

Appendix 2: Lephale artificial recharge options

I. INTRODUCTION

The water requirements in the Lephale area will increase significantly with the planned new coal-fired power stations, and artificial recharge has been considered as one of the options in augmenting the water supply to the area (**Figure A2.1**). Unlike the case studies that follow this one where conceptual ideas for artificially recharging specific aquifers are described, this example presents a list of options that can be considered in the early planning stages.

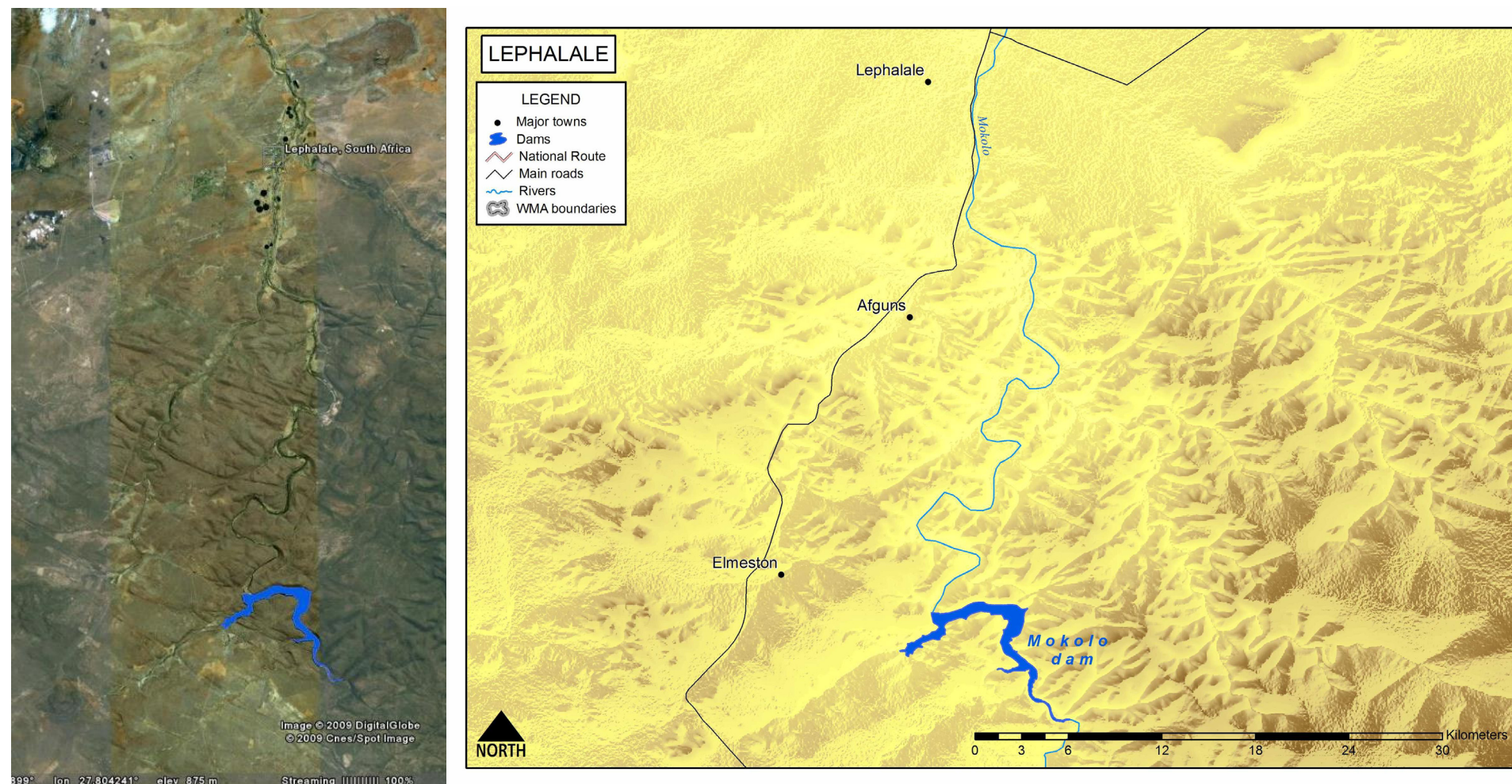


Figure A2.1 Google Earth and hill-shade images of the Lephale area showing the Mokolo Dam upstream of the town

2. ARTIFICIAL RECHARGE OPTIONS

The groundwater and artificial recharge water supply/ augmentation options are listed below:

1. Maximise deep/ hard-rock aquifer
2. Maximise shallow/ alluvial aquifer
3. Artificially recharge the shallow aquifer with stormwater
4. Artificially recharge the shallow aquifer with treated waste water
5. Artificially recharge the shallow aquifer with untreated dam water
6. Artificially recharge the deep aquifer with treated dam water
7. Artificially recharge the deep aquifer with stormwater
8. Artificially recharge the deep aquifer with water from the shallow aquifer by creating easy flow paths between the two using “linking” boreholes

2.1. Maximise deep/ hard-rock aquifer

Aim: Maximise groundwater abstraction from the hard-rock aquifer

Tasks:

1. Identify, drill and test pump the remaining geological structures within an acceptable economic radius of:
 - a. The town
 - b. The pipeline from the dam that supplies the town (if this option is considered, first establish if it is possible to feed into the existing pipeline – ie establish engineering requirements)
2. Delineate the groundwater units/ wellfields and quantify them under conditions of simultaneous usage (ie take interference into account). This probably requires pumping from the wellfields for a considerable period and monitoring adjacent areas. The aim would be to establish their sustainable yields based on simultaneous pumping.
3. Establish their “mining” yield. If the deep aquifers are needed to bridge a period of supply until surface water becomes available, then the aim would be to establish how long the deep aquifer can supply the required rate on a continuous basis before the storage has been drained.
4. Linked to point 2 above: Establish whether water is induced from the alluvium if nearby deep, hard-rock boreholes are pumped heavily. Do this by large-scale abstraction from the deep boreholes and assess the drawdown curves and monitor isotopes and water quality. A nearby shallow borehole would also be best for monitoring purposes.

2.2. Maximise shallow/ alluvial aquifer

Aim: Maximise groundwater abstraction from the alluvium

Tasks:

1. Establish the volume in storage by delineating the alluvial aquifer, establishing thickness, water levels and S-values:
 - a. consult the WSM report

- b. drill a few shallow boreholes to test the thickness of the alluvium, to verify WSM results (assuming they have thicknesses) & to get S-values (ie drill nearby monitoring boreholes)
 - c. possibly do geophysics to determine thickness in selected areas
2. Establish borehole yields in the alluvium – ie test pump a few shallow holes (& monitor both pumped and nearby observation boreholes)
3. Establish throughflow (either using Darcy or a simple numeric model)
4. Determine whether a collector well system (horizontal “well/s” across the river bed) or numerous shallow boreholes parallel to the river are most cost and water supply efficient.

2.3. Artificially recharge the shallow aquifer with stormwater

Aim: Recharge the alluvium with stormwater that is collected in the stormwater dam

Key assumption: The alluvium is sufficiently transmissive to yield significant quantities of water (ie establish the borehole/collector well yield from the alluvium first)

Tasks:

1. Quantify the stormwater. Obtain an estimate of the volume of water available for recharge and only consider this option if the volume is significant. Establish whether storm runoff is already allocated or used by others.
2. Assess the quality of the stormwater if the abstraction boreholes are close to the stormwater discharge point. If so, this water will have to settle in the dam before being used for recharge. Key factors are turbidity, oils, heavy metals, etc – the determinands that are found in urban storm runoff. Note that the first storm runoff for the season should go to waste (discharged elsewhere if possible) – to flush all the remnants from the dry season.
3. Enhance canal infiltration by ripping the base and sidewalls of the canal where it crosses the alluvium.
4. Enhance infiltration in the second stormwater dam (the dam shortly before the discharge point) by ripping the base and sidewalls of the dam – ie convert to recharge basin
5. Drill a few shallow monitoring boreholes to establish effectiveness of these interventions
6. Check the discharge point – eg ensure the stormwater is not being taken by farmers.
7. Determine whether a collector well system or numerous shallow abstraction boreholes parallel to the river should be drilled below the stormwater discharge point.
8. Drill a few shallow monitoring boreholes.

2.4. Artificially recharge the shallow aquifer with treated waste water

Aim: Recharge the alluvium with treated waste water

Key assumption: The alluvium is sufficiently transmissive to yield significant quantities of water (ie establish the borehole/collector well yield from the alluvium first)

Tasks:

1. Quantify the waste water. Obtain an estimate of the volume of water available for recharge. Establish what portion is already allocated.
2. Assess the quality of the waste water.
3. Establish where waste water is discharged into the river

4. Establish all sites where (deep) alluvial boreholes could be drilled adjacent to the river (consider land ownership, access, etc).
5. Alternatively, establish a site for a collector well.

2.5. Artificially recharge the shallow aquifer with untreated dam water

Aim: Recharge the alluvium with surplus untreated dam water:

- a. At a point close to town (ie where a take-off point can be installed in the existing pipeline that is not far from town)
- b. From normal dam releases

Key assumption: The dam managers are willing to release surplus water in a manner that will enhance recharge (this will require selling the concept to them).

Tasks:

1. Establish current dam release practices (when and for how long)
2. Quantify releases - ie water available for recharge, and establish existing allocated water (ie compulsory releases)
3. Establish pipeline capacity to see whether surplus water can be transferred close to town for recharge; quantify this water source
4. Identify preferred discharge point
5. Cost pipeline diversion
6. If this is not an option, establish if dam managers would be amenable to large-scale releases in pulses rather than a continuous "trickle". The aim would be to try and get a pulse of dam water to recharge the alluvium close to town (ie close to where you'd place your wellfield).
7. Study the DWA "pulse" report
8. Compare the water savings if water is left in the dam (evaporation losses) and trickle releases (evapotranspiration losses and abstraction from upstream farmers) to if it is transferred to the alluvium (evapotranspiration losses and abstraction from all farmers)

2.6. Artificially recharge the deep aquifer with treated dam water

Aim: Borehole injection (ASR) with municipal drinking water

Tasks:

1. Establish if there is ever surplus water available and surplus capacity in the water treatment works (WTW)
2. Assess water compatibility (municipal water and deep groundwater)
3. Conduct injection tests

2.7. Artificially recharge the deep aquifer with stormwater

Aim: ASR using storm water

Tasks:

1. Establish quantity and quality of stormwater (see Option 3 points 1 & 2)
2. Determine stormwater treatment requirements
3. Assess water compatibility (stormwater and deep groundwater)
4. Conduct injection tests

2.8. Artificially recharge deep aquifer with shallow aquifer by creating easy flow paths between the two with "linking" boreholes

Aim: Create conduits for alluvial aquifer to recharge hard-rock aquifer.

Note:

1. This is only an option if water in the alluvium is not drawn into the deep aquifer by large-scale abstraction from deep boreholes (see Option 1, point 4). If so, it is not necessary.
2. Under current (ie natural conditions), deep water will probably flow into the alluvium. For this to work, the water level in the deep aquifer must be continuously pumped.
3. Consider long-term environmental implications of this option as this will cause a permanent connection between the shallow and deep aquifer. I do not recommend this option for this reason.

Tasks:

1. Drill a deep borehole on a hard-rock structure where the alluvium is thick and perforate the casing opposite both the alluvium and the deep aquifer.
2. Assess whether the shallow aquifer will feed the deep aquifer:
 - a. Analyse chemistry and isotopes of shallow water (prior to puncturing the deep aquifer)
 - b. Analyse chemistry and isotopes of deep aquifer from another, nearby deep borehole that only intercepts the deep aquifer.
 - c. Test pump the nearby deep borehole and monitor chemistry and isotopes
 - d. Assess drawdown curve for leakage (in the test pumping of the nearby deep borehole)
3. Test pump the "linking" borehole and establish yield.
4. Repeat in other areas where structures cross the alluvium.

3. RECOMMENDATIONS

The recommended process to determine which options to pursue is as follows:

1. Establish which of the above options are realistic.
2. If any of the artificial recharge options are considered to be realistic, initiate an artificial recharge pre-feasibility study as described in the Artificial Recharge Strategy (DWAF, 2007).

REFERENCE

VSA Report (Undated). Hydrogeology assessment and aquifer recharge potential at Lephalale Local Municipality (Ver I.I, undated).

Appendix 3: The Cedarville flats: Potential for large-scale sub-surface storage

I. INTRODUCTION

The Cedarville Flats is a 36 000 ha expanse of flat land near Matatiele in the Eastern Cape Province (**Figure A3.1**). It consists of a deep alluvial basin with the Mzimvubu River running through it (see Figure A2-1). Boreholes with depths of up to about 100 m penetrate the alluvium and draw water from gravel layers near the base of the clays and sands that have filled the basin. Their yields are commonly between 10 - 20 l/s. The water is used for irrigation by a number of commercial farmers. Unfortunately there is no monitoring taking place, so the effect of abstraction on the water table is not known except that farmers say heavy abstraction affects boreholes' yields.

There are two key factors about this area that make it a significant potential artificial recharge area:

1. The only major undeveloped river in South Africa, the Mzimvubu, runs through this area. It could supply huge volumes of water for recharge.
2. Although the storage capacity of the aquifer is not known, it must be very large. Crude calculations of its storage capacity put it at about 400 Mm³ (assuming a conservative thickness of 10 m, a storage coefficient of 10% and an area of 36 000 Ha).

The summer rainfall, although variable, is reliable, and thus the source water for recharge is dependable. The aim of artificial recharge would be to substantially increase groundwater usage. The subsurface storage would be used as a reservoir that could be "mined" to some extent on an annual basis with the knowledge that it can be rapidly replenished every summer.

2. THE ARTIFICIAL RECHARGE POTENTIAL

The increase in the assured yield of the aquifer cannot be given at this stage, since current usage is not known. However, the storage volume of the aquifer must be substantial (rough estimates puts it in the order of 700 Mm³) and thus the potential to utilise this storage in a conjunctive way with surplus surface water from the Mzimvubu River make this a very attractive proposition.

3. THE CONCEPTUAL SCHEME

The most favourable option would be to divert river water into specially designed recharge trenches that run along the up-slope side of the basin where the soil type is suitable and where there is good hydraulic connection to the main basin. This should not require any treatment prior to infiltration, although settling of particulate matter in basins may be needed. If this is not an option, and if the water is of suitable quality, borehole injection up-gradient and in the centre of the basin could be considered.

Without knowing how the natural recharge system works, and how the aquifer responds to abstraction and natural recharge, it is difficult to provide a plan of how the recharge-abstraction cycle would go. In principle, the idea would be to "feed" the aquifer for far longer periods and at far greater rates than natural recharge, thereby creating the opportunity to abstract at higher rates and for longer periods of the year.

4. KEY ISSUES THAT AFFECT THE VIABILITY OF THE SCHEME

The pre-feasibility study would need to focus on the following key issues:

1. Understanding the existing operation of the aquifer. This would entail establishing current usage, borehole water level responses to abstraction and natural recharge.
2. Getting a reasonable estimate of the aquifer's storage capacity and the potential gains in aquifer yield if artificial recharge were to be practiced on a large scale.
3. Establishing if the institutional aspects could be reasonably sorted out. Since numerous farmers have access to the existing groundwater, a system that benefits those who practice artificial recharge would need to be put in place.
4. Establishing whether the increased yield of the system makes economic sense.

5. RECOMMENDATIONS

This is one of the few areas in South Africa where there is both a substantial and dependable water source for artificial recharge and a sizeable aquifer that could receive and store the water. The steps required to get an indication of the viability of the scheme are:

1. Conduct a detailed hydrocensus to locate boreholes; establish borehole, yields, depths, geology and water strikes; establish water levels and water quality; and get an estimate of groundwater abstraction.
2. Implement a monitoring system to establish a time-series of borehole water levels and if possible, abstraction volumes.
3. Implement a monitoring system to develop an understanding of natural recharge.
4. Establish flows in the Mzimvubu.
5. Identify areas of potential artificial recharge.
6. Provide a first order assessment of the economics of implementing large-scale artificial recharge.
7. Liaise with stakeholders to establish the institutional issues that would affect the implementation of such a scheme.

