periodic scouring is probably confined to relatively narrow central channels, especially in the vicinity of bridges and culverts. This is born out by the historical records shown in Teurlings (1998), which display marked reductions in phosphate concentration between the R555 road crossing near the start of the wetland and the Marivale Bird Sanctuary, with the median phosphate concentration dropping to less than 0.1 mg/l.

In normal river sections that are in regime (i.e. the river bed is not aggrading with time) there should be a long-term balance between the sediment (and hence phosphate) load deposited and taken up. However, even here there is a re-distribution in time, with a pronounced deposition loss apparent during low flow conditions (i.e for most of the time) and phosphate loss confined mainly to the more extreme flood conditions when significant scouring occurs. However, these events are associated with large flow volumes which tend to dilute the phosphate, except for a brief "first flush" effect that can occur on the early rising limbs of floods. Such effects are seldom detected since they are usually missed by routine sampling programmes based on periodic grab samples. However, they can move significant loads of phosphate down the river system, where it is usually trapped in the sediments of downstream dams.

5.2 Inferred impact of Welgedacht options

The lower Blesbokspruit and lower Suikerbosrand River from the R42 road bridge to the confluence with the Vaal River near weir S2 represents a long river reach that is largely devoid of storage elements such as wetlands or lakes. It can therefore be assumed that this river reach is in regime. Irrigation abstractions would remove part of the phosphate load, but essentially during lower flow periods when the phosphate concentration is low (median below 0.1 mg/l). During flood periods little of the elevated phosphate load will be removed since this represents a very short time and besides this farmers don't need to irrigate during floods. Hence, despite the fact the fact that the median phosphate concentration at S2 is quite low, a significant phosphate load is still contributed to Vaal Barrage.

The Baseline and Welgedacht effluent Bypass Options make an important difference to the phosphate dynamics. In the Baseline Option the treated Welgedacht effluent passes through the entire length of the Blesbokspruit wetland, during which most of the phosphate load is removed from the water column. The wetland Bypass Option results in the entire Welgedacht WCW phosphate load being discharged to the Blesbokspruit downstream of the wetland. While for both options in-steam processes would reduce the phosphate concentrations to quite low levels at S2 near the confluence of the Suikerbosrand River with the Vaal River, the effluent Bypass Option would substantially increase the phosphate load entering Vaal Barrage.

Vaal Barrage in turn is a long shallow reach of the Vaal River backed up by Vaal Barrage, some 53 km further downstream. Although technically a long thin lake, this reach of the Vaal River is subject to periodic scouring and can be considered to be in a state of dynamic equilibrium. The phosphate load entering Vaal Barrage can therefore be considered to remain in play, since it can continue to contribute nutrients to feed local eutrophication problems, as well as promoting eutrophication down the entire length of the Middle Vaal River, until it is trapped in the sediments of Bloemhof Dam.

Consequently the effluent Bypass Option can be expected to increase the phosphate loading on Vaal Barrage, and hence further promote eutrophication in Vaal Barrage and the rest of the Middle Vaal River.

5.3 Effect on phosphate concentrations

Without recourse to modelling in the scoping study only the coarsest of estimates can be made based on the results given in Teurlings *et al* (1998), which in itself relied on a simplified methodology based on a very small dataset. These results were given for projected 2015 flow conditions and included the Baseline and Welgedacht sewage Bypass Options.

The estimated 2015 treated sewage discharges used in Teurlings *et al* (1988) are actually quite close to the current 2020 projections (although the Grootvlei Gold Mine discharge has dropped to less than half that used in the earlier study). Accordingly the coarse assumption has been made that the 2015 results of the 1998 study roughly equate to the conditions arising after the Welgedacht extensions reach capacity in about 2020.

On this basis the 2020 phosphate concentrations would be as given in Table 5.1.

Table 5.1: Rough estimate of 2020 phosphate concentrations (mg/l)

Option	Baseline Option		Bypass Option	
	P50	P90	P50	P95
R555	0.38	0.98	0.26 (-32%)	0.68 (-31%)
MBS	0.09	0.15	0.08 (-11%)	0.13 (-13%)
Below wetland	0.08	0.27	0.25 (+212%)	0.78 (+189%)
S2	0.06	0.10	0.09 (+50%)	0.16 (+60%)

The underlying assumptions are subject to considerable error, but the basic trends are that the wetland Bypass Option would result in a reduction in phosphate concentrations at the top of the wetland, largely as a result of removing the source of phosphate nearest to the R555. (Most of the upstream point sources have intervening lakes where sedimentation of phosphate occurs). However, by the time the Marivale Bird Sanctuary is reached most of the phosphate load has been removed and the wetland Bypass Option results in only a .01 mg/l increase in the median phosphate concentration.

5.4 Effect on phosphate loads

The big change occurs below the wetland, where the Bypass Option would result in a significant 3-fold increase in the median phosphate concentration, with a similar increase in the 90-percentile concentration. In-steam decay processes reduce the increase to about 50% at the downstream end of the Suikerbosrand River, with a quite low median concentration of only 0.09 mg/l.

On face value this would imply a 50% increase in the phosphate load exported to Vaal Barrage. However, as discussed in Section 5.2, most of the Welgedacht WCW phosphate load discharged downstream of the wetland can be expected to reach Vaal Barrage.

Table 5.2 gives an approximation of the median phosphate loads expected below the wetland and near the confluence with the Vaal River for the two options.

