SDP 8

Determining a water reserve for the Kuiseb River

1999/2000

Authors:

Introduction

Since SDP 2 first studied water use in 1994 many developments have taken place in the Kuiseb river catchment area and in the water management policy of Namibia. The depleted lower Kuiseb aquifer, the increasing cost of seawater desalination, and the role of farm dams have started to receive more attention. Meanwhile, communal Topnaar farmers in the central Namib Desert have reported lower yield from their !Nara fields (a nutritious cucurbit, indigenous to the dunes near the Kuiseb River) which provide the only cash crop available to them. They have also observed a decline and death of riverine acacia and other plant species.

The Kuiseb River Basin

Now, however, the concept of using environmental reserves in the sustainable management of river catchments is starting to take hold. SDP 8 was the first case of using the environmental reserve concept in an ephemeral river basin and it had as its main objective the assessment of the interrelated impacts of the various water-use and management strategies. It also showed the impact of competing demands on a single critical resource within the context of sustainable development.

During the project the condition and diversity of the vegetation of the lower and middle reaches of the Kuiseb were measured and analysed. Information about water supply and use was gathered from sources including the Department of Water Affairs, the Weather Bureau, NamWater (the bulk water provider in Namibia) and the port town of Walvis Bay. Stakeholder workshops were held and other participatory rural appraisal approaches were also taken.

It was found that water abstraction from the lower river was unsustainable and that the main causes of water loss included evaporation, infiltration and aquifer recharge. The results of SDP 8 were passed on to the communal farmers involved in the participatory rural appraisals and were also presented as a role-play at a Gobabeb information weekend held for donors, representatives of relevant ministries and stakeholders. The overall model developed has served as the basis for further investigation of the viability of basin management committees by various authorities and is one of the inputs to the Environmental Learning and Action in the Kuiseb Programme which led to the establishment of the first Basin Management Committee in Namibia.
This report looks at the water inputs and outputs from the Kuiseb River with the aim of finding a balance between the two.

**Background**

Namibia has twelve major western ephemeral river catchments that are important sources of water for people and the environment. There is a continuous increase in the use of the catchments’ limited resources which a previous study has suggested is unsustainable.

The Kuiseb River, one of the twelve western-flowing ephemeral rivers, originates 24-30km west of Windhoek in the Khomas Hochland, draining a catchment of 14 700km\(^2\) and flowing 503km through the Namib Desert towards the Atlantic Ocean. For the purposes of this study the catchment was divided into the lower (most western), middle and upper sections.

When the Topnaars, who are indigenous residents of the lower and middle Kuiseb first started living there, they could access water in open hand-dug wells at depths of between 1m – 4m. Rooibank, one of the settlements, used to be a natural fountain with semi-permanent springs and pools of water. Groundwater then could also sustain large fields of !Nara plants and other vegetation.

Water abstraction from the lower river system has increased substantially over the past century and numerous farm dams have been built in the upper Kuiseb. In 1899 a small desalination plant was built at Walvis Bay and operated at the high cost of 1 £/m\(^3\). When the town outgrew the capacity of the plant, a water supply scheme was developed at Rooibank in the lower Kuiseb and by 1923 supplied all the water needed by the town.

Subsequently, the Kuiseb has provided water for Swakopmund and the Rössing Mine (which in 1981 used more water than both towns combined). To be able to provide this amount of water a second aquifer, the Swartbank, was put into production. However, despite the mine having cut back on water consumption, the level in the Kuiseb river aquifers fell dramatically and the Omdel artificial recharge dam in the Omaruru River is used to supplement water supply to Swakopmund and Arandis (including the mine).

In the study, Namis was a direct link between SDP8 and the community and information was primarily gathered through Namis methodology. Information on the status of the environment of the catchment was compared to information collected during field surveys.

The overall aims of the project were:

- To test whether the generic procedure for determination of the water reserve (South African Department of Water Affairs) could be applied in Namibia with necessary changes.
- To test the validity of the Namibian Monitoring and Information System (Namis) which is a methodology of obtaining data through workshops and participatory rural appraisal methods with the emphasis on participation and interaction.
The South African Department of Water Affairs and Forestry in 1999 established a generic procedure for determination of Resource Directed Measurements (RDM) for protection of water resources. This has been tested on perennial rivers in South Africa and we wanted to determine whether this methodology could also be used in Namibia for water reserve determination in ephemeral rivers. Level 3 was selected for the study of the lower Kuiseb because of the time limit of ten weeks of the study.