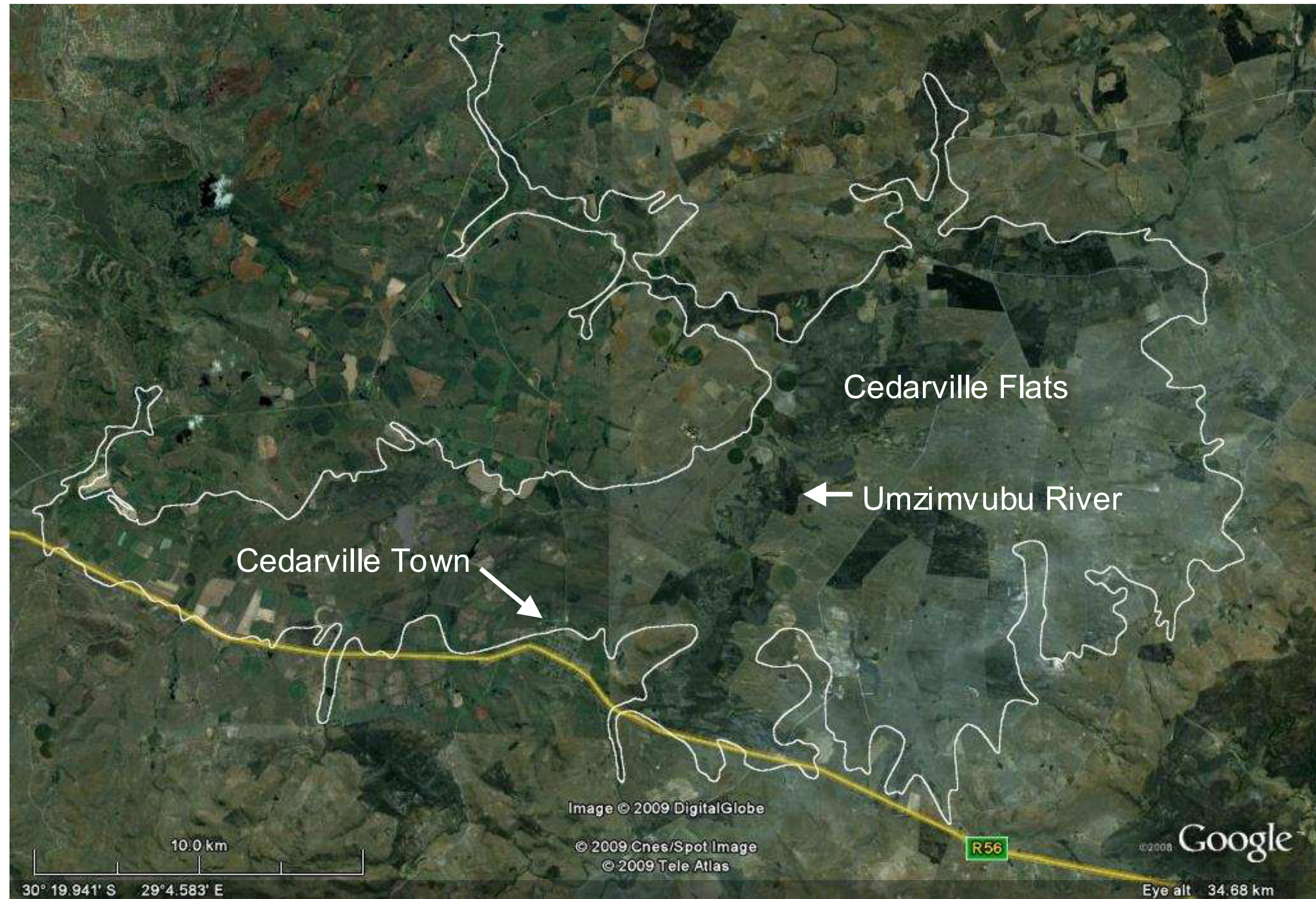


Figure A3.1 The Cedarville Flats showing the outline of the alluvium

Appendix 4: The Klein Karoo: A plan to raise heavily depressed water levels

I. INTRODUCTION

The wellfields under consideration are in the Vermaaks River catchment in the Eastern Section of the Klein Karoo Rural Water Supply Scheme (KKRWSS) They serve the town of Dysseisdorp. Artificial recharge is proposed in two wellfields, namely the Vermaaks and the Voorsorg wellfields (**Figure A4.1**). Both aquifer transmissivities and borehole yields are high, and this allows for abstraction to be in excess of natural recharge. Over the years estimates of sustainable borehole yields have come down as a result of this, and the most recent estimates are (Woodford, 2008):

Vermaaks Wellfield:	505 000 m ³ /a
Voorsorg Wellfield:	79 000 m ³ /a
Total:	584 000 m ³ /a

The intention of artificial recharge would be twofold:

- i) To raise the water table in the Vermaaks Wellfield. The water levels in the upper Vermaaks Aquifer have dropped by tens of meters over the years and raising them would be of great environmental benefit to the area.
- ii) If possible, and only if the first objective can be achieved as well, would be to increase the aquifer's yield.

Artificial recharge would have the aim of meeting these objectives by injecting flood runoff into as many boreholes as possible. A rough target injection rate would be in the order of 100 000 m³ per annum.

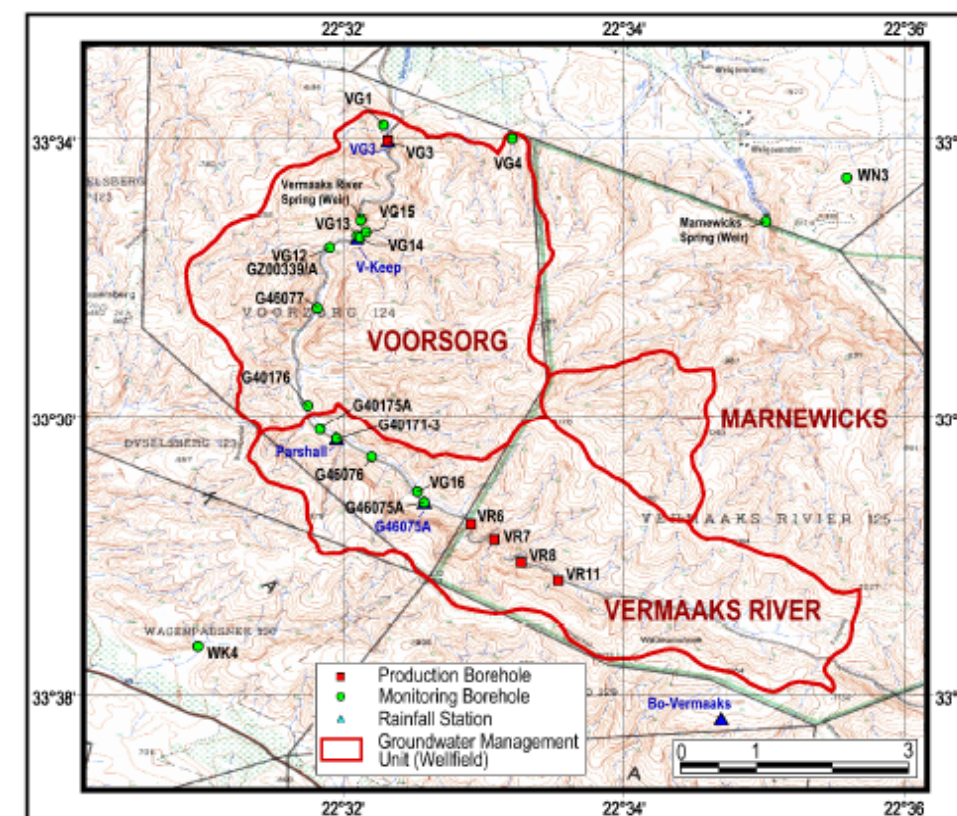


Figure A4.1 Borehole locations in the Vermaaks River Catchment (from Woodford, 2008)

Two options have been considered to augment the groundwater supplies using artificial recharge:

- Recharge the Peninsula Formation in the Vermaaks Wellfield
- Recharge the Nardouw Formation in the Voorsorg Wellfield.

Option I: Recharge the Peninsula Formation (Vermaaks Wellfield)

The Peninsula Formation Aquifer consists fractured sandstones of the Table Mountain Group. Water levels in boreholes in the Vermaaks Wellfield have declined since abstraction began in early 1990s. An example is borehole VR6 where the water levels have dropped by about 30 m (blue line in **Figure A4.2**).

Figure A4.1/...

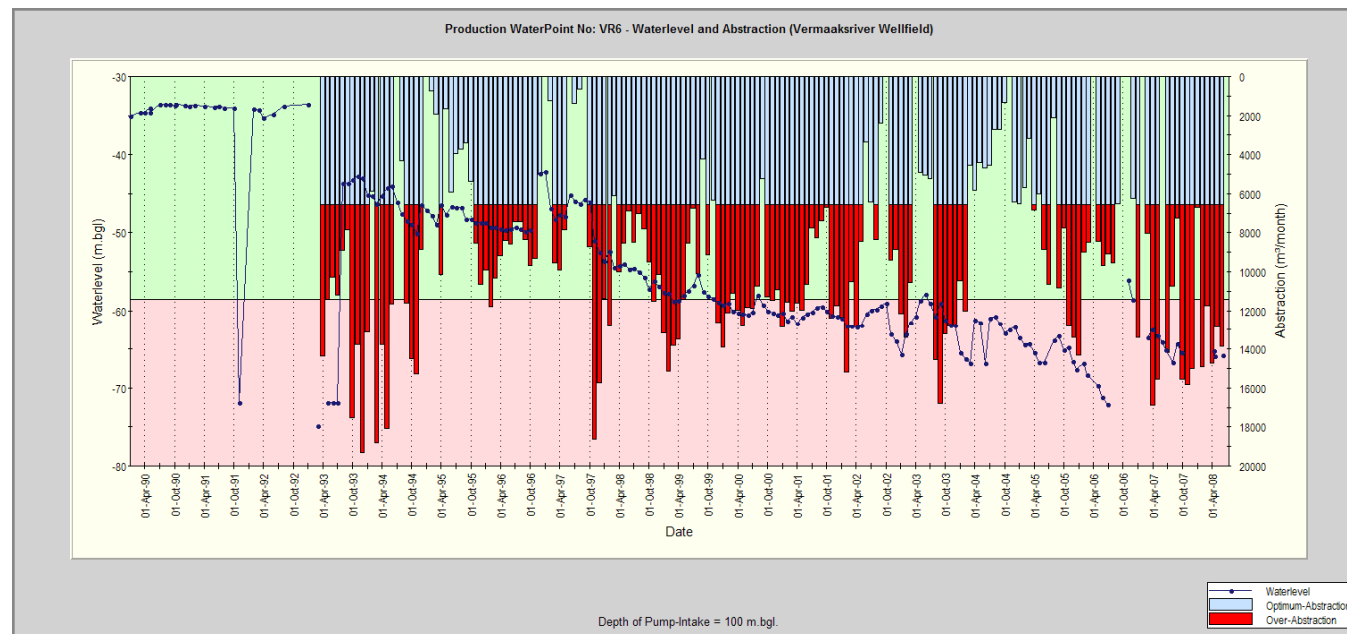


Figure A4.2 Water levels in borehole VR6, Vermaaks Wellfield (from Woodford, 2008)

The artificial recharge plan would entail diverting runoff into one or more of the boreholes in the Vermaaks Wellfield. If necessary the water would be fed through a sand filter prior to injection. The injection rates would be at each borehole's maximum capacity as the injection period would usually be short due to the rapid runoff from the steep catchment. Table A4.1 gives an estimate of the artificial recharge potential. This is based on pumping test data, and in particular, the step-test data.

Table A4.1 Estimated Artificial recharge potential in the Vermaaks Wellfield

Borehole number	Injection rate (l/s)	Injection rate (m ³ /day)	Injection volume over 7 days (m ³)
VR 6	15	1 300	6 050
VR 7	35	3 000	15 120
VR 8	15	1 300	6 050
VR 11	10	860	6 050
Total	75	~6 500	~45 000

Option 2: Recharge the Nardouw Aquifer (Voorsorg Wellfield)

Like in the Vermaaks Wellfield, the Voorsorg Wellfield also consists of fractured TMG sandstones, but the plan in this area would be to increase abstraction from the Voorsorg Wellfield to create space for increased natural and artificial recharge. Often there is not space in the aquifer to store surplus water which is why this aquifer would need to be pumped more than the currently recommended rate. Borehole VG3, located in the Voorsorg Wellfield (Figure A4.3) shows that the water levels lie between 10 - 20 mbgl with recommended abstraction (~7000 m³/month/ blue bar

graph), but drop down to as much as ~40 mbgl with abstraction greater than this (red bar graph). The intention would be to keep the water levels down so that when water is available for recharge, there is space in the aquifer to receive it.

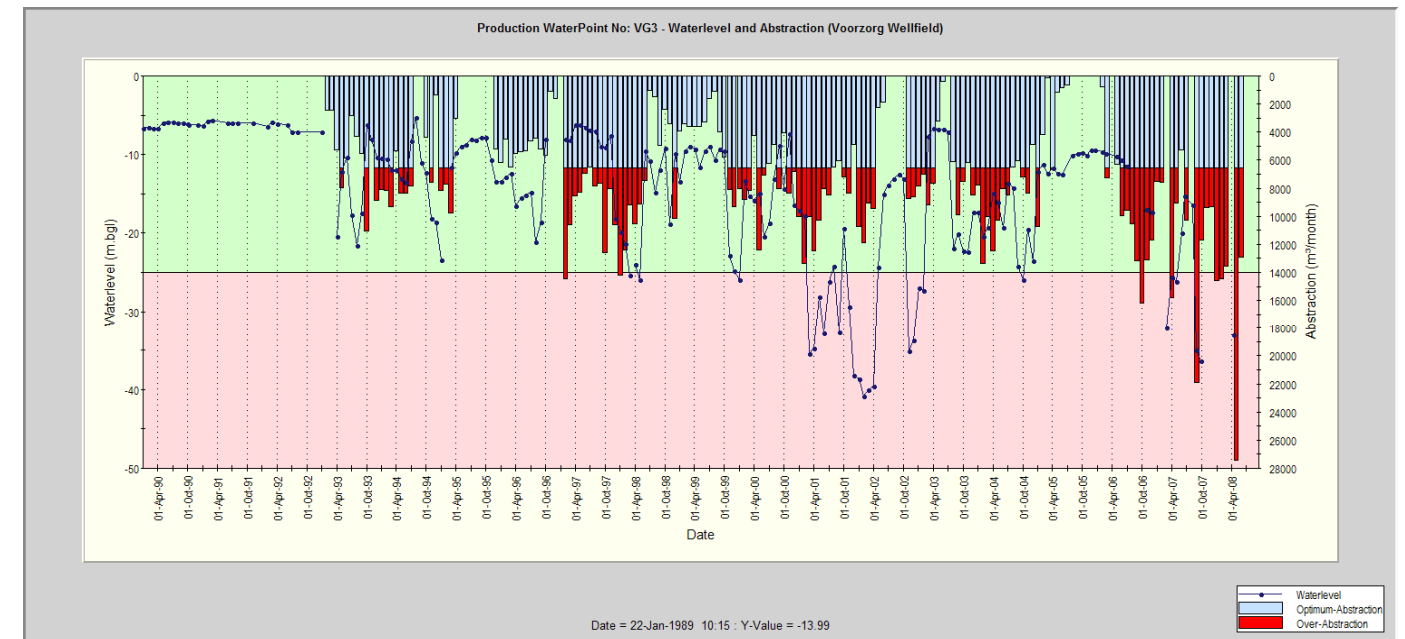


Figure A4.3 Water levels in borehole VG 3, Voorsorg Wellfield (from Woodford, 2008)

At present there are only two abstraction borehole in the lower aquifer (VG3 and GZ00339 which was put into production in 2008), however, if other existing boreholes or additional new boreholes in this area were drilled and utilised, it would potentially increase the yield of the aquifer significantly. The estimated injection rates, assuming four boreholes, are given in Table A4.2.

Table A4.2 Estimated Artificial recharge potential in the lower aquifer

Borehole number	Injection rate (l/s)	Injection rate (m ³ /day)	Injection volume over 7 days (m ³)
VG 3	10	860	6 050
Existing/new 1	10	860	6 050
Existing/new 2	10	860	6 050
Existing/new 3	10	860	6 050
Total	40	~3 400	~ 24 000

2. AVAILABILITY OF WATER FOR RECHARGE

A key question is: Is there enough water to recharge the aquifers? From **Figure A4.4** it appears as if there is usually not enough water, but every now and then, and since daily flow reading commenced in 2004, there have been three occasions where there has been enough water to artificially recharge the aquifers - twice the stream flowed at more than 50 l/s and once about 25 l/s (**Figure A4.5**). The 2006 high flow event resulted in elevated flows for a 6 week period peaking at a flow of 200 l/s while the 2007 event lasted 2 months and peaked at 600 l/s. If rainfall events are changing to be more erratic and more intense as is commonly thought with climate change, then opportunistic artificial recharge may be a good solution to what might be becoming less reliable natural recharge.