Table 5.2: Rough estimate of 2020 phosphate loads

Option	Flow	Baseline Option		Bypass Option		Load increase
	(Ml/d)	(mg/l)	(kg/d)	(mg/l)	(kg/d)	(kg/d)
Below wetland	319	0.08	26	0.25	80	54
S2	288	0.06	23	0.09	26	3

The median concentrations at S2 indicate that the wetland Bypass Option would only increase the phosphate load entering Vaal Barrage by about 3 kg/day. However, if it is assumed that the entire additional load in the river below the wetland will reach Vaal Barrage, then the load increase for the wetland Bypass Option increased 18-fold to 54 kg/day.

The above analysis is based on the sparse data available at the time when the Teurlings (1998) report was compiled, equating this simulation with the current 2020 projection, and the coarse assumption of mixing average flows with median concentrations, which are not identical. Moreover, the fundamental relationships may well have changed over the last 11 years. The results should therefore be viewed only in their proper context as an initial scoping of the problem aimed at identifying the most important issues at stake and giving pointers to what needs to be investigated more rigorously.

The results indicate that while bypass of the treated Welgedacht WCW effluent below the Blesbokspruit wetland would serve to reduce water levels in the wetland, it would mean foregoing the service currently provided by the wetland in polishing the final effluent and reducing the phosphate load. This would have the unwanted effect of increasing the phosphate load entering Vaal Barrage. This could promote eutrophication in this water body and the downstream Middle Vaal River. The significance of the change in the Suikerbosrand River’s contribution has not been investigated.

It is also recognised (Teurlings, 1998) that continued discharge of effluent to the wetland may eventually lead to breakthrough of nutrients. (i.e. the stage may be reached where the effectiveness in removing phosphate may be reduced due to the storage becoming so large that the export begins to tend towards to input. The potential for and consequences of such breakthrough needs to be investigated.

6. CONCLUSIONS

An initial course scoping of the scenarios of continued discharge of the Welgedacht WCW effluent to the head of the Blesbokspruit wetland (Baseline Option) and the alternative of bypassing the wetland (Bypass Option) has been carried out based on the results of the 1998 Environmental Impact Assessment assuming continued discharge by Grootvlei Gold Mine. The main findings are as follows:

6.1 Effect on flow rate

- For the Baseline Option continued development growth would increase the median flow at the R555 by about 23% by 2020 when the extensions reach full capacity. The flow at the Marivale Bird Sanctuary would increase by 17%.

- The Bypass Option would reduce the median flow at the R555 by 43% and at the Marivale Bird Sanctuary by 30%.

6.2 Effect on water levels and inundated width

- The Baseline Option would increase the 2020 median water level near the R555 by about 9 cm and at the Marivale Bird Sanctuary by 4 cm. The corresponding increases in the inundated widths at these two sections would be 28 m (14 m on either bank) and 4 m (2 m on either bank).

- The Bypass Option would reduce the 2020 median water level at the R555 by 20 cm with a corresponding reduction in surface width of 64 m. At the Marivale Bird Sanctuary the reduction in water level would be about 7 cm and the inundated width would reduce by 9 m.

6.3 Effect on salt concentrations

- For the Baseline Option increasing dilution of industrial and mining sources would reduce the 2020 median salinity at the R555 by 7% and by 9% at the Marivale Bird Sanctuary and further downstream near the confluence with the Vaal River.

- The Bypass Option would cause a 12% increase in the median 2020 salinity at the R555, with a 26% increase at the Marivale Bird Sanctuary. There would be no change in salinity downstream of the wetland.

6.4 Effect on phosphate

- The Bypass Option would reduce the median phosphate concentration in the Blesbokspruit near the R555 by about 32%, with an 11% reduction at the Marivale Bird Sanctuary. However, the phosphate concentration below the wetland is expected to more than treble and that near the mouth of the Suikerbosrand River increase by 50%.

- The phosphate load in the Blesbokspruit below the wetland would double, thereby increasing the nutrient load entering Vaal Barrage.

6.5 Other water quality effects

- The two options can also be expected to affect other water quality variables, such as E-coli counts, COD and ammonia levels. These effects have not been considered in the scoping evaluation.

6.6 Effect of other Welgedacht WCW effluent disposal options

- **Inter-basin Transfer Option**: The option of pumping the effluent to another catchment has not been considered. The effect on the Blesbokspruit wetland would be identical to that for the Bypass Option. However, the effect below the Wetland and on the downstream Vaal River would be very different.

- **Reclamation Option**: This option has not been evaluated. In terms of flows, flow depth, water level and most other water quality variables this option would be identical to the Inter-basin Transfer Option. However, the salt feedback effect would elevate TDS concentrations in supply, thereby increasing the cost to consumers. This option would also increase the salinity of the remaining effluent discharges to the Blesbokspruit. Alternatively, even larger costs would be incurred in desalinating the supply water.

6.7 Effect of Grootvlei Gold Mine closure

- The Baseline and Bypass Options are both based on the assumption that Grootvlei Gold mine will continue to discharge to the Blesbokspruit. However, it must be recognised that both the flow rate and the salinity of this source have reduced over the last 11 years. Complete closure would have even more pronounced effects on water levels and salinity.

7. RECOMMENDATIONS

In view of the environmental implications regarding flow rate, water depth, inundated depth, salinity and nutrient concentrations and nutrient load export, it is prudent to carry out a more rigorous evaluation making full use of the data that has been collected over the last 11 years and the modelling tools that were developed during the previous investigation. Changes that have taken place during this period also need to be considered. Other effluent disposal options also need to be evaluated, with and without the influence of continued discharge by Grootvlei Gold Mine.