Levels of RDM procedure

<table>
<thead>
<tr>
<th>Level</th>
<th>Term</th>
<th>Characteristics</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Desk top estimate</td>
<td>Very low confidence, about two hours per water resource</td>
<td>For use with a National Water Balance only</td>
</tr>
<tr>
<td>2</td>
<td>Rapid determination</td>
<td>Low confidence; desktop + quick field assessment of present status, takes about two days</td>
<td>Individual licensing for small impacts in unstressed catchments of low importance and sensitivity</td>
</tr>
<tr>
<td>3</td>
<td>Intermediate determination</td>
<td>Medium confidence, specialist field studies takes about 2 months</td>
<td>Individual licensing in relatively unstressed catchments</td>
</tr>
<tr>
<td>4</td>
<td>Comprehensive determination</td>
<td>Relatively high confidence, extensive field data collection by specialists takes 8-12 months</td>
<td>All compulsory licensing. In individual licensing, for large impacts in any catchment</td>
</tr>
<tr>
<td>5</td>
<td>Flow management plan</td>
<td>Acknowledges present operating constraints on a river; modified operating rules are drawn up between the management agency and RDM study team, which will result in a more environmentally friendly flow regime, as far as possible.</td>
<td>For use in highly regulated systems where present flow control structures do not have outlets from which releases can be made to provide for the water quantity component of the reserve.</td>
</tr>
</tbody>
</table>

Once the level was selected, the next steps included
2. Determining ecoregional types, delineating resource units and selecting sites for the study. The site selected was the entire Kuiseb catchment
3. Determining resource quality reference conditions, which describe the natural unimpacted characteristics of a water resource
4. Assessing the present status, importance and sensitivity of resource units. This includes the ecological, social and economic relevance of the units.

**Groundwater dynamics of the Kuiseb River**

The Kuiseb, which flows only after good summer rains, maintains narrow but dense riparian forests and groups of wildlife, which mostly feed on trees. Their only source of water is groundwater stored within the sandy and gravel alluvium of the river.

Groundwater differs from surface water in the following respects:
• Movement cannot be seen so it requires indirect methods of measurement and quantification
• It moves at slow rates measured in metres/year

Therefore, management of the resources and proper monitoring are essential as they provide information about groundwater responses to natural and human induced factors.

In this section of the project we attempt to test the assumption that groundwater is sufficient to supply present domestic, environmental, livestock and industrial water demands. This raised the following research questions:
• Is rainfall received in the upper Kuiseb adequate to maintain the water balance in the Kuiseb?
• How do the influences of evaporation, evapotranspiration and groundwater abstraction impact the groundwater level?

Water inputs and outputs from the Kuiseb River Catchment
As can be seen from the figure above, activities in one part of the catchment have an influence on other parts. The entire catchment relies almost exclusively on rain falling in the
upper catchment as the source of water input as rainfall is very low and sometimes non-existent in the middle and lower catchments. In the upper Kuiseb, farm dams take up about 20\% of the runoff, 76\% is unaccounted for and only 13\% enters the middle Kuiseb as runoff.

This surface water, together with the little rain that falls, recharges the aquifers in the middle Kuiseb. Abstraction does occur but between 1986 and 1996 this occurred at a lower rate than the recharge. Over the same period, water abstraction in the lower Kuiseb was greater than recharge.

<table>
<thead>
<tr>
<th>Combined safe yield for lower Kuiseb aquifers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3.6Mm$^3$ per annum</td>
</tr>
<tr>
<td>Abstraction rate for Walvis Bay alone:</td>
</tr>
<tr>
<td>• 4.7Mm$^3$ per annum</td>
</tr>
</tbody>
</table>

Swakopmund also receives water from the aquifers.

Obvious over-extraction

During workshops, participants were of the opinion that the river’s ground water levels were dropping.

The Topnaar people felt that the reduced runoff and infiltration was as a result of farm dams in the upper catchment.

Quality of alluvial groundwater throughout the catchment appears to be acceptable for direct human consumption (upper and middle catchments) or with minimal treatment. Groundwater of the lower Kuiseb varies between 600 and 1000 part per million of total dissolved solids (TDS).

Flood water typically contains very low TDS except when the floodwater originates from Namib tributaries in the middle and lower section, where it becomes highly mineralised. As a result mineralised ground water in the Kuiseb aquifer occurs mainly along the north bank.

**State of the environment in the upper Kuiseb**

There have been some studies on the feasibility of constructing dams in the upper parts of the catchment that would supply water to Windhoek. However, if the proposed Donkersan Dam is built, it will reduce the total runoff into the lower parts of