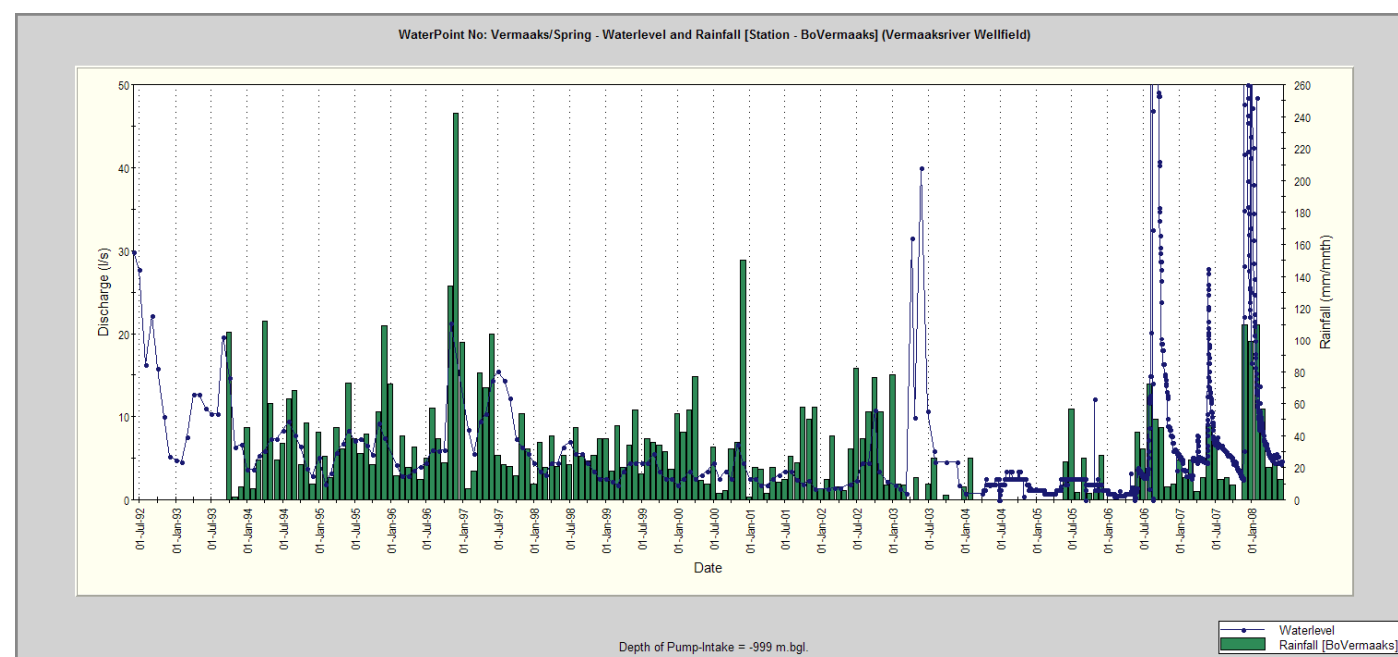


Figure A4.4 Rainfall and stream flow in the Vermaaks River (from Woodford, 2008)

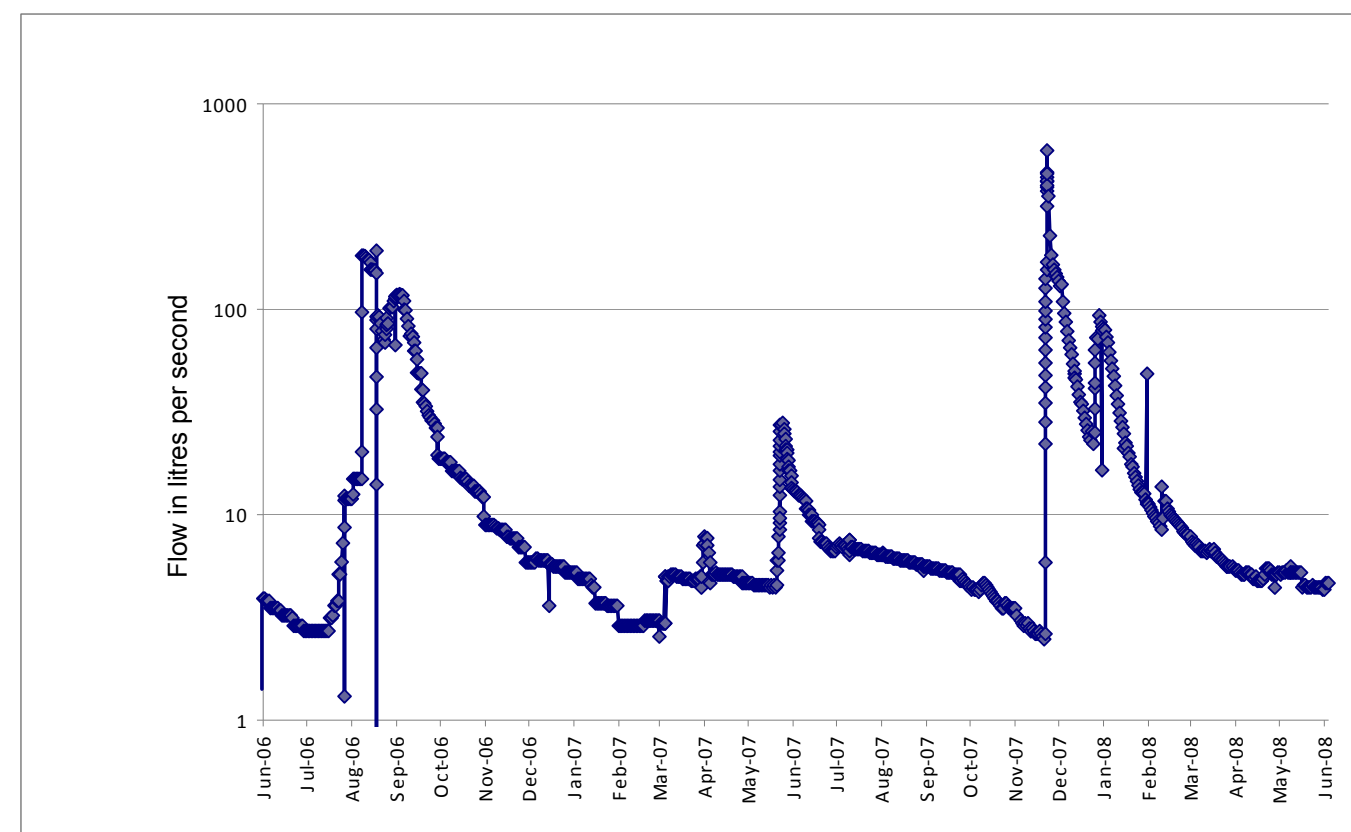


Figure A4.5 Stream flow in the Vermaaks River showing high flow events between 2006 and 2008 (from Woodford, 2008)

The flow in the stream that could be available for artificial recharge has been estimated for the four boreholes of the Vermaak Wellfield in two ways: A theoretical estimate, based on WR2005, and using measured flows from the Weir J3H043. **Table A4.2** describes the WR 2005 estimate and **Table A4.3** describes the estimate derived from the measured flows. The WR2005 estimate is double the measured value and this is could be due to inaccuracies in the measurement of high flow events.

Taking Option 1: Recharge of the Peninsula Formation (Vermaaks Wellfield) as an example, and using the more conservative measured estimate with an allowance for baseflow, it appears as if a minimum of 90 000 m³/a would be available for artificial recharge. If all this water was available during one 7-day flood event the river would flow at about 150 l/s and if it was available during a 14 day flood event, it would flow at about 74 L/s. The injection target of 45 000 m³ over seven days, as mentioned in **Table A3-1**, could be met if the injection boreholes could receive the estimated injection rates, and in some years, water may be available to do this more than once or for a longer period.

The estimated potential artificial recharge rates would be a small fraction of the annual flow in the Vermaaks River (12% of MAR) and would only take place during winter when the riverine alluvium is saturated (as rainfall first saturates the alluvium before runoff takes place). The environmental impact of reduced flow in the river would likely be negligible compared to the substantial environmental benefits of raising the water table in the aquifer.

Table A4.3 Source water availability based on WR2005

Description	Value	Unit	Source
Quaternary Catchment	J33E		
Mean Annual Runoff (MAR)	24.3	Mm ³ /annum	WR2005
Mean Annual Precipitation (MAP)	446	mm	WR2005
Quaternary Area	329	km ²	WR2005
Portion of Quaternary J33E at Borehole VR6 (Lowest borehole in Option 1: Recharge the upper aquifer (Vermaaks River Wellfield))			
Mean Annual Runoff (MAR)	0.722	Mm ³ /annum	Proportional - calculated
Mean Annual Precipitation (MAP)	501	mm	Measured at VR16
Area	8.7	km ²	Arcview; 1:50 000 Topographical map
MAR Volume	721,826	m ³ /annum	

Flow in the stream based on MAR		
Flood event lasting 7 Days	1,193.50	l/s
Flood event lasting 14 Days	596.75	l/s
Flood event lasting 21 Days	397.83	l/s
Flood event lasting 28 Days	298.37	l/s

Table A4.4 Source water availability based on measured flows

Description	Value	Unit	Source
Measured cumulative flow at Weir J3H043	367,694.71	m ³ /annum	June 2005 to June 2008 measured
Area	23.5	km ²	Arcview; 1:50 000 Topographical map
Estimated average baseflow at weir	4	l/s	Estimated from consistent minimum flow at the weir
Estimated average baseflow at weir	126,144	m ³ /annum	
Stream flow (of which a portion could be available for recharge)	241,551	m ³ /annum	
Proportion available to VR6 (by area)	89,425	m³/annum	12% of MAR

Flow in the stream based on measured flow reduced for baseflow		
Flood event lasting 7 Days	148	l/s
Flood event lasting 14 Days	74	l/s
Flood event lasting 21 Days	49	l/s
Flood event lasting 28 Days	37	l/s

This artificial recharge concept can be relatively easily tested at Borehole VR11 where there are two boreholes that are not equipped (VR9 and VR10). Both could be used as an injection boreholes and VR11 could be used for monitoring. The abstraction point and the 150 m long gravity pipeline would have a limited environmental impact as they are located adjacent to the existing road. The layout is shown in **Figure A4.6**.



Figure A4.6 Layout of proposed gravity pipeline to injection boreholes VR 9 and VR10

4. KEY ISSUES THAT AFFECT THE VIABILITY OF THE SCHEME

The pre-feasibility study would need to focus on the following key issues:

1. The availability of water for recharge. This may not be too big an issue, since in relation to Option 1 (Recharge the Peninsula Formation), the cost of supplying existing boreholes with gravity-fed artificial recharge water would be small, and if any opportunistic recharge would be of value.
2. Identifying the best injection boreholes and their injection capacities.
3. Environmental concerns around:
 - a. Option 1: Constructing a gravity-fed recharge scheme for the Peninsula Formation Aquifer (ie capturing streamflow and diverting it to the injection boreholes)
 - b. Option 2: Lowering borehole water levels in the Nardouw Aquifer.
4. Borehole clogging relating specifically to iron bacteria (and possibly other forms of clogging).
5. Operation and maintenance requirements.
6. The economics of the scheme in relation to the expected environmental benefits.

5. CONCLUSIONS AND RECOMMENDATIONS

The artificial recharge options presented here involve small-scale, simple interventions that could significantly increase the yield of the aquifers. During a 2-week rainfall event, and assuming artificial recharge at 75 l/s in the Vermaak Wellfield, the recharged volume would be in the order of 100 000 m³, or 20% of the wellfield's annual average yield.

Option 1 which involves recharging the Peninsula Formation Aquifer would ensure that the water levels are as high as possible in the aquifer, which from environmental and supply perspectives, is clearly favourable. Option 2 would need more careful thought as the impacts of maintaining a lowered water table while waiting for the recharge events need to be carefully assessed. The immediate recommendation is to conduct a pre-feasibility study that addresses the main concerns around the recharge volumes and environmental issues.

References

- Woodford, AC. 2008.** Klein Karoo Rural Water Supply Scheme. Monitoring and Management Report. 2007/2008 Monitoring period. Technical Report No 357308/8 prepared for the Oudtshoorn Municipality by SRK Consulting, Cape Town.
- WR2005.** Water Resources of South Africa, 2005 Study. Report to the WRC by B J Middleton & A K Bailey, July 2008.

Appendix 5: Albertinia: An cost saving option that incorporates seasonal sub-surface storage

I. INTRODUCTION

Albertinia is a small town in the Western Cape Province with a population of about 5000 people (2001 census data) and water requirements of about 1400 kl/day (~16 l/s) (SSI, 2008). Recently the plans for 749 low-income houses were approved – this amounts to a third of the current number of houses in the town. The water requirements are likely to increase significantly and a variety of options have been identified (SSI, 2008). One option that is not described in the SSI 2008 report is to obtain water from an existing farm dam about 20 km north of the town. If this option is pursued, it may be possible with artificial recharge to reduce the size of the conveyance infrastructure (pumps and pipelines) and thus save significantly on the capital costs. This water would then be used to recharge the aquifer during winter when the demand is low.

The artificial recharge plan would involve transferring water from the planned dam, treating the water and injecting it via boreholes into the existing wellfield where the water levels are depressed due to regular abstraction (**Figure A5.2**). Artificial recharge would take place during winter when the dam is full, when the treatment plant is under-utilised, and when the town's water demand is at its lowest.

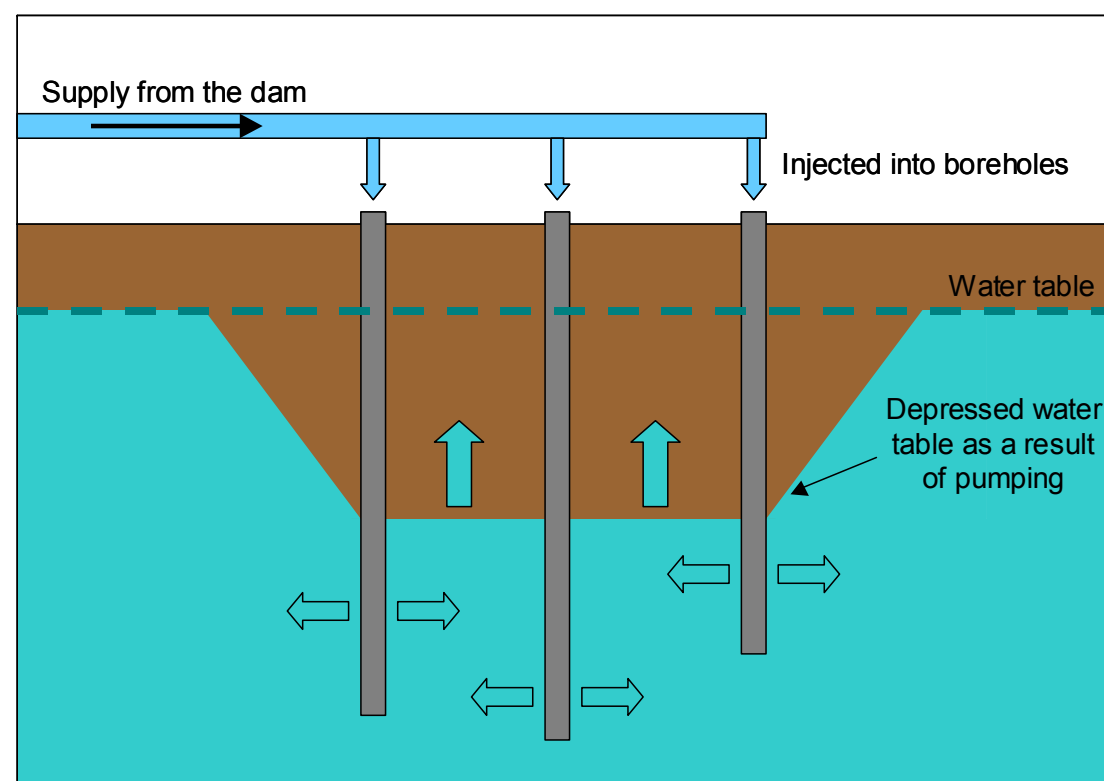


Figure A5.2 Schematic diagram of borehole injection scheme

Currently the town draws its water from two springs and six boreholes (drilled into the Nardouw Formation), although one borehole (SDR) is seldom used due to its high iron concentration (Andreas Michaels, Hessaqua Municipality *pers comm.*). **Figure A5.1** shows the location of the main spring and the municipal boreholes (AG1 – AG 4 are all located within 100 m of one another, and are immediately south of the town). **Table A5.1** gives permitted use and abstraction in 2007/8. From these figures it is evident that actual use was about half the permitted use and well short of the 2005 demand estimate of 1400 kl/day. However, with the new housing plan and other envisaged developments, it appears as if new sources will be required. The 2027 demand projections are 3500 – 4000 kl/day (SSI, 2008).