The following actions are required to quantify the hydrological and water quality impacts.

7.1 Flow and salinity modelling

Use the NACL daily time step hydro-salinity model to simulate flow and TDS concentrations for a wide range of historical meteorological conditions and provide vital information at key points in the Blesbokspruit / Suikerbosrand rivers for present day and projected future time horizons for each of the main options. The NACL model simulates the rainfall-runoff process, salt recharge and washoff from impervious urban and pervious surfaces, surface and subsurface salt storage, wetlands, lakes, river reaches and riparian irrigation (Herold, 1981). Since it is run for a wide range of historical meteorological conditions, it will provide the means of estimating not only median flow conditions, but also the full range of flows from floods to dry conditions at key points in the Blesbokspruit / Suikerbosrand rivers for present day and selected future time horizons. Proper account can also be taken of projected changes in urban areas, irrigation and growth in diffuse source pollution inputs. This model would also provide boundary conditions for the backwater model (see Section 6.2). This model has been well tested and has been set up and calibrated for the Blesbokspruit catchment (Pitman, *et al*, 1999) and has been used in previous studies (Herold, 1995, Teurlings *et al*, 1998 and Herold, 2002). Use can be made of the recent WR2005 study to improve on present day urban and irrigation information as a basis for making future projections.

7.2 Backwater modelling

The HEC-RAS backwater model has already been set up for the Blesbokspruit wetland area and supporting surveys carried out (Teurlings *et al*, 1998). It is anticipated that most of the previous survey will suffice, but additional surveys are likely to be required at locations where waterways have been modified since 1998. At least one causeway is known to have been affected by such changes. The backwater model will be used to determine the effect of the basic Welgedacht extension option and the major ameliorative options on water levels in the Blesbokspruit wetland for present day and future time horizons, taking due account of the expected discharges from Grootvlei Gold Mine.

7.3 Non-conservative pollutant modelling

None of the key non-conservative pollutants (phosphate, ammonia, COD and E-coli) can be assessed using the NACL model. Detailed, but very costly modelling could be adopted to evaluate the impact on these variables. However, a much simpler approach was developed in the previous study (Teurlings *et al*, 1998) using the DECAY model developed by Dr Herold. This same approach is recommended for this study, since the limited spatial extent of the impact of most of these variables does not justify the high cost of much more detailed modelling.

An advantage of the present study is that historical water quality data for the Welgedacht WCW is now available, permitting the use of actual data at Welgedacht instead of having to estimate it from the characteristics of other works and the design features of the new works (as had to be done in the initial study)

7.4 Estimation of impact of phosphate breakthrough

The possibility of phosphate breakthrough from the Blesbokspruit wetland was assessed during the 1998 Welgedacht study by comparing unit loading on the Blesbokspruit wetland with that on the Olifantsvlei (Stewart Scott, 1996). Initially a similar approach will be adopted, since the alternative of investigating the phosphate balance of the Blesbokspruit wetland would require a long-term comprehensive research project, which would yield useful results only long after a decision has to be made regarding the Welgedacht extensions.

7.5 Vaal Barrage impact assessment

Assessment of the impact on Vaal Barrage will stop short of a detailed evaluation since this would require simulation of the entire Vaal River system. This is because the flow regime of the Vaal River is a complex function of the upstream and downstream hydrology and the Vaal River system operating rules. In addition, complex phosphate modelling would be required. This would be a most demanding task and the application of appropriate technology has yet to be demonstrated.

Instead, the intention is to estimate the impact of the different scenarios on phosphate concentrations and phosphate load export from the Suikerbosrand River to the Vaal River. An approach similar to that used in the previous study is envisaged, except that the phosphate load to Vaal Barrage will be compared to that from other major sources.

7.6 Siting of point of discharge

From an engineering perspective the benefit in terms of reduced water level of diverting the effluent to below the Blesbokspruit wetland appears to be outweighed by the large associated cost and the increased phosphate loading on Vaal Barrage. However, the relative impact of the increased phosphate load on the Vaal River has not been assessed. If phosphate breakthrough were to occur in the wetland then this factor would reduce in importance.

It is recognised that the engineering perspective alone will not determine the final decision. Broader environmental and socio-economic factors also need to be taken into consideration.

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APPENDIX B

CORRESPONDENCE WITH DWAF

PROJECT:	**Welgedacht WCW 50 MLD Extension** **ERW2007/11/135**
CLIENT: **ERWAT**	**CONSULTANT:** **SSI Engineers and Environmental Consultants and Palace Consulting Engineers**
Min 002 20081113 DWAF Welgedacht Discharge **DATE:** 13 November 2008 **VENUE:** DWAF, PTA **TIME:** 14:00 – 16:00 PM	

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Marius Keet (MK)	DWAF	**012 392-1306**	**012 392-1359**	**0828073522**	keetm@dwaf.gov.za
CIRCULATION					
All Above					

The purpose of these minutes is to record attendance, discussions and decisions taken at the Meetings on an ongoing basis. These records are deemed to be an integral part of Contract Administration and all parties are required to take action on the decisions reached. These minutes should not be construed as formal notification of any contractual matter.