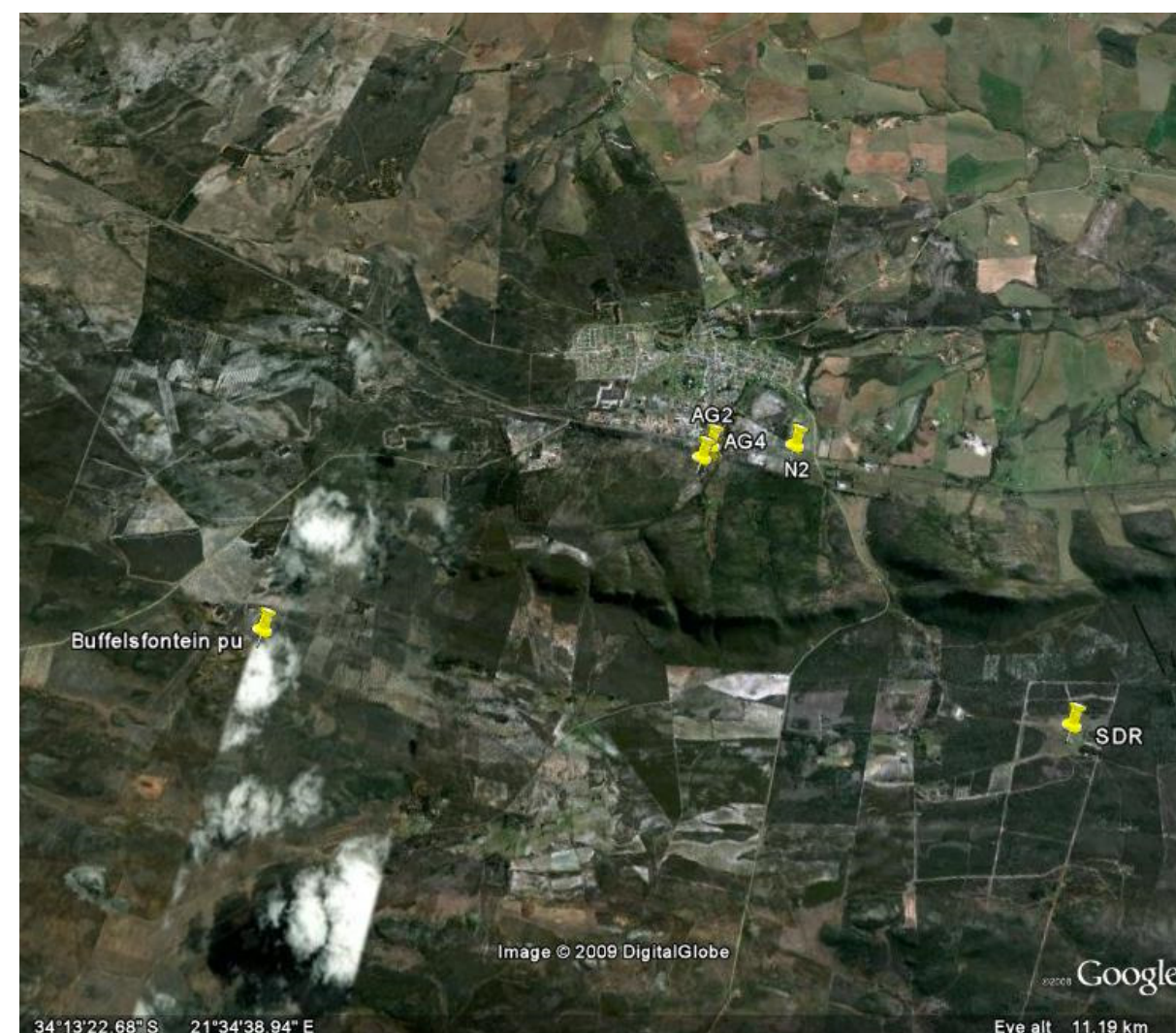


Figure A5.1 Location of municipal boreholes (Albertinia is the town north of the AG boreholes)

Table A5.1 Permitted and actual abstraction

Source	Permitted Abstraction			Actual Abstraction (07/08)		
	(l/s)	(Ml/a)	(kl/d)	(l/s)	(Ml/a)	(kl/d)
Buffelsfontein	5,0	157,68	430,0	4,37	138,2	377,5
AG1 Borehole	2,5	78,84	216,0	1,96	61,9	169,2
AG2 Borehole	1,5	47,30	129,6	0,85	27,0	73,7
AG3 Borehole	2,5	78,84	216,0	0,91	28,8	78,7
AG4 Borehole	3,5	110,37	302,4	0,56	17,7	48,5
SDR borehole	2,0	63,07	172,8	0,44	3,8	37,6
N2 borehole	1,2	37,84	103,7	0,07	2,3	6,2
Fontein	2,0	63,00	172,8	0,60	19,1	52,2
TOTAL	20,2	651,94	1 786,0	9,8	308,8	843,7

2. THE ARTIFICIAL RECHARGE POTENTIAL

Continual groundwater abstraction from the AG1 – AG4 area has resulted in a cone of depression in this area. Without a network of monitoring boreholes around the wellfield, it is not possible to determine the extent of this cone, but it does not extent to borehole N2 which is 1 km east of the wellfield (see Figure A5.2). Figure A5.2 shows that the water levels in and around the pumped boreholes are about 20 – 30 m below the natural groundwater levels. At borehole N2 the water levels are generally about 40-50 mbgl and at AG1 they are about 70-80 mbgl. The volume of water that has been displaced is not much – assume a 500 m radius cylinder of aquifer has been dewatered by 30 m, and assume a storage coefficient of 0.001- 0.003 – this equates to only about 24 000 – 70 000 m³. Most of the groundwater comes from recharge and inflow from the surrounding areas to the wellfield. The surrounding areas are not stressed at all as can be seen in the stable water levels in GZ00333 (3.2 km SE of the wellfield) and GZ00330 (4.3 km E of the wellfield). See Figures A5.3 and A5.4.

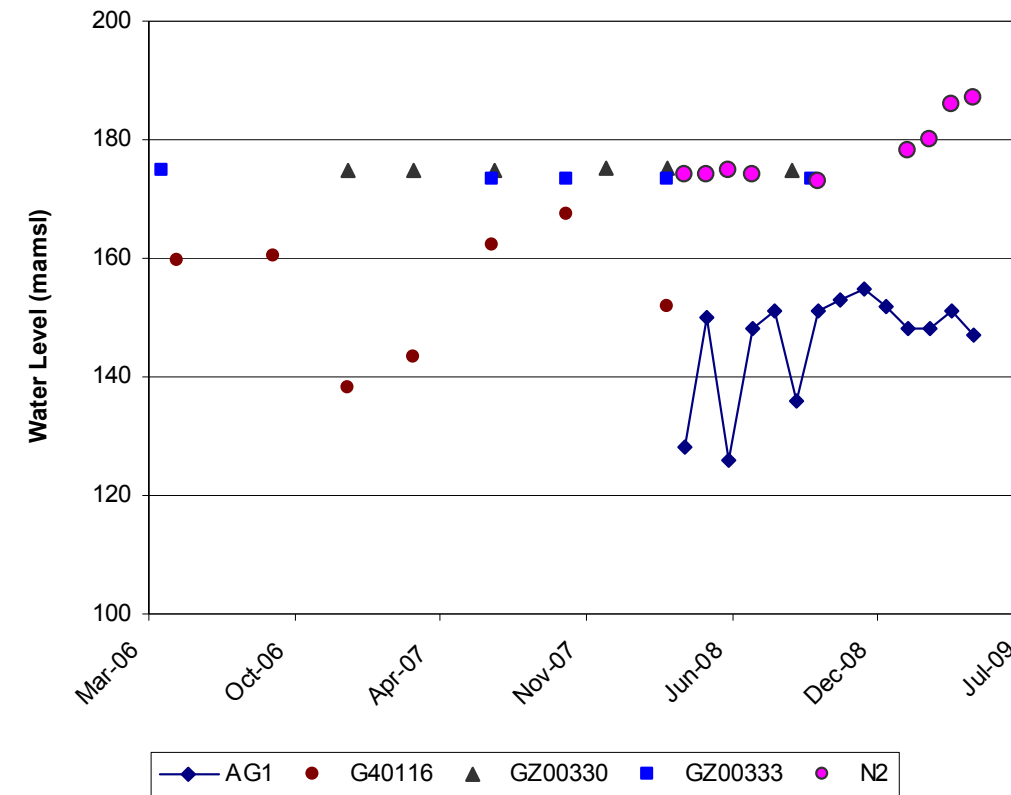


Figure A5.3 Borehole water levels (Elevations estimated from Google Earth)

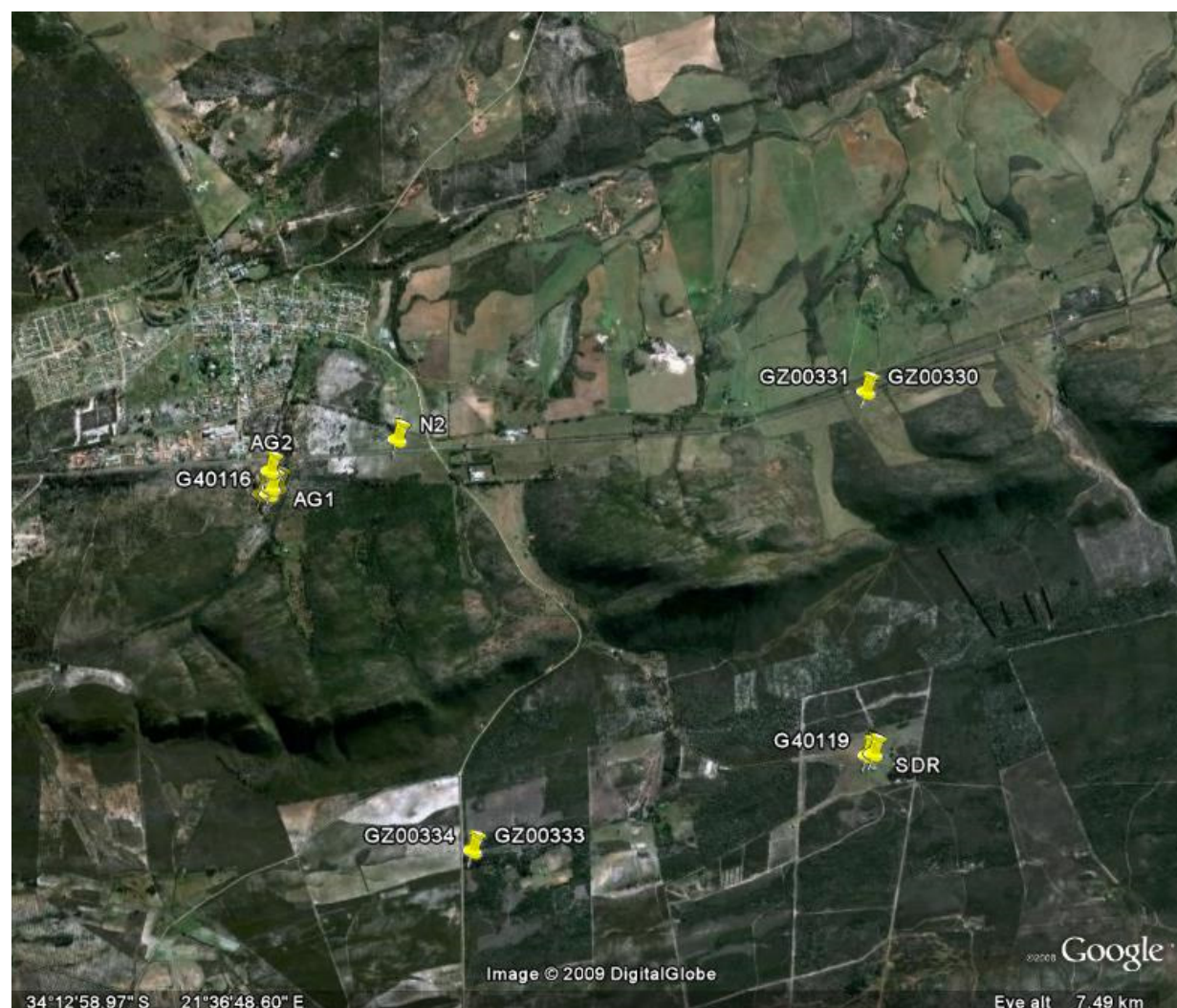


Figure A5.4 Location of municipal boreholes and monitoring boreholes

The value of artificial recharge would be twofold:

1. The potential cost saving on conveyance infrastructure
2. Having the ability to ensure the aquifer is full prior to the onset of summer

Whilst the first point makes economic sense, the second may be of greatest value if climate change predictions of greater variability in rainfall hold true.

3. THE POTENTIAL COST SAVINGS IN CONVEYANCE INFRASTRUCTURE

A hypothetical example is given below to show that a **savings of between 11 and 17 l/s** in conveyance infrastructure could be realised with artificial recharge. Assume the year 2027 demand of 3500 kl/day or 1.3 Ml/annum (SSI, 2008) is broken into 910 000 kl (70%) in summer (4986 kl/day), and 390 000 kl (30%) in winter (2137 kl/day). **Table A5.2** provides three scenarios:

1. The dam supplies the summer backlog
2. Artificial recharge during winter and high groundwater abstraction in summer
3. No artificial recharge but 70% of permitted groundwater use in summer and 30% in winter

The key assumptions are:

1. Groundwater can provide the permitted rate of 416 million litres per annum (SSI, 2008)
2. Groundwater can supply this over 6 summer months provided the aquifer is full prior to summer (ie if the aquifer has been fully replenished by artificial recharge)
3. The aquifer will be able to receive 50 kl of artificially recharged water. (By utilising more groundwater in summer, space will be created in the aquifer for artificial recharge).
4. For Scenario 3 it is assumed that groundwater can provide 70% of the permitted water over summer

Table A5.2 Water supply scenarios with the dam and artificial recharge

	Scenario 1	Scenario 2	Scenario 3
	Dam provide the balance	Artificial recharge	Alternative to Scenario 1
	kL	kL	kL
Summer			
Groundwater	208000	466000	291200
Dam water	702000	444000	618800
Total	910000	910000	910000
Winter			
Groundwater	208000	0	124800
Dam water	182000	390000	265200
Additional dam water for artificial recharge	0	50000	0
Total	390000	440000	390000
Dam needs to be able to supply (kL/day)	3847	2433	3391
	L/s	45	28
			39

With artificial recharge, groundwater would be pumped heavily in summer and the aquifer would be recharged in winter. At this stage the potential artificial recharge volume is not known, but in this scenario, greater space in the aquifer would be created by higher abstraction over summer. Using this scenario, the conveyance infrastructure from the dam would need to be able to cater for 28 l/s as opposed to 39 – 45 l/s without artificial recharge. At these flows, this equates to being able to reduce the pipe size from a 315 mm diameter to a 250 mm diameter which is a significant saving over the 23 km distance from the dam source.

However, noting the capacity of the Weyer catchment, the existing dam capacity and the restrictions on obtaining a water use licence, it is highly unlikely that the Weyer Dam would be able to provide the stated 2027 water demand. Planning done by MVD Consulting Engineers describes the planned surface water infrastructure sized to provide only

5.5 l/s. In this scenario the use of artificial recharge would enable the pipeline to be used to its full capacity in summer and winter, storing the surplus winter water in the aquifer.

4. THE TYPE OF ARTIFICIAL RECHARGE

The dam water would need to be settled to get rid of suspended particles and then it would be injected into the existing abstraction boreholes or into newly drilled injection boreholes near the existing abstraction boreholes. The injection rate would need to be 3.2 l/s continuously over the 6 winter months in order to recharge a volume of 50 000 kl.

5. KEY ISSUES THAT AFFECT THE VIABILITY OF THE SCHEME

Prior to undertaking an artificial recharge feasibility study two key issues would need clarification:

- i) Why the municipality uses less than half of their permitted abstraction.
- ii) Why additional groundwater sources in the TMG aquifer close to the town cannot be used.

If artificial recharge appeared a suitable option, key factors to assess in a pre-feasibility study would be:

- If artificial recharge is needed. The key issue here is: Could more groundwater be abstracted from the aquifer by increasing the existing boreholes' rates or by drilling additional boreholes away from the current wellfield? (See points i and ii above).

- The cost savings of artificial recharge.
- Establish artificial recharge volumes. This would entail establishing a better understanding of the aquifer's response to existing groundwater abstraction.
- Establish water compatibility (ie water quality issues associated with sub-surface blending)
- Establish borehole clogging potential.

6. CONCLUSIONS AND RECOMMENDATIONS

Artificial recharge would only be a viable option if the cost savings on conveyance infrastructure warranted it. In the case of the City of Windhoek, artificial recharge saved them in excess of R 1 billion in conveyance infrastructure. In this case the economics may not be as attractive, but it may be worthwhile, particularly if the uncertainty of climate change can be incorporated into the costing model.

REFERENCES

SSI. 2008. Water resource study for the urban supply of water in Hessequa Municipality.

MVD. 2007. Albertinia: Ondersoekverslag na alternatiewe waterbronne vir Albertinia – February 2007. Report by MVD Consulting Engineers for the Hessaqua Municipality.

Appendix 6: Vanrhynsdorp: The potential for large-scale irrigation in an arid area

I. INTRODUCTION

The town Vanrhynsdorp receives a reliable supply of water from the Olifants River, however, the farmers upstream (east) of the town rely on groundwater for irrigation. This arid area is characterised by hot dry summers and mild winters with a mean annual precipitation of less than 186 mm/a. Natural groundwater recharge is very limited. Despite this, aquifer storage together with the limited recharge to the dolomitic aquifer has over the years provided a reliable source of water for the farmers. The groundwater levels are however dropping and the water quality, which is fairly saline (EC in the region of 100 – 300 mS/m), is deteriorating, and the long-term sustainability of the aquifer is in question. Fortunately, the conditions appear very favourable for artificial recharge - for two main reasons:

1. The dolomitic marble aquifer contains boreholes with high yields. This means that artificial recharge by means of borehole injection can be at high rates and therefore in a short time large volumes of water can potentially be transferred underground.
2. A reliable, underutilised water sources, the Doring River, is nearby.
3. The salinity of the source water is very low (~ 25 mS/m) and would dilute the saline groundwater.

The drawback of this option is the cost. Water would have to be transferred across a catchment divide and it would have to be treated to reduce the turbidity prior to recharge (**Figure A6.1**). Both these factors imply significant expenditure, but if the farming activity could be modified to produce “top-end” crops that thrive on hot dry summers with large-scale irrigation, then this option could transform this land into a promising agricultural area. An alternative option of capturing flash floods in the catchment would be far less expensive, but the potential benefits would also be far less.

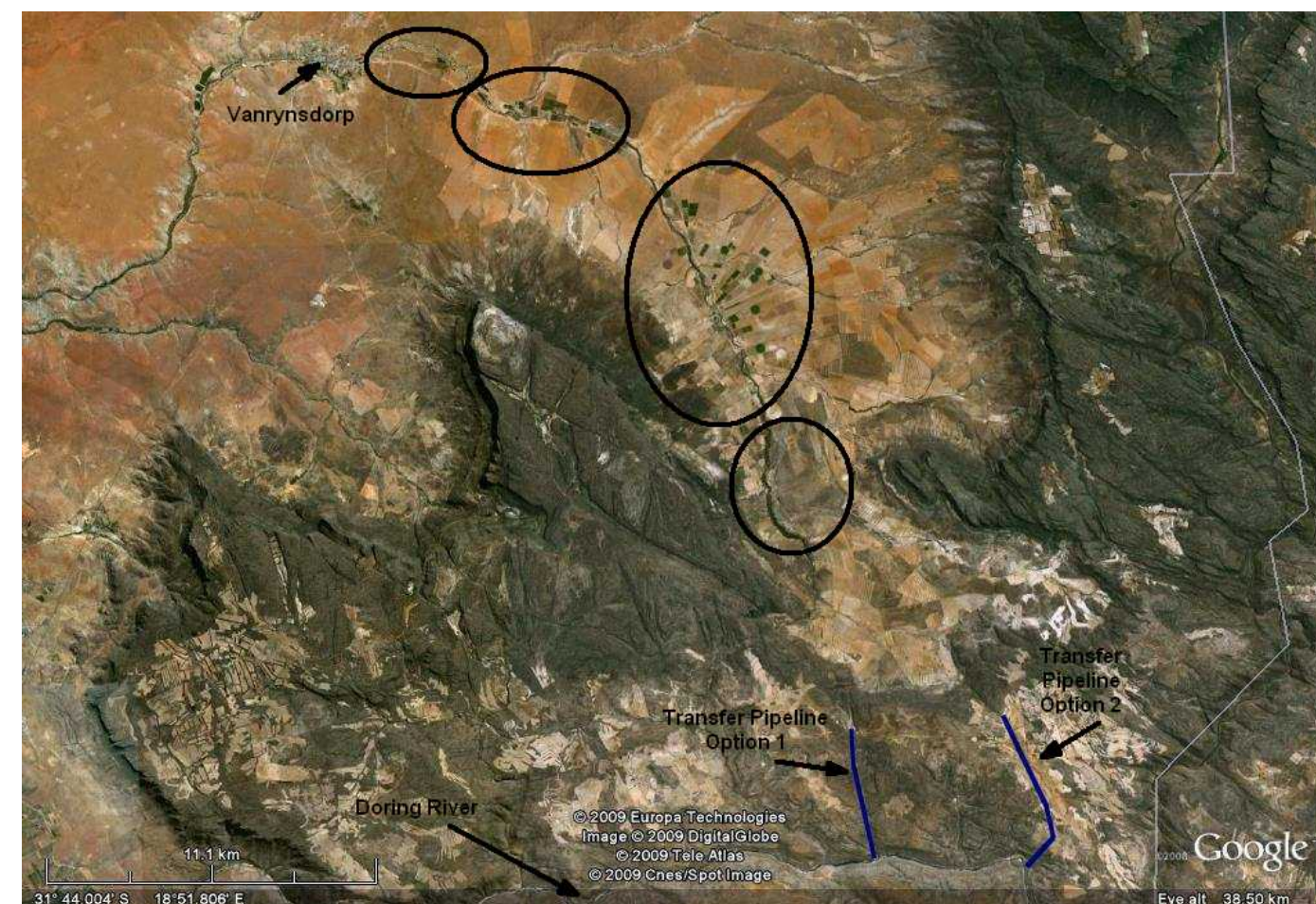


Figure A6.1 Location of current irrigation areas and transfer pipeline options from the Doring River

2. THE AR POTENTIAL

Aquifer storage potential

The storage potential of the dolomitic aquifer is not known, however, it is likely to be substantial considering the rate of groundwater abstraction for irrigation and the low rainfall and natural recharge potential. The water levels have dropped over a large area by about 5 m in 10 years (or ~ 0.5 m/a on average) (**Figure A6.2**), and thus the aquifer currently has a sizeable volume of “dewatered” aquifer material that can be replenished. A rough estimate of this is about 2 Mm^3 , assuming the aquifer is $20 \text{ km} \times 4 \text{ km}$ in area with a storage coefficient of 5×10^{-3} .

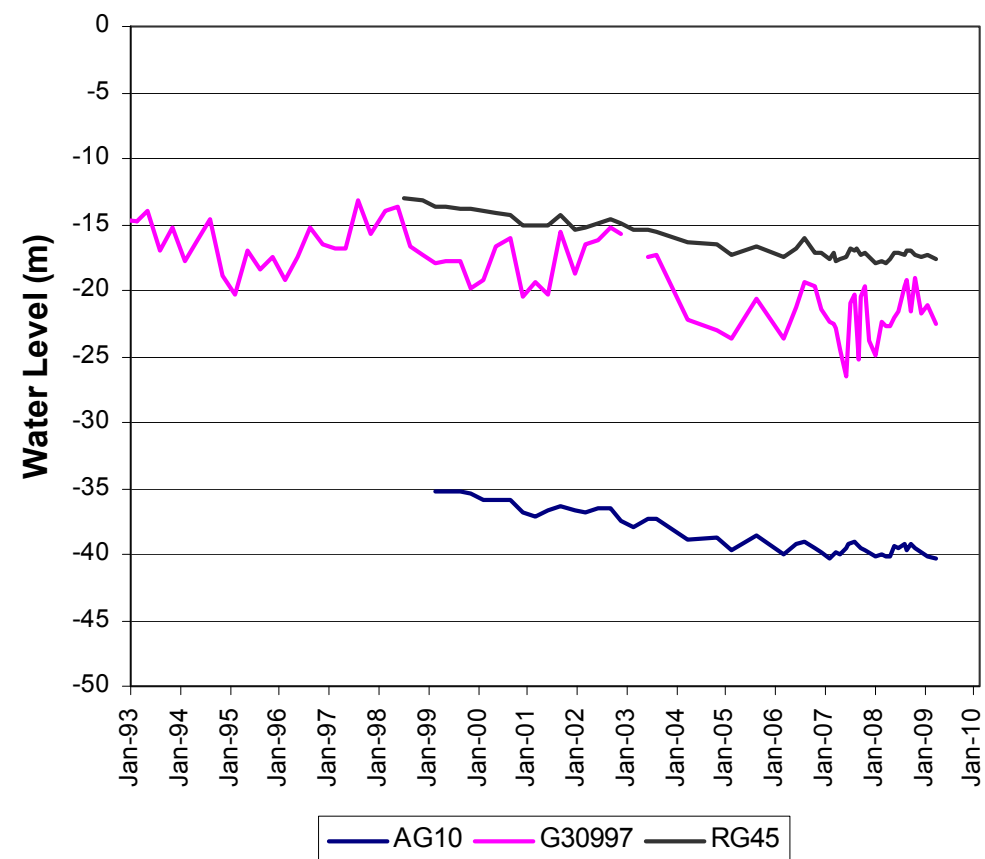


Figure A6.2 Boreholes water levels East of Vanrhynsdorp showing a general decline over the years
(AG10 is far east of Vanrhynsdorp in the upper catchment; G30997 is immediately east of town; and RG45 lies between the two)

Replenishing groundwater levels would only be the first step in the overall plan. The main aim of artificial recharge would be to provide a reliable volume of water between September and April for irrigation purposes. Annual crop requirements for a mixture of wine grapes, table grapes and vegetables is in the order of 12 000 m³/ha/a of which about 96% is required during the eight months between September and April. These are the approximate figures taken from a detailed study on the irrigation potential of the nearby Atties Karoo (PGWC, 2006).

Assuming the soils in the area east of Vanrhynsdorp are suitable for intensive irrigation, 100 ha would require 1.2 Mm³/a. Assuming a target abstraction of 2.4 Mm³/a of artificially recharged water (to irrigate 200 ha), and assuming each borehole can provide a continuous supply of 10 l/s, it would take 12 boreholes to supply this volume. If the alluvium along the Troe-Troe River is suitable for artificial recharge trenches or basins, then these would be the best method, if not, the same boreholes used for abstraction could be used for injection (although a few more may be needed if the period over which the water is available is less than 8 months).

Source water potential

The Doring River, with a MAR of 382 Mm³/a (PGWC, 2006), has no dam on the river although studies have been conducted to assess dam sites and yields. This is a winter rainfall area, and virtually all this water flows out to sea. **Figure A6.3** shows the mean monthly flows in the Doring River at gauge E2H003. Any volume that can be stored in winter for use in summer would be of value. The 2.4 Mm³/a example used above is not even 1% of the MAR – ideally the annual artificial recharge volume should be far greater than this.

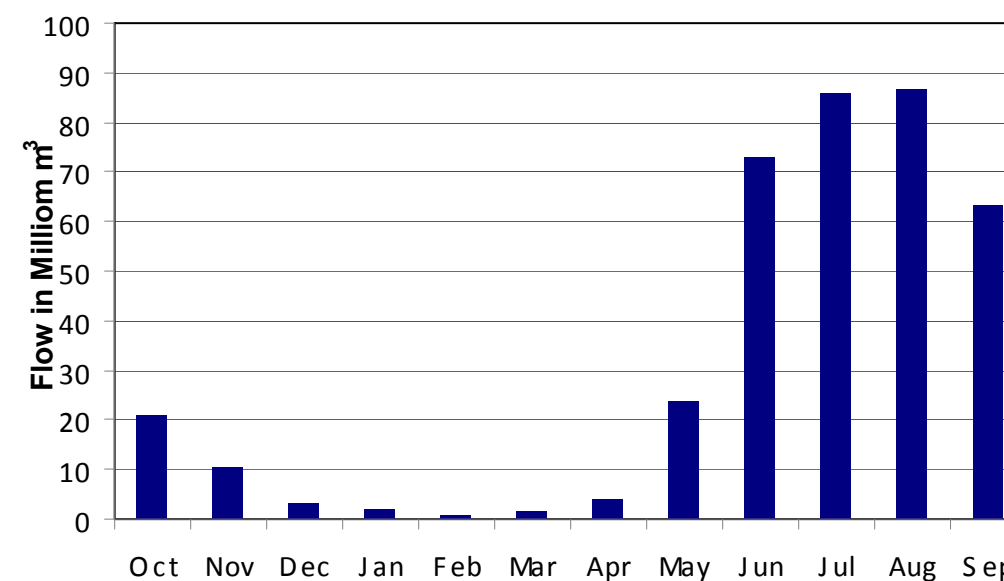


Figure A6.3 Mean monthly flows in the Doring River at gauge E2H003

An alternative source of water for artificial recharge would be the Troe-Troe River during high flow periods. The river only has a MAR of 4.6 Mm³/a and high flow periods are infrequent and sporadic. Average monthly flows in the Troe-Troe River at gauge E3H001 located downstream of Vanrhynsdorp are shown in **Figure A6.4**.

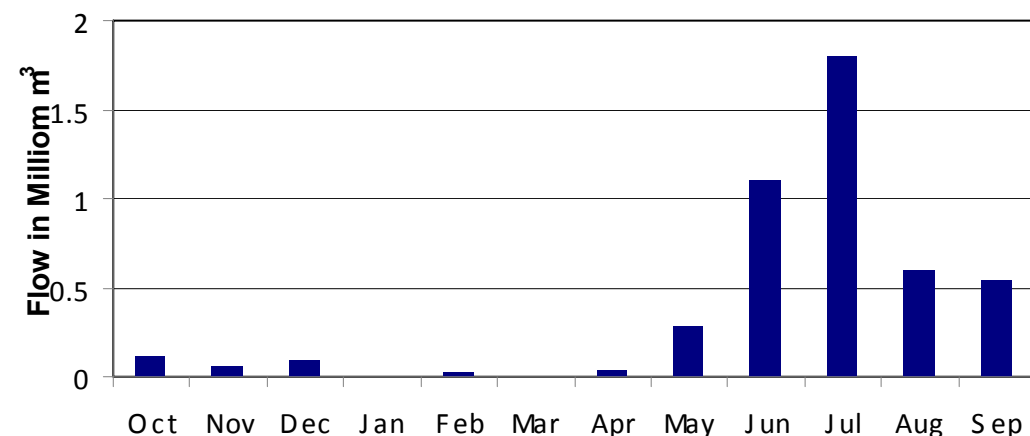


Figure A6.4 Average monthly flows in the Troe-Troe River at gauge E3H001 located downstream of Vanrynsdorp

3. THE CONCEPTUAL SCHEME

The scheme would require transferring water from the Doring River over the catchment divide into a tributary of the Troe-Troe River from where it would flow to the aquifer for recharge (see **Figure A6.1**). The water would have to be pumped up a vertical elevation difference of about 470m over a distance of 5 km. A soil survey and study of the infiltration potential would be necessary to establish whether recharge by means of basins or trenches would work, as this would require the least treatment to reduce the turbidity of the water prior to recharge. The river bed of the Troe-Troe River contains clean quartzitic sand that may well provide a direct link for recharge to the dolomites. Clean sand is found in cavities at depth far from the river, and this suggests that there may be a good link between the sands

and the dolomitic aquifer, and that infiltration along the river course could be an option. If not, the far more expensive option of borehole injection would be necessary, and this would require that most of the turbidity is removed otherwise the boreholes would clog with fine particulate matter.