No.	Description	Action
Welgedacht WCW 50 Ml/d Extension		
1	**Welcome**	
	FG welcomed all to the meeting and thanked DWAF for the opportunity to meet.	
2	**Introduction and apologies**	
	All present at the meeting introduced themselves (See attendance list on cover page). Apologies received from:- Jo-Anne Thomas (Savannah Environmental) Irene Lea (Pamodzi Gold) Marc de Fontaine (Rand Water) Retha Stassen (DWAF) Marius Keet (DWAF)	
3	**Approval of agenda**	
	The format of the agenda was approved and accepted.	
4	**Anticipated effluent flows**	
	FG informed all of the background of the project:- SSI Engineers and Environmental Consultants had been appointed by ERWAT for the design, tender preparation, project management and construction supervision of an additional 50 Ml/d module at the Welgedacht Water Care Works (WCW). AV of SINTEC has been appointed to manage the process design of the plant extensions. A preliminary study by AV indicates that the plant is currently receiving an ADWF of 59 Ml/d (the plant is designed to cater for 35 Ml/d). A projection of the anticipated future flows yields the following figures (a High, Interim and Low flow scenario was considered). Incoming total flow projections by 2018 High – 91 Ml/d Interim – 79 Ml/d Low – 68 Ml/d Incoming total flow projections by 2028 High – 141 Ml/d Interim – 113 Ml/d Low – 89 Ml/d AV stated that planning should be considered for, between the high and interim scenario. The first 50 Ml/d extension should be commissioned as soon as possible followed by a further 50 Ml/d extension in 2021.	

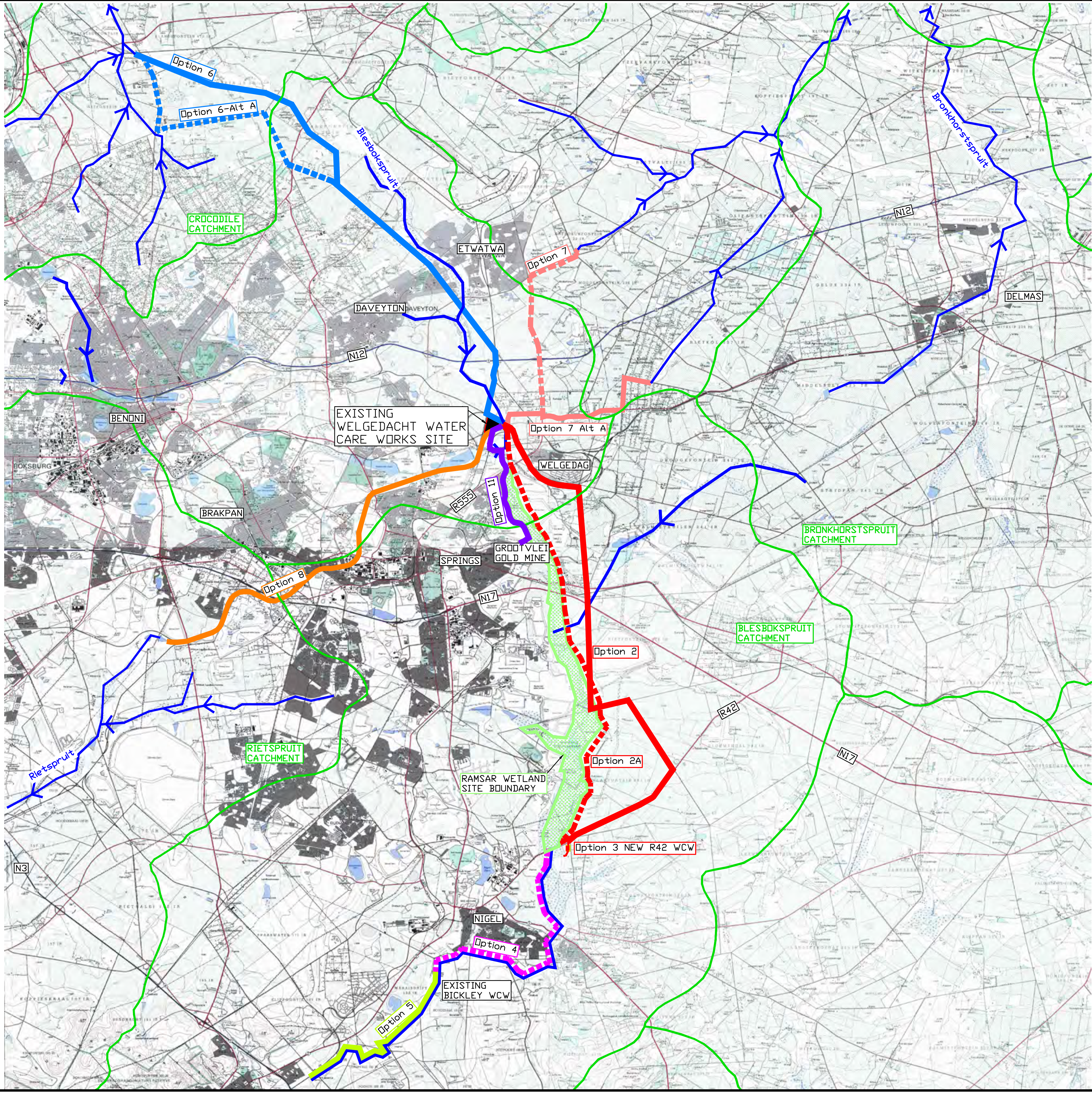
5	**Restrictions on discharge into the Blesbokspruit**	
5.1	**Status Quo**	
	The plant is currently discharging the full 35 Ml/d into the Blesbokspruit. A meeting was held with Mr Marius Keet (DWAF) on the 12th September 2008, regarding the planned extensions to the plant. It was stated at this meeting that no further discharges into the Blesbokspruit would be approved at the plant and that alternative discharge solutions should be considered for the expected increase in effluent volumes.	
5.2	**Mine Pumpage**	
	It is understood that the mines in the area are currently discharging more than the current 35 Ml/d from the Welgedacht plant. The exact figure however is unconfirmed.	
5.3	**Ramsar site impacts**	
	It is understood that there are negative issues regarding silting / loss of land etc. that are associated with increased volumes into the spruit. These are to be investigated as part of a hydraulic study on the spruit. Other issues to be considered include the advantage of additional polishing the spruit provides to the effluent. By bypassing the spruit this advantage is obviously lost.	
6	**Possible alternative discharge arrangements**	
	JVR stated that from a water resource perspective, the effluent to be discharged is very valuable and must be re-used. It is suggested that a first order study be carried out, so as to ascertain how and where this supply could be best utilised as well as the costs associated with the necessary infrastructure required.	
6.1	**Deviation around Ramsar site**	
	The full effect on the additional discharge into the spruit must be investigated and understood. Time delays and environmental issues associated with bypassing the entire spruit with a pipeline must be considered when determining the final solution. It must also be understood who would have to carry the financial costs associated with this infrastructure.	
6.2	**Pumping into the Olifants catchment**	
	Pumping into the Olifants catchment area must be considered. However unless illegal abstractions in the area for irrigation purposes is enforced the area could potentially not experience any benefit from the additional discharge. There may also be some concern regarding discharging effluent into the good / high quality water catchment area.	
6.3	**Pumping into the Crocodile catchment**	
	There is a huge need for additional water in the Crocodile catchment area which needs to cater for additional power plants etc. Transferring into the Crocodile catchment area would require additional phosphate removal in the process design, (tertiary treatment and chemical dosing).	