The cycle of recharge and abstraction would entail diverting the winter runoff from the Doring River to the aquifer over the 4 to 6 months when water is available, and then abstracting it from the aquifer during the summer months.

The second option utilising the Troe-Troe River peak flows would also be dependent on the suitability of using infiltration basins or trenches and diverting water into these during high flow periods. The observed river flows indicate that this would probably only be viable in one out of every three years.

4. KEY ISSUES THAT AFFECT THE VIABILITY OF THE SCHEME

The key issues that affect the viability of this scheme are:

- Is there a need? Linked to this is whether the area east of Vanrhynsdorp is suitable for intensive agriculture.
- Can the aquifer receive the water at the required rates?
- Is it economically viable to transfer water to this area (with the high pumping heads) and reduce the turbidity so that it is suitable for recharge?

REFERENCE

PGWC. 2006. Provincial Government Western Cape: Department of Agriculture: Western Cape. 2005. Main Report. Draft Final. Prepared by Arcus Gibb (Pty) Ltd as part of Contract No. 259-2000/2001. Western Cape Olifants/Doring River Irrigation Study. PGWC Report No. 259/2004/02.

Appendix 7: Lamberts Bay: The potential for using an aquifer for balancing storage

I INTRODUCTION

Within the northern Sandveld area there are four towns that are entirely dependent on groundwater for their domestic supply. For the towns of Graafwater and Leipoldtville, the supply is able to meet demand; however for Lamberts Bay and Elands Bay both the water quantity and quality, in terms of supply, have been problematic. These problems are being addressed but the option of artificial groundwater recharge to their sandy aquifers should be considered for these two towns.

The town of Lamberts Bay faces water shortages, especially in the summer period, when there is a significant increase in the town's demand. Currently groundwater is abstracted from the Wadrif Aquifer to the south of the town (titled "Area 1"), however the area to the north-east of Lamberts Bay has also been explored (titled "Area 2") as part of a study to address all the possibly supply options to Lamberts Bay (Figure A7.1). Other supply options that have been tabled for Lamberts Bay include the desalination of sea water and the piping of water from the Clanwilliam Dam.

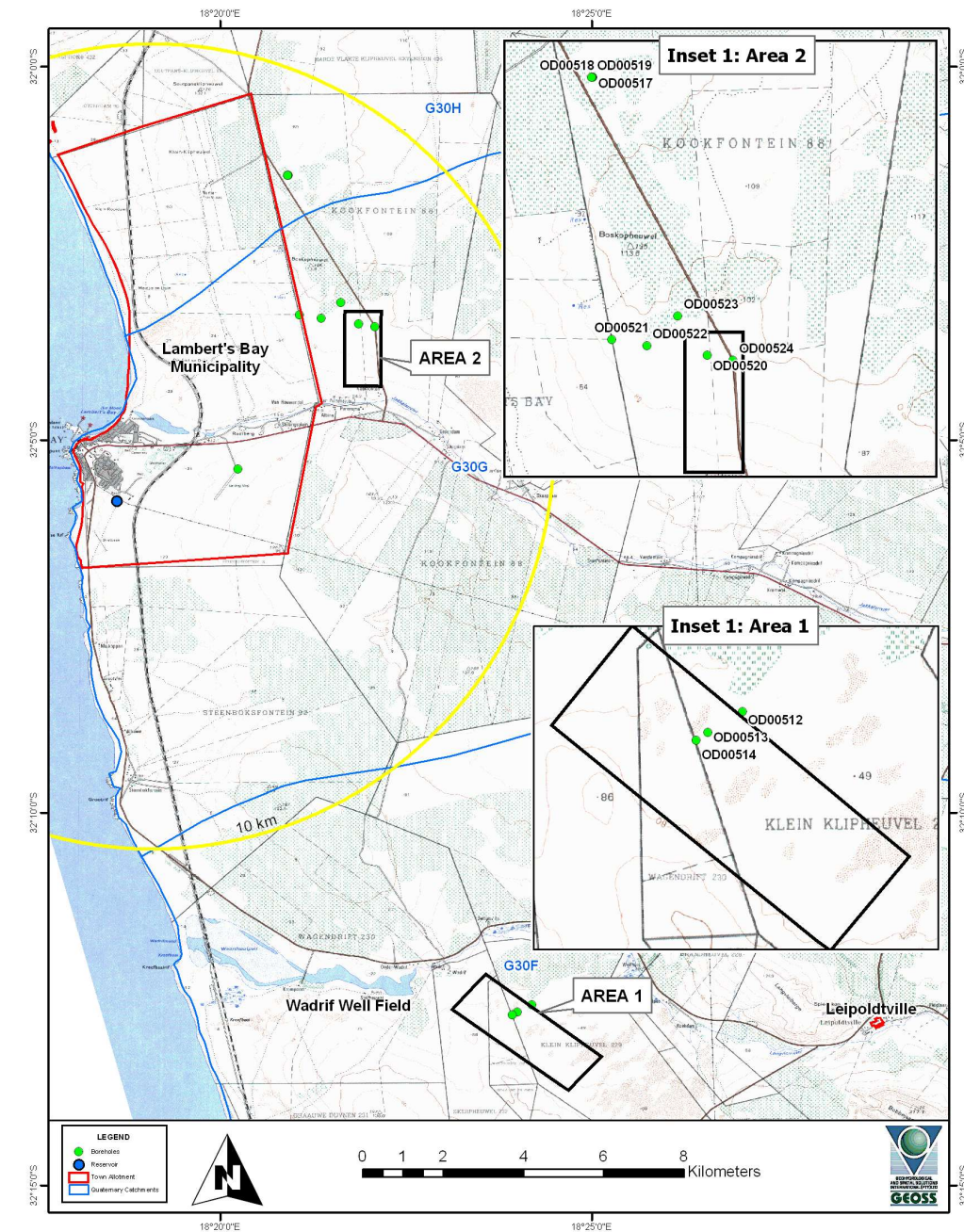


Figure A7.1 Wellfield options for the town of Lamberts Bay (Area 1 = existing wellfield and Area 2 = possible new wellfield)

2 OPTION 1: SMALL – MEDIUM SCALE ARTIFICIAL RECHARGE OF THE CENTRAL WADRIF

There are two options in this area:

- i) Artificial recharge to the Lower Wadrif (the previous wellfield)
- ii) Artificial recharge to the Central Wadrif (the current wellfield)

The location of these two areas is shown in **Figure A7.2**. The Lower Wadrif Aquifer is labeled “Previous wellfield” and the Central Aquifer is labeled “Current wellfield”.

This aquifer is located in a low rainfall region situated on the arid west coast. The surface flow of the Langvlei River is very low and typically only flows after concurrent years of good rainfall. Abstraction of water from the Jakkalsvlei River is not seen as a viable option as the flow itself – when it occurs – has significant ecological value. Water used for artificial recharge will need to be piped into the area from the Clanwilliam Dam on the Olifants River.

i) Artificial recharge to the Lower Wadrif

The wellfield in this area has been decommissioned because of poor quality groundwater. The deterioration of water quality has been a result of two activities:

- a. Groundwater abstraction that resulted in the lowering of water levels and the consequent induction of more saline water into the wellfield, and
- b. Natural, infrequent high rainfall that results in the mobilization of salts from the salt pan which in turn affects the groundwater salinity.

The aim of artificial recharge would be to enable the re-commissioning of the wellfield by ensuring groundwater levels are maintained between optimum elevations.

The groundwater levels are shown in **Figure A7.3** for both the lower and central Wadrif aquifers. Due to the good rainfall in 2007 and 2008 standing rain water in the normally dry Wadrif salt pan resulted in the mobilization of salts which leached into the aquifer. This was exacerbated by the unusually high water table at this time, which allowed for a short travel path to the aquifer for the recharging surface water. This resulted in an increase in the salinity of the groundwater from ~200 mS/m to ~700 mS/m (**Figure A7.4**).

Thus for the lower Wadrif, if artificial recharge is to be considered, it must be done at the very eastern end of the lower Wadrif wellfield, possibly using boreholes SRK1 and Borehole C. The objective of artificial recharge would be to maintain groundwater levels between specific elevations so that abstraction can continue without the deterioration in water quality that can arise from both depressed and elevated water levels. Key to this would be ensuring that the water quality deterioration that arises from the more common lowered water levels is prevented. Once the groundwater quality improves with artificial recharge, the wellfield could be reconsidered for use at an abstraction rate that maintains the water quality between acceptable limits. The problem does exist that from time to time (with exceptionally high rainfall events), the salinity problem associated with the salt pan will cause the groundwater quality to temporarily deteriorate.

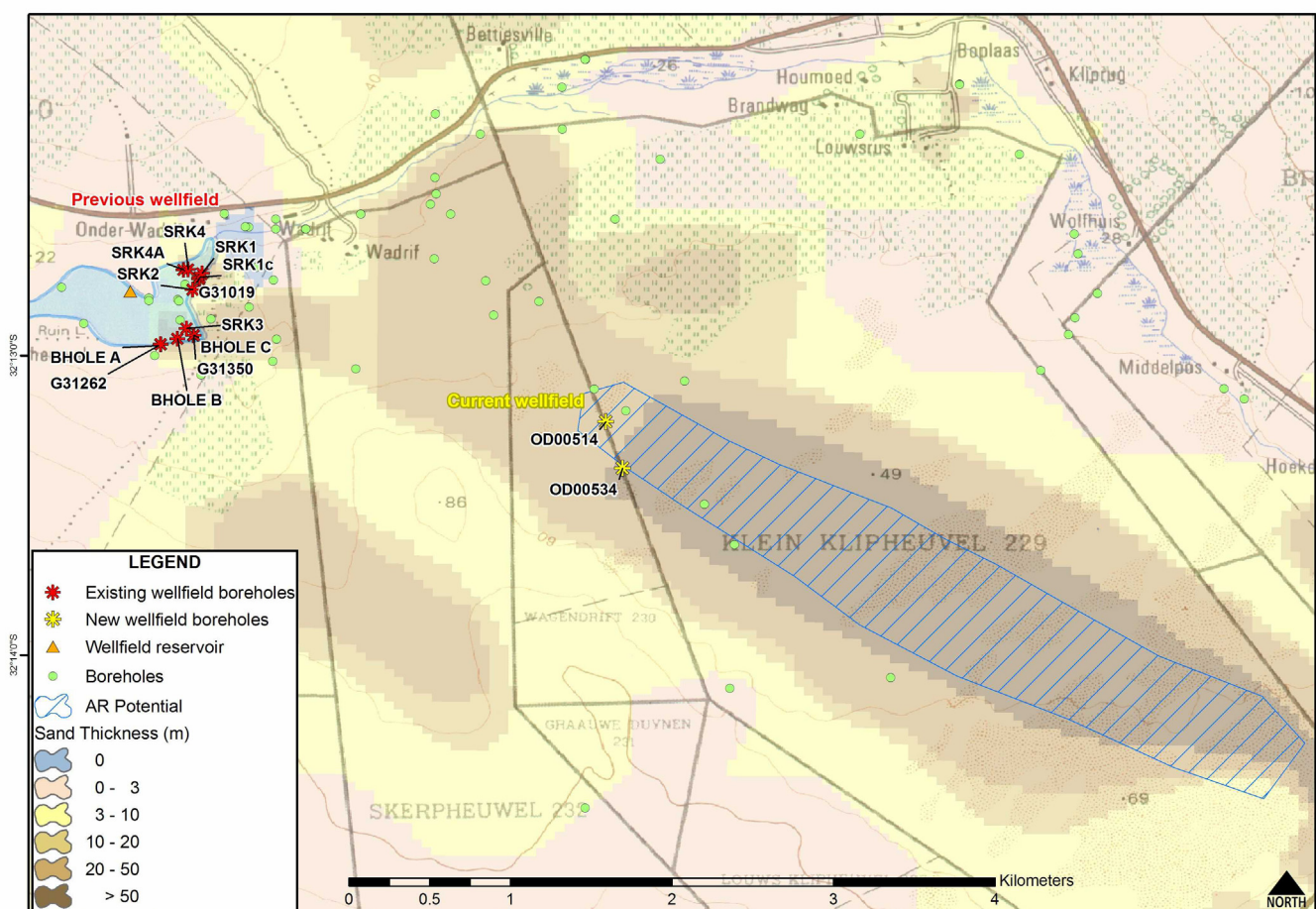


Figure A7.2 Lower and Central Wadrif wellfields used for the supply of water to Lamberts Bay (Area I in Figure A1)

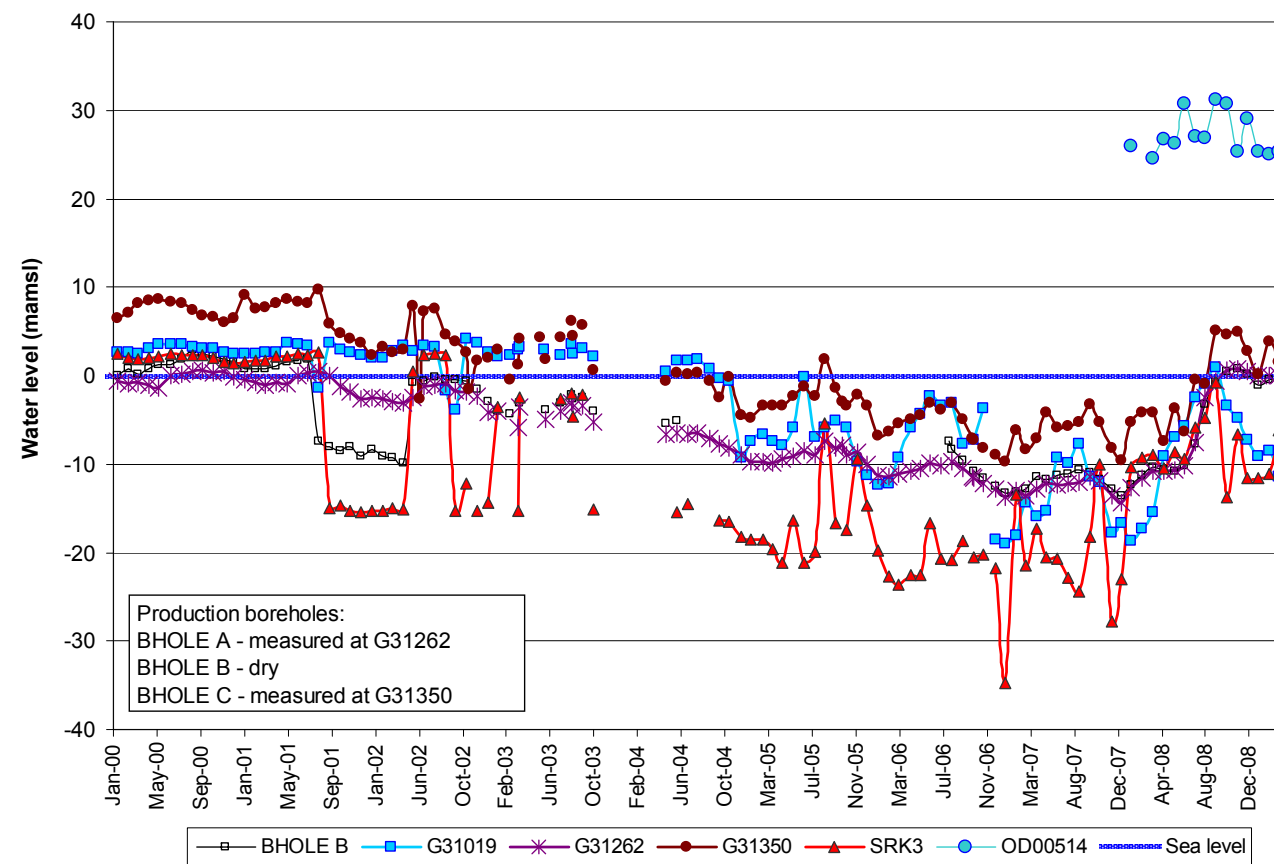


Figure A7.3 Groundwater level for lower and central Wadrif aquifer

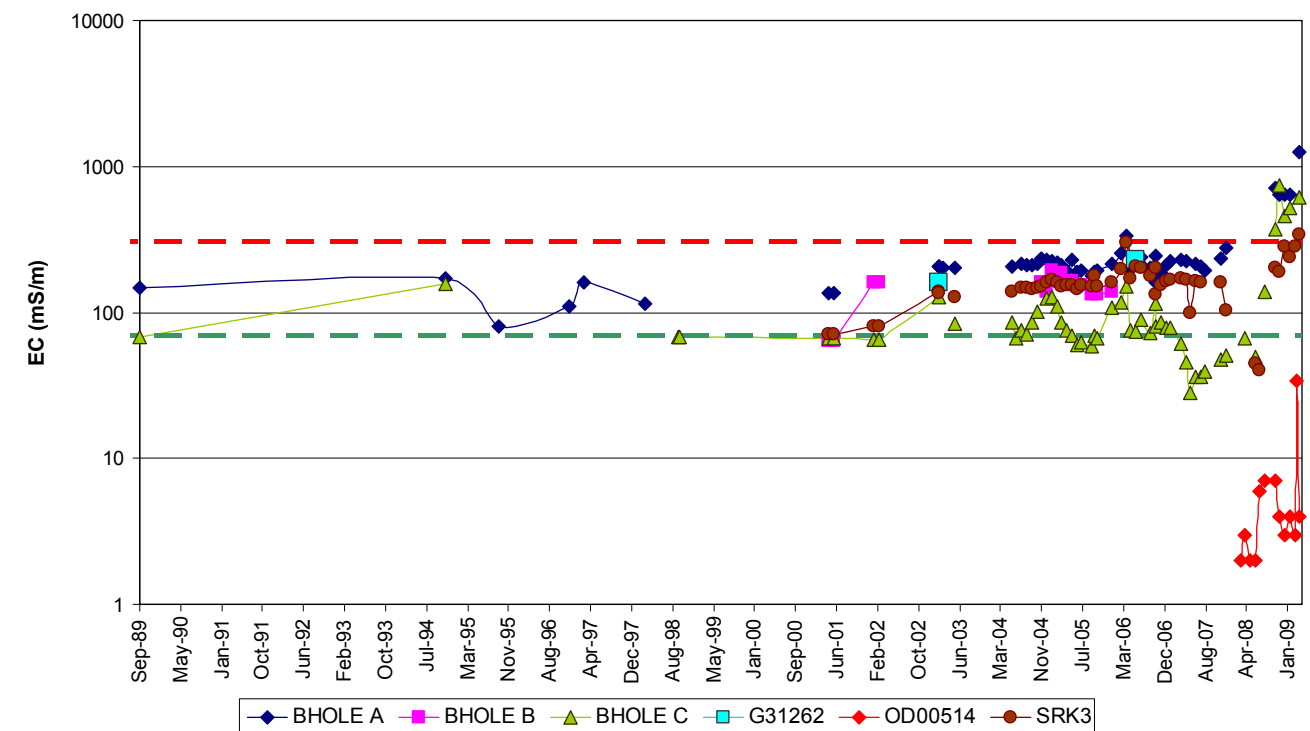


Figure A7.4 Water quality for the lower and central Wadrif aquifer

ii) Artificial recharge to the Central Wadrif

Unlike the Lower Wadrif where groundwater salinity is relatively saline, the Central Wadrif is characterised by fresh groundwater (EC ~40 mS/m). The aim of artificial recharge in this area would be twofold: i) To store water in the aquifer during winter for use in summer; and ii) To assist in the rehabilitation of the environment. The scheme would require transferring water from the Clanwilliam Dam when surplus water is available in winter for use in summer when the demand is high. This would require drilling injection boreholes either in or up-gradient of the existing wellfield, and supplying them with treated surface water. Infiltration basins in the wellfield area would not be an option because the aquifer is semi-confined due to an overlying clay layer. The existing Lamberts Bay production boreholes are used continually and would not be available as dual injection/recovery boreholes. The environmental benefits would be realised if over the long term more water was transferred into the aquifer than was abstracted. Over the years nearly all the springs and wetlands have dried up, and this could be reversed if the recharge volumes and cycles were planned for both water supply and environmental rehabilitation purposes.

Figure A7.4/...

The main benefit of artificial recharge would be to utilise the aquifer as balancing storage, transferring water during winter when the demand is low and when the Olifants River is flowing strongly, and then extracting the water during the high demand summer months. The surface water supply pipelines and pumping infrastructure could be optimally sized rather than sized to meet the peak summer demand. Alternatively, artificial recharge could be used as balancing storage for a desalination scheme with the same objective.

The artificial recharge potential would largely depend on the number of boreholes drilled for recharge purposes. One injection borehole should be able to receive about 20 l/s (~1800 m³/day). Assuming the aquifer is suitable for receiving water via injection boreholes (which would require testing), and assume five injection boreholes are drilled, then about 9000 m³/day or about 1 Mm³ could be recharged over a four-month winter period of artificial recharge.

Key issues relating to Option 1:

- The source water and its availability for recharge
- The positioning and number of injection boreholes
- The economic viability of the scheme
- The timing of the recharge/abstraction cycle.

3 OPTION 2: LARGE SCALE ARTIFICIAL RECHARGE TO THE UPPER- CENTRAL WADRIF

The aim would be to heavily utilize the aquifer during summer (far more than its sustainable yield) for both town and irrigation supplies, and to fully replenish the aquifer during winter from the Clanwilliam Dam. This would require transferring large volumes of water to the upper and possibly the central Wadrif (to areas as yet identified) for recharge to the entire Wadrif Aquifer. This option would require a detailed investigation to assess its feasibility, however, the potential for large-scale seasonal storage may be an attractive option. The storage capacity of an area 20 km in length, 5 km in width and 30 m deep, using a storage coefficient of 10% is 300 Mm³. By comparison, this is nearly five times the additional volume that would be realized by raising the Clanwilliam Dam wall 5 m (63 Mm³). Ideally it would be best to locate areas where the clay layer is absent so that artificial recharge by means of infiltration basins could take place, as this would require the least pre-treatment (settling only).

The key factors that would affect the rate of artificial recharge and the annual recharge volume (over the winter months), are:

- The rate at which the aquifer can receive the water
- The availability of the source water
- The rate at which water can be retrieved from the aquifer via boreholes.

Any one of the above factors could be the limiting factor of the scheme's potential. Assuming the availability of the source water and the ability of the aquifer to receive water are not the limiting factors, then the number of high-yielding boreholes that would be needed to supply 10 Mm³/a for example, would be about 30 if each could supply 2000 m³/day over 6 summer months (assuming each borehole can deliver 1800 m³/day).

This option would entail transferring water from the Clanwilliam Dam to the Jakkals River catchment from where it would flow to the recharge area. The water would have to be pumped up a vertical elevation difference of about 330m over a distance of 19 km.

Key issues that affect the viability of the scheme:

- The viability of transferring water from the Clanwilliam Dam to the upper Wadrif would need to be assessed
- The recharge mechanism and location of the recharge facilities would need to be established
- The economic viability of the scheme would need to be assessed.

4 OPTION 3: SMALL – MEDIUM SCALE ARTIFICIAL RECHARGE OF THE NORTH-EAST AQUIFER

The aquifer targeted for development lies about 6 km north east of Lamberts Bay (Figures A7.1 and A7.5). The aim of recharging this area would be to increase the aquifer's yield in summer. The aquifer is currently not being utilized for town supply, however the boreholes have been drilled and the supply scheme is ready for implementation. A bonus would be to add artificial recharge to the implementation plan at the onset.

The potential artificial recharge rate would be in the region of 15 l/s (~ 1300 m³/day) per borehole. Additional injection boreholes would need to be drilled as all the existing boreholes will likely be used for the groundwater abstraction. An advantage of artificial recharge to this area is that the aquifer is not intensely utilized for farming like some of the other areas are.

Recharge water would need to be brought to this area. This aquifer lies immediately to the north of the Jakkalsvlei River and the flow in this river is even less than the Langvlei River. When this river flows it also has significant ecological value. As with the previous options, source water would have to be brought from either the Olifants River or obtained from desalination.

An advantage at this site is that because this wellfield has not yet been developed, the infrastructure design can accommodate artificial recharge from the onset, if artificial recharge proves to be feasible.

Key issues that affect the viability of the scheme:

- The source water and its availability for recharge
- Borehole clogging will need to be taken into account as this aquifer is characterized by high iron and manganese concentrations.

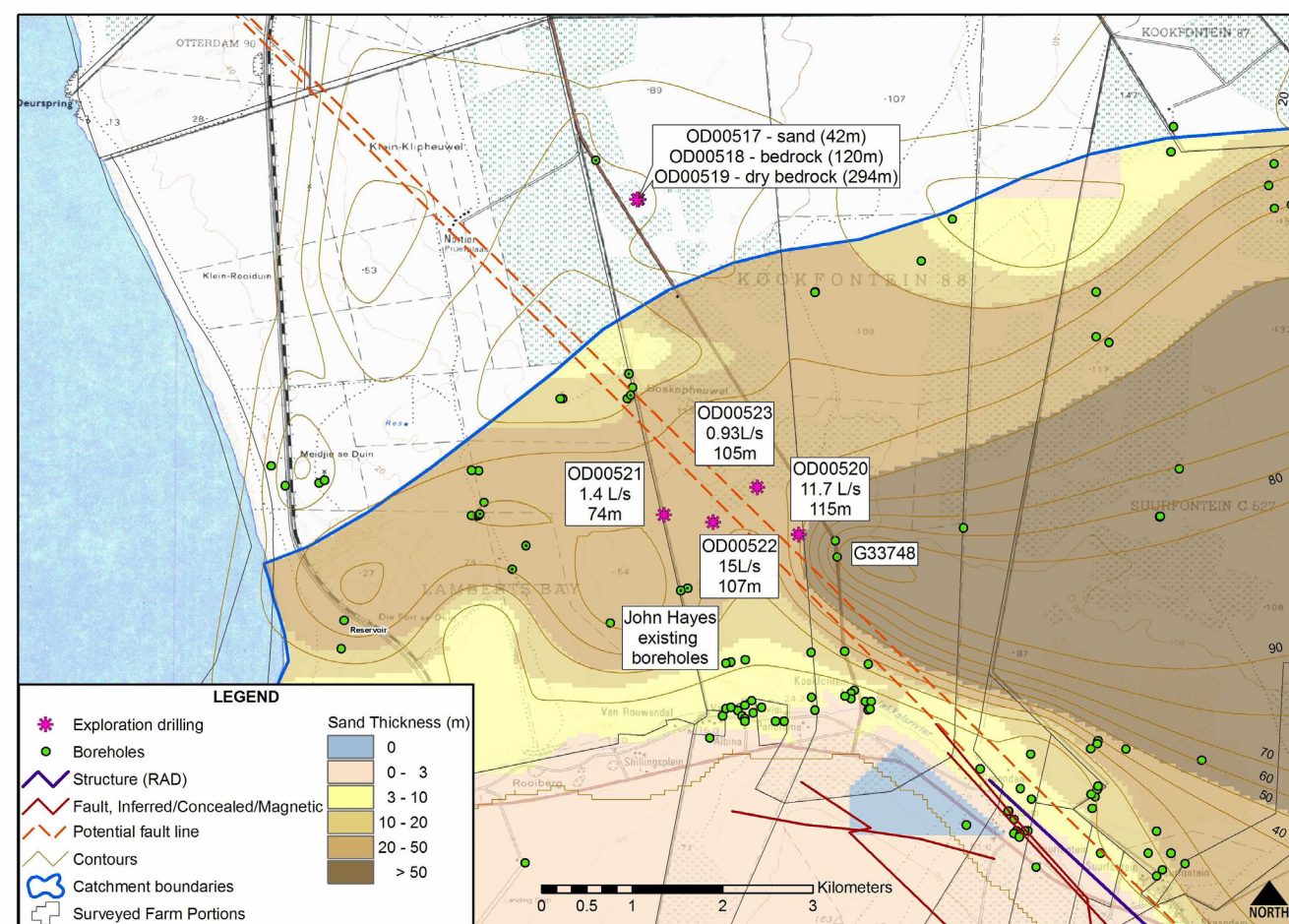


Figure A7.5 Potential wellfield to the north-east of Lamberts Bay (Area 2)

The benefit of utilizing artificial recharge is that it can provide storage close to where the water is needed and fulfill a balancing function between winter and summer demands for any of the sources that may be developed for the area. This translates into smaller and cheaper infrastructure components, but greater running costs, as additional costs would be incurred in injecting and re-abstracting the recharged water.

The existing Lamberts Bay wellfield (central Wadrif)

The introduction of an artificial recharge scheme would be beneficial. Groundwater is used both for municipal supply and for agricultural purposes. In addition it plays an important ecological function. Thus there would be benefit if groundwater levels can be raised. In the area, especially in summer, there is additional aquifer storage capacity. However the challenge remains that, due to the low rainfall within the areas and very limited surface water flow within the Langvlei River, water to be used for recharge would have to be piped into the catchment area and recharge would have to be via dedicated artificial recharge boreholes.

Lower Wadrif wellfield

For this wellfield, which is no longer being used as a source of domestic supply for Lamberts Bay, artificial recharge would be beneficial if the water levels can be raised and the water quality improved. In the longer term the wellfield could be used again (at a low abstraction rate) to supplement the water supply to Lamberts Bay. The issue of the source water for recharge to the central Wadrif is the biggest problem.

The possible sources of recharge water need to be investigated with associated costings, to be able to evaluate the economic viability of groundwater recharge in the Wadrif area.

Aquifer to the north-east of Lamberts Bay

A groundwater supply from this aquifer is under consideration, but it should be noted the water will require treatment prior to use. This option is cheaper than desalination of sea-water. If this wellfield is to be developed then planning for artificial should be included if the source water for recharge can be addressed.

5 CONCLUSION AND RECOMMENDATIONS

The availability of fresh water in this area is severely limited and finding a source of water for artificial recharge is a major constraint. Source water would have to come from one of the following:

- The Olifants River
- Desalination
- Groundwater sources in the TMG aquifer

Appendix 8: Elands Bay: Artificial recharge potential in an unsaturated aquifer

I INTRODUCTION

The town of Elands Bay obtained its water from seven boreholes (R1 to R7) in the past (**Figure A8.1**). Boreholes R1, R2 and R3 are situated in the dune field to the north-east of Elands Bay. The groundwater yields are acceptable although quite low, and the water quality is also acceptable. The boreholes have been in use for many years and are very important for the town supply. Their abstraction rates and volumes cannot be increased because any further drop in water levels could induce saline water into the aquifer (the water levels are currently at or below sea level). Boreholes R4 to R7 are situated to the north of the Elands Bay/Redelinghuis road at an elevation similar to that of Velorenvlei. The water quality from these boreholes is very poor and for this reason the boreholes need to be decommissioned as part of the water supply. Three new production boreholes have been drilled further to the east (OD00525, OD00526 and OD00528). These boreholes are in a different aquifer to the previous seven boreholes and have only recently been brought into use. **Figure A8.1** shows the position of the boreholes in relation to Elands Bay. Potato farming occurs in the area and groundwater is abstracted for irrigation purposes as well.