6.4	**Other**	
6.4.1	**Water re-use**	
	FG stated that water re-use for industrial purposes has been investigated, but it appears that there is not much opportunity in the area for this. JVR questioned whether there were others ERWAT sites discharging into the spruit. AV stated that there are a few, but all contributing comparatively small volumes. All future growth in the area is anticipated to happen and be handled at the Welgedacht plant.	
6.4.2	**Contribution from the mines**	
	KW stated that the flows from the mines must also be considered in the overall design philosophy. Depending on their life spans, should their flow contributions be halted, this would make a significant difference in the volumes being discharged into the spruit. JVR stated that DWAF are currently considering harnessing the water directly at the mines, treating them to potable standards and injecting it directly into the Rand Water supply system. If this is realised it could potentially alleviate problems with volumes into the spruit.	
6.4.3	**Comments forwarded by Irene Lea (Pamodzi Gold)**	
	E-mail received 2008/11/11 *"My most significant concern is the potential increase in the volume of water that seeps to our underground workings with an increase in discharge upstream of our mining area. We have identified a number of areas where river water seeps into the underground workings, which we have to pump out and treat before discharging back to the Blesbokspruit. To complicate matters further, the capacity of infrastructure crossing the Blesbokspruit (roads, railways, power lines, causeways, etc) to allow through flow have not kept up with the volume of water that is currently flowing/discharged to the river. This has resulted in a number of "dams" on the river, which chokes the system and allows further ponding of water over areas where seepage to the underground working occur. You can appreciate that additional water in the system would add to this problem as well."*	
6.4.4	**Comments forwarded by Marc de Fontaine (Rand Water)**	
	E-mail received 2008/11/11 *"My issues of concern relate to:* *(1) the works is currently experiencing high loads and volumes. To say that the increase in 50Ml must not be discharged to the catchment either via a canal or pumping scheme will not happen over night. The EIA process for this will be incredibly timeous, difficult and financially exorbitant.* *(2) erwat is already behind the curve with increased loads and volumes and therefore if the 50Ml option is not done within the catchment, overflows on a regular basis can be expected. Therefore poor quality water will still end up in the Blesbokspruit."*	

7.	**Responsibilities**	
	JVR reiterated that consideration of the effluent discharge options must not be the disposal thereof but rather how and where it can be best utilised and harnessed for future use. ERWAT (through SSI) agreed to carry out a high level investigation, including all technical and financial consequences associated with the various discharge options for the Welgedacht plant . The options to be considered will include:- • Do Nothing Scenario i.e. consider the consequences of continuing to discharge into the Blesbokspruit at the plant. • Bypassing the RAMSAR site and continuing to discharge into the Blesbokspruit downstream. • Discharging (pumping) to the Olifants catchment area • Discharging (pumping) to the Crocodile catchment area • Treating to potable standards at the plant. DWAF will continue to study the feasibility of harnessing and treating the mine water for potable use and injection directly into the Rand Water supply system. JT enquired as to when this decision is likely to be formalised. JVR stated that the concept of water re-use at the mines had already been approved as a strategy at national level however DWAF were in the process of engaging with involving all the interested and affected parties in the strategy.	ERWAT / SSI DWAF
8.	**Way forward**	
	DWAF to continue with investigating the strategy of harnessing mine water at the source for treatment to potable standards. ERWAT (through SSI) to carry out a high level investigation of the alternative discharge options at the plant. The current design for the 50 Ml/d upgrade is to continue. A follow-up meeting was proposed to discuss the findings once complete. The exact date to be confirmed, but envisaged to happen towards the end of February of 2009. ERWAT / SSI to make the necessary arrangements once their study has been completed.	DWAF ERWAT / SSI ERWAT / SSI
9.	**Closure**	
	FG once again thanked all for attending. Meeting adjourned.	
Minutes prepared by (RB)		

APPENDIX C

DRAWINGS



LINE	DESCRIPTION	APPROX. LENGTH
	Water Courses	
	Catchment Boundaries	
	Option 2: Pumping / Gravity Main to R 42	30 Km
	Option 2: Alt Route - A Pressurised Gravity Main	
	Option 4: New WCW at Bickley Plant	41 Km
	Option 5: New WCW at Heidelburg Plant	66 Km
	Option 6 : Pump to Crocodile Catchment	30 Km
	Option 6: Pump to Crocodile Catchment - Alt A	
	Option 7: Pump to Bronkhorstspruit Catchment	11 Km
	Option 7: Pump to Bronkhorstspruit Catchment - Alt A	
	Option 8: Pump to the Rietspruit Catchment	24 Km
	Option 11: GROOTVLEI MINE	9.5 Km

SSI-PCE JOINT VENTURE

SSI A DHV COMPANY

PCE

APPROVED :

CLIENT

ERWAT INNOVATIVE WASTEWATER SOLUTIONS

PROJECT/DRAWING TITLE

WELGEDACHT ALTERNATIVE

DISCHARGE OPTIONS

FIGURE 1

SCALE	SHEET
NTS	
CONTRACT No.	PROJECT No.
DRAWING No.	REV △

APPENDIX D

MINE WATER RECLAMATION PROJECT

MINE WATER RECLAMATION PROJECT

1. INTRODUCTION

Western Utilities Corporation (Pty) Ltd (WUC) is planning a project to collect mine affected water from underground mine voids, treat the water and distribute the treated water to third parties on commercial terms. The proposed project will consist of:

- The collection (pumping) of water from the Western, Central and Eastern basins of the Witwatersrand area via existing mine shafts, and existing and new water pipelines to a centralised water treatment plant (WTP).
- The construction and operation of the WTP where mine water will be treated to potable standards.
- The conveyance of potable water from the WTP to a bulk storage facility such as the existing Rand Water reservoir at Klipriviersberg.
- The disposal of waste generated during the mine water reclamation process at an existing mine waste disposal facility, or through refinement of waste streams to yield commercial products.

2. BACKGROUND AND MOTIVATION FOR THE PROPOSED PROJECT

Over the past 120 years, mining activities in Gauteng have significantly impacted on the environment, particularly on water resources. Pumping systems have been employed by the mines since the beginning of the 20^{th} century to remove water from underground workings via mine shafts. Although this method has been successful in removing water to enable the safe continuation of mining, many unintended negative environmental consequences have resulted:

- Dolomite formations in the area have been disrupted and the water that naturally filtered through them has begun to subside. This has resulted in the creation of sinkholes.
- The quality of water that drains through the dolomitic rock into the voids left by mining operations has deteriorated through contact with the products of geochemical weathering on exposed rock surfaces. This mine affected water is saline, sometimes acidic (acid mine drainage or AMD), and is often not suitable for drinking and other domestic uses.
- The underground mine voids contain large volumes of mine affected water which threatens to pollute shallow groundwater and surface water resources.

This poses a real environmental threat to the downstream users if mine water level control and decant is not effectively addressed. The problem is perhaps most severe in the Western Basin where the decanting AMD threatens to pollute and severely impact on the Sterkfontein Caves, Krugersdorp Nature Reserve and Cradle of Humankind.

This problem is not unique to any mining house but rather reflects the legacy of mining within the Witwatersrand. To tackle this problem, various mining houses in the Witwatersrand area have formed non-profit Section 21 Companies. Each Basin, represented by a S21 Company, has/will enter into a management agreement with WUC to develop and implement a strategy to collectively tackle this challenge on their behalf.

WUC proposes to provide a commercially viable and sustainable solution to address the contaminated mine water problem within the Western, Central and Eastern basins. This will be done in collaboration with mining companies, government departments and environmental groupings.

3. MINE WATER SOURCES AND COLLECTION

Mine water will be sourced from the Western, Central and Eastern Basins of the Witwatersrand mining area (see **Figure 1** below for the location and areas covered by the three basins). The collection in the 3 basins is as follows:

Western Basin: In the Western Basin, Harmony Gold currently pumps mine water to surface at Randfontein Estates Mines as part of ongoing dewatering operations. As part of the proposed project, this mine water may be transferred into West Wits Shaft No. 4 in the Central Basin. A new collection pipeline located within existing mine, railway, power, and/or water servitudes, where possible, will be used to connect the Western and Central Basins.

Central Basin: Until recently, East Rand Proprietary Mines (ERPM) pumped mine water to surface and conveyed the mine water via a pipeline system to a High Density Sludge Plant for pre-treatment and re-use/discharge into the environment. Currently, the mines wish to re-establish the dewatering operations to enable the safe continuation of mining and to prevent AMD from reaching the Critical Environmental Level. The mines are investigating the installation of a pumpstation. WUC proposes to collect this water from the preferred shaft and transport it to a new centralised WTP via a new collection pipeline, which will be placed within existing mine, railway, power and/or water servitudes, where possible.