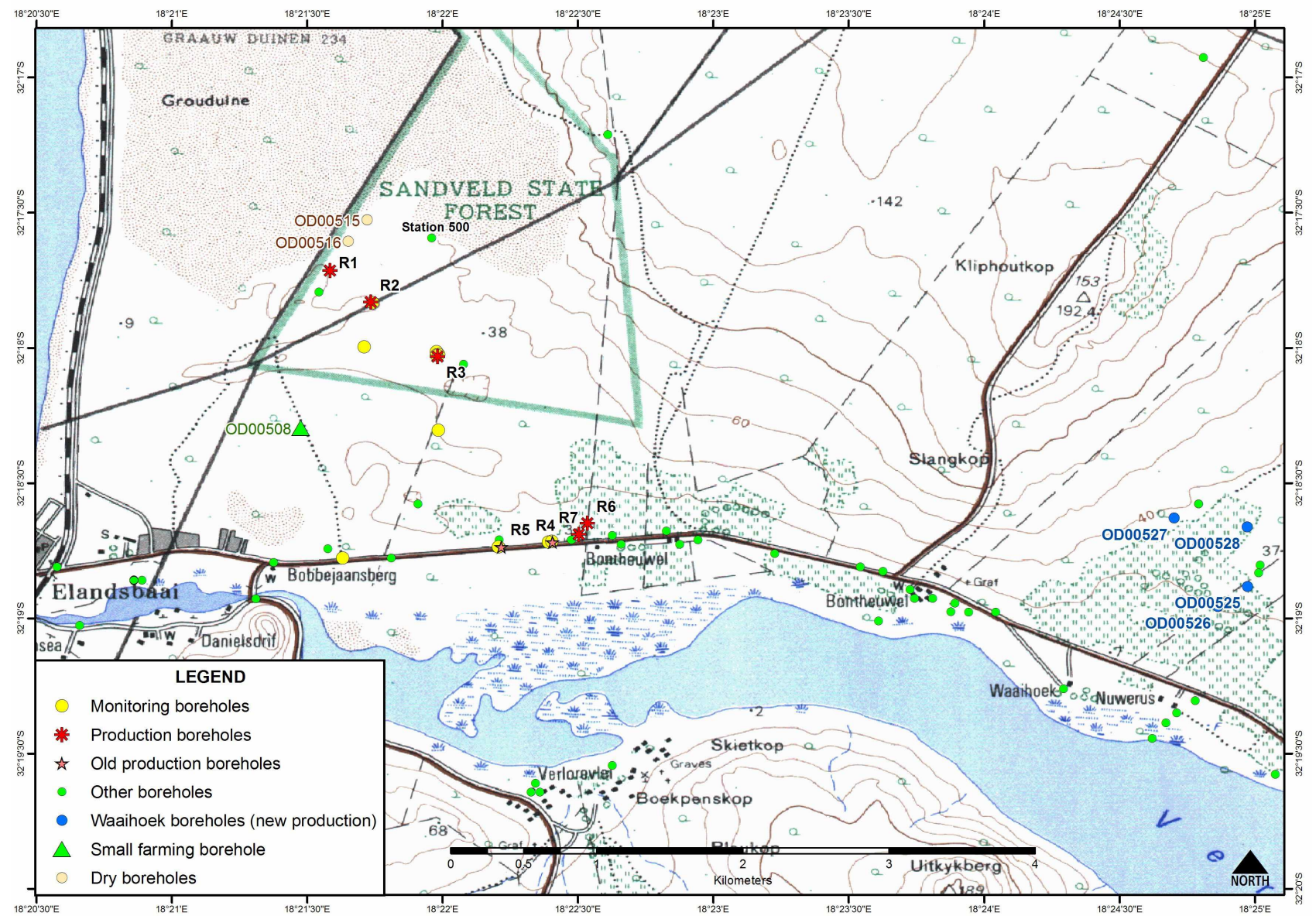


Figure A8.1 Location of boreholes for Elands Bay

The yields of the Elands Bay production boreholes are shown in **Table A8.1**.

Table A8.1 Borehole Yields

Borehole ID	Yield (ℓ/s)	Annual Yield (m ³ /a)	Comment
R1	1.3	39,000	Dune field
R2	0.9	29,112	Dune field
R3	1.9	57,864	Dune field
R6	0.5	15,636	North of road reserve
R7	1.4	41,928	North of road reserve
OD00525	6.5	102,492 ¹	Waihoek
OD00526	3.7	58,342	Waihoek
OD00527	9.0	141,912	Waihoek

All the boreholes abstract groundwater from a primary aquifer. **Figure A8.2** and **Figure A8.3** show the groundwater level and groundwater quality variation with time for the production boreholes.

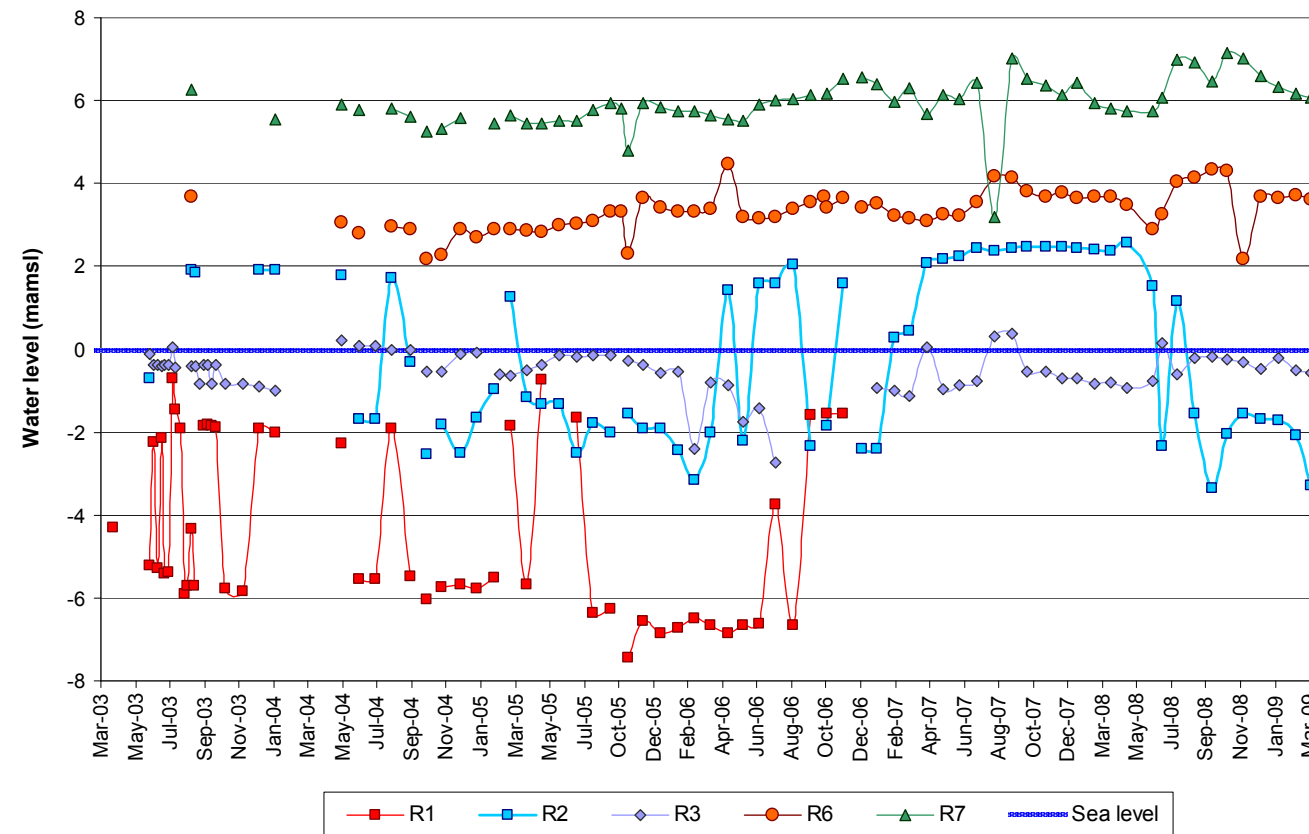


Figure A8.2 Groundwater levels at Elands Bay boreholes

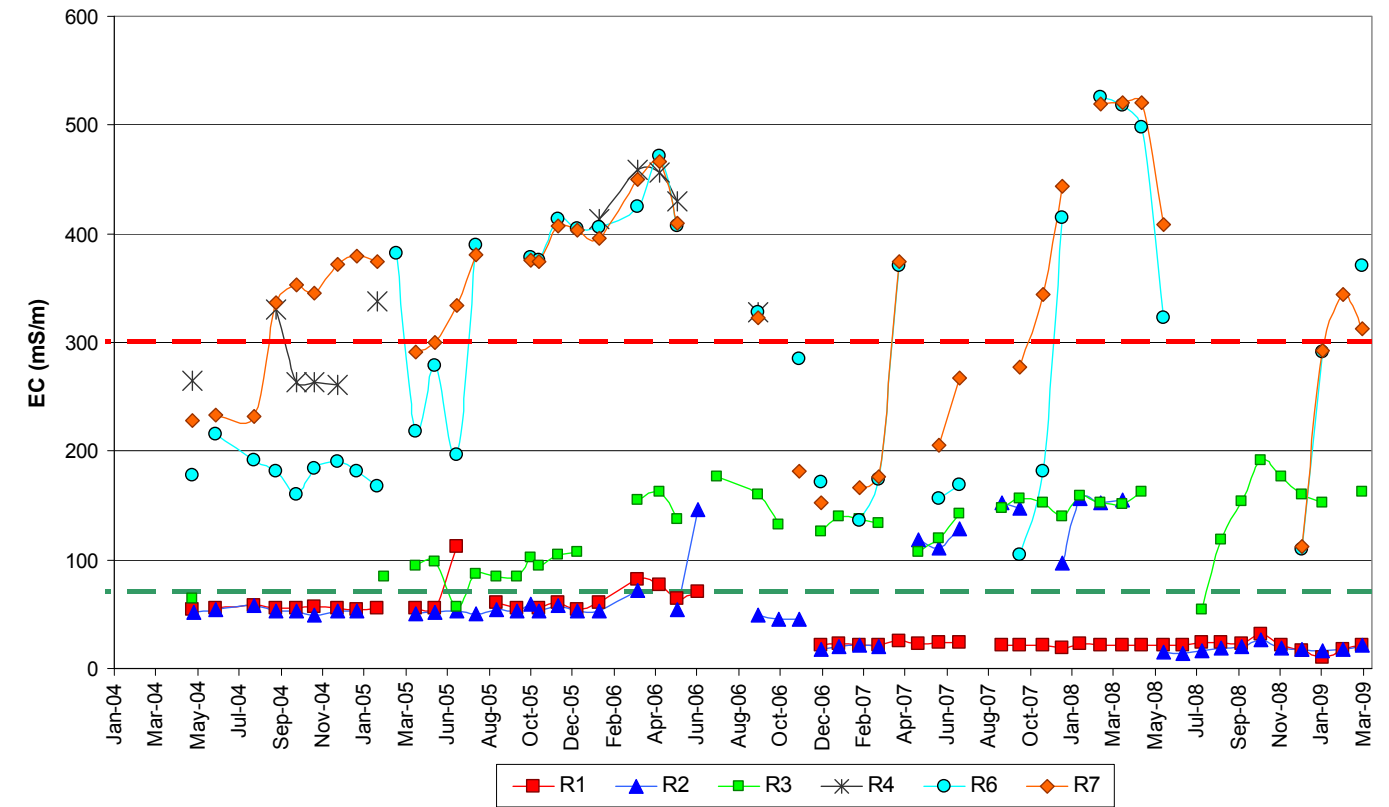


Figure A8.3 Groundwater quality at Elands Bay boreholes

Since water quality issues needed to be addressed at two of the R boreholes (R6 and R7) and additional good quality was required, groundwater exploration took place in the dune field area to the north of borehole R1. Two good drilling sites were identified and drilled. Promising aquifer material was intersected, but the groundwater levels were below the good aquifer material. The boreholes were classified as “dry”. Thereafter exploration commenced on the Waihoek Farm.

The two exploration boreholes (OD00515 and OD00516) north of R1, hold great promise for aquifer recharge. These boreholes are up gradient of boreholes R1, R2 and R3 – thus recharging the area will have significant benefit. The volume of groundwater that is currently being abstracted from R1, R2 and R3 cannot be increased as the water levels are at or below sea level and must not be allowed to drop further.

As the Waihoek wellfield was only commissioned recently, more data needs to be collected. In principal, however, this wellfield area will also benefit from recharge as the area is used both for municipal supply and agricultural purposes.

For the two dune field boreholes the estimated artificial recharge potential is about 900 m³/d (based on the characteristics of the sand material that constitute the potential aquifer), whilst in the Waaihoek area this is approximately 1 700 m³/d (based on the recommended abstraction rate of the three existing production boreholes).

2 AVAILABILITY OF WATER FOR RECHARGE

Elands Bay is located on the arid west coast with rainfall <100 mm/a. The aquifers are predominantly recharged by inflow from deep seated faults systems. The potential source of recharge water could be from the Velorenvlei itself. However such a comment is made with caution and the water would only be abstracted when Velorenvlei is in flood and flowing out to sea. The water quality of Velorenvlei varies seasonally with the electrical conductivity (EC) of the vlei being highest during summer (EC >400 mS/m) and lowest in winter (EC <200 mS/m). The level of the vlei is monitored by DWA, thus the 'flood' volumes can be calculated. The CSIR is compiling an estuary management plan for Velorenvlei and this will also address the water quality variations of the vlei.

DWA have three monitoring stations at Velorenvlei, one at the start of the vlei at Redelinghuis, one at Bonteheuwel mid way along the vlei and another at the mouth at Elands Bay. Unfortunately these stations only monitor water quality and have only a few readings recorded (15 in total spanning 27 years). The EC values range from over 800 to 12 mS/m but there is insufficient data to make any conclusions. Anecdotal accounts are that the river seldom flows out to sea but it did so in 2008 for the first time in seven years.

The only gauge that does record water level data in the catchment is located on the Kruis River at Tweekuilen, over 26 km upstream from Redelinghuis, which is itself about 20 km upstream of Elands Bay. The flow data from this station indicates that the average flows peak at 3 Mm³ during August (Figure A8.4). It is assumed that this flow fluctuation is carried through to Velorenvlei but it is so far upstream of the vlei that it is not possible to make any conclusions about the flow in the vlei.

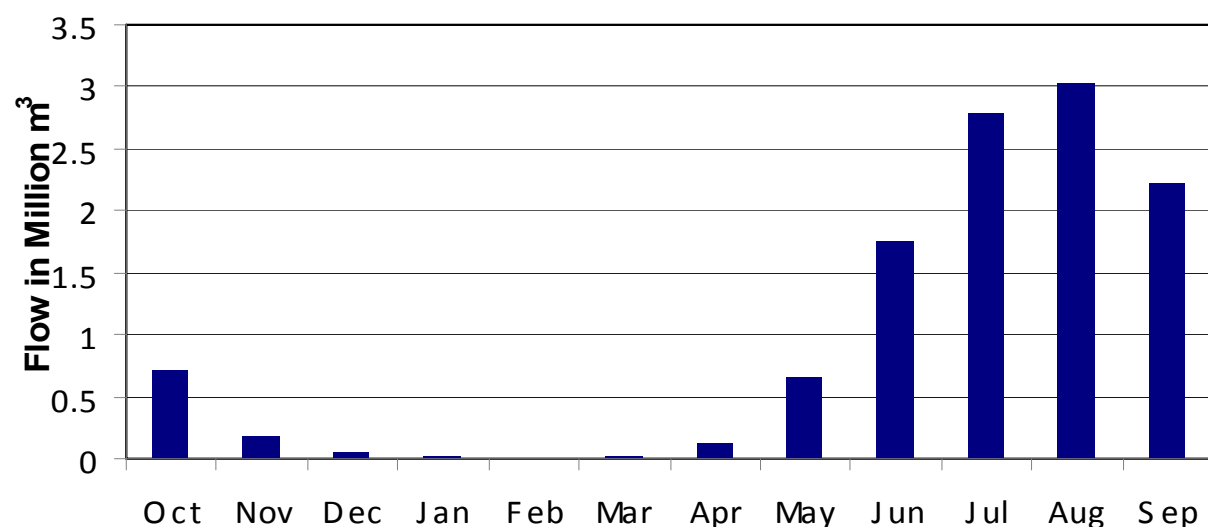


Figure A8.4 Average monthly flows in the Kruis River at gauge G3H001 at Tweekuilen (MAR 60.9 Mm³/a)

The seasonal water quality variation of the Verlorenvlei would have to be well understood before it could be considered as a possible artificial recharge source. However, it is unlikely that using Verlorenvlei as a source of recharge water would be environmentally acceptable because of the existing water use from the vlei, the infrequent flooding events and because the vlei is an integral component of a Ramsar site.

As with Lamberts bay, artificial recharge could provide balancing storage close to where the water is needed but source water would probably have to come from one of the following:

- The Olifants River
- Desalination
- Groundwater sources in the TMG aquifer

Treated sewage effluent is not a potential artificial recharge source, as it is already used to irrigate the sports field.

3 KEY ISSUES THAT AFFECT THE VIABILITY OF THE SCHEME

The key issues are:

- The source water for recharge would have to be established
- If the volume of flood events make water form Verlorenvlei and option, this source would have to be very carefully assessed, as the vlei is a key component of a Ramsar site. The water quality would also have to be established to see if it is suitable for recharge.
- Estimated recharge volumes needs to be determined
- The economics of an artificial recharge scheme would have to be compared with other water supply options.

4 CONCLUSION AND RECOMMENDATIONS

Groundwater constitutes the entire water supply to Elands Bay which is located in a low rainfall area. There are two boreholes (OD00515 and OD00516) that could be solely dedicated to artificial recharge in the Velorenvlei Reserve within the dune field. These boreholes intersect good, high conductivity aquifer material that site above the water table, and are directly up-gradient of three production boreholes. Like the Lamberts Bay options, the potential for artificial recharge is limited by the availability of a suitable water source for recharge, however, if this can be sorted out, then the conditions appear very favourable to use the local aquifer in the dune fields of the Velorenvlei Reserve to provide balancing storage close to where the water is needed.

**Potential Artificial Recharge
Areas in South Africa**