Eastern Basin: Currently, Grootvlei Proprietary Mines is pumping mine water to surface via their Shaft No. 3 and pre-treating the mine water for re-use/discharge. As part of the proposed project, WUC plans to collect this pre-treated water and transport it to the proposed WTP site via a collection pipeline placed within existing servitudes where possible. Some of this water will be piped off and supplied to ERGO to be used mainly for re-treating the gold tailings in the area.

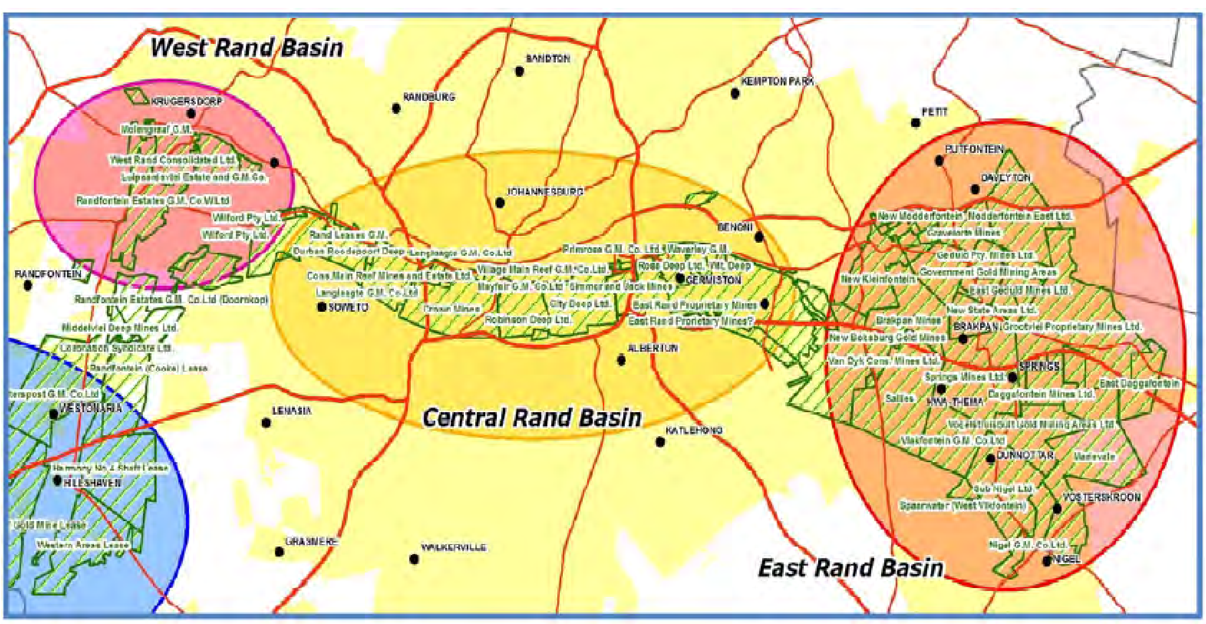


Figure 1: A graphical illustration of the three basins from which water will be abstracted as part of the Mine Water Reclamation Project

4. MINE WATER TREATMENT PLANT

4.1 Location of the mine WTP

The proposed Mine Water Reclamation Project will be developed in two phases. The first phase will comprise the collection of mine water from the Western, Central and Eastern Basins and the treatment/reclamation thereof at a centralised WTP able to process approximately 75 Mℓ per day capacity which may increase to 200 Mℓ per day, potentially in a different location.

The WTP should be sited at a central location with the most preferred position adjacent to the defunct South West Vertical Shaft section of ERPM, an historical extraction point of contaminated mine water in the Central Basin.

4.2 Mine water treatment technology to be used

Based on a pilot plant campaign, WUC has selected the CSIR's Alkaline Barium Calcium (ABC) process as the most suitable technology for this application (see **Figure 2** below).

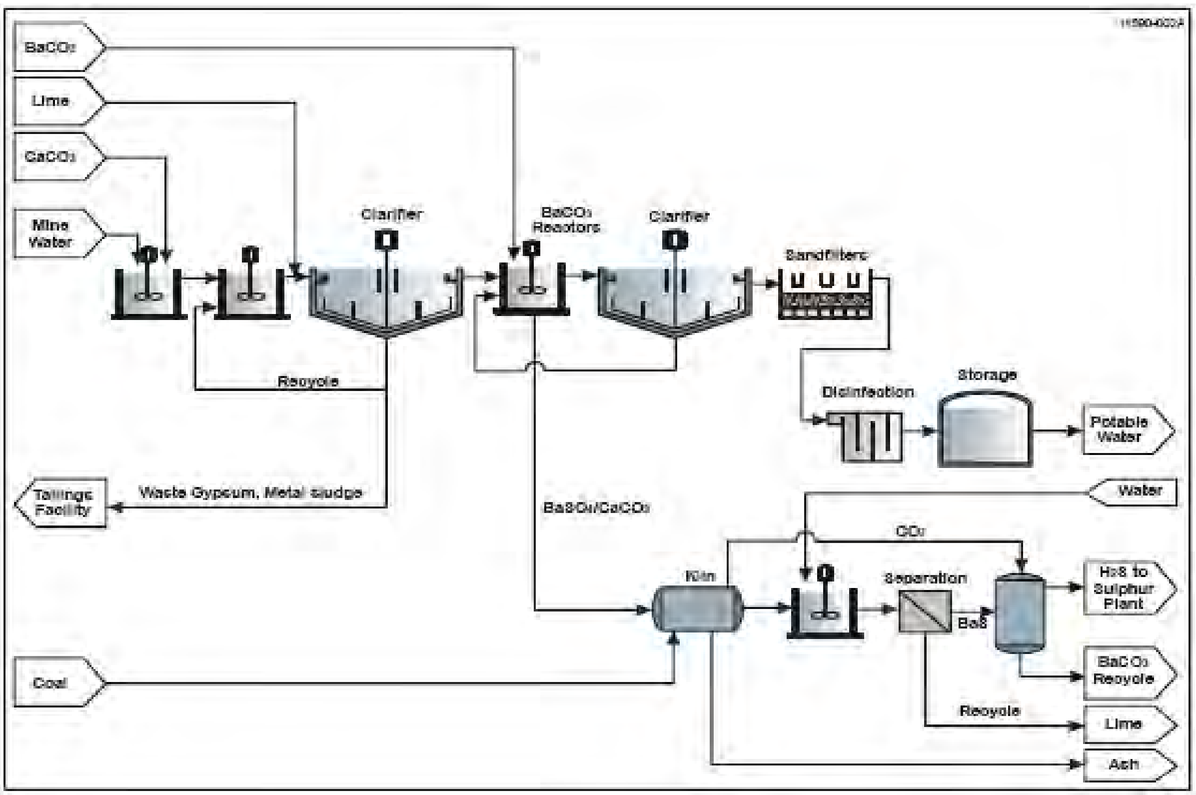


Figure 2: The mine water treatment process

In summary, the ABC water treatment process consists of the following:

- The acidity of the mine water is neutralised and heavy metals are removed by adding lime, which causes the metals to precipitate as pH is raised. The metal containing precipitate is removed in a clarifier.
- Sulphate is removed by contacting with barium carbonate, which results in insoluble barium sulphate and calcium carbonate being formed.
- The water is then clarified, filtered, disinfected and tested for final compliance to the applicable potable water standards before distribution.

- Barium carbonate, calcium carbonate, calcium oxide (lime) and elemental sulphur will be recovered for re-use or for sale as commercial by-products of the process.

The existing Central Basin water treatment works waste was disposed of at an existing tailings storage facility. This practice will continue. The waste generated at Grootvlei's operations is currently being deposited onto the existing Grootvlei tailings storage facility. This practice will continue.

5. TREATED WATER DISTRIBUTION AND END USER

5.1 Pipeline route selection

The potable water that is produced by the new water treatment plant may be distributed to the Klipriviersberg Reservoir via a new 20 km distribution pipeline. The end user of the water will be Rand Water and/or other bulk water service providers.

The alternative routes for pipelines will be assessed and documented in a route selection report. Initial technical work involving pipeline engineering teams is underway in order to identify areas through which this infrastructure could be routed. See **Figure 2** for an indication of alternative and preferred pipeline routes/corridors (preferred collection pipeline routes/corridors are indicated as green, the distribution pipeline route/corridor as blue, the preferred sludge pipeline route/corridor is indicated as red, and alternative routes/corridors are indicated as yellow).

5.2 Collection pipeline routes

For the Western Basin to Central Basin pipeline route, four alternative routes were identified (refer to **Figure 3**). The preferred route was chosen because it is mainly located within an existing mine pipeline servitude.

Eastern to Central Basin Collection Pipeline

Section from Grootvlei Shaft No 3 to ERGO Plant
Two alternative routes have been identified – a Northern and a Southern Route. It appears as though the Northern Route may be the preferred route. This is because informal settlements have developed across the existing mine pipeline servitude in two areas of the Southern Route. It would not be possible to construct and operate a pipeline in these areas without resettlement of people and disruption to these informal settlements. The Northern Route is also preferred as it follows existing servitudes registered in the name of the mines, Eskom, Transnet and others, and is not impacted by informal settlements.

Section from ERGO Plant to centralised WRP
Two alternative routes were identified for this section of the collection pipeline:

- Van Dyk Park Route.
- Windmill Park Route.

The Windmill Park Route appears to be the preferred route as it follows existing Eskom and mine servitudes.

Central Basin Collection Pipeline

Mine affected water will either be pumped from ERPM's Cason Shaft, Central Shaft or South West Vertical Shaft, to the centralised WTP. Once a preferred shaft has been selected, alternative pipeline routes will be investigated. As far as is possible, the pipeline route will follow existing mine pipeline servitudes.

Distribution Pipeline Routes

Since it is anticipated that the centralised WTP will be located within the vicinity of the existing ERPM water treatment works and that existing infrastructure will be used and upgraded, it is assumed that the pipeline to the Klipriviersberg Reservoir will be routed from that site. Five alternative routes have been identified. The preferred route is located in less densely populated areas, has sufficient space for the placing of the pipeline and is located mainly within existing servitudes registered in the name of the mines, Eskom, Transnet and others. The preferred route proposed runs for about 20 km south west to Klipriviersberg. Should an alternative end user be selected, the treated water will be distributed to an alternative bulk storage reservoir, and alternative distribution pipeline routes will be investigated.

Sludge Pipeline Route

A sludge pipeline will be routed from the centralised WTP to ERGO's existing Withok Tailings Storage Facility, along an existing mine pipeline servitude.

Figure 3: Preferred and alternative collection, distribution and sludge pipeline routes for the Mine Water Reclamation Project

Source: Environmental Impact Assessment for Western Utilities Corporation Mine Water Reclamation Project; Background information for public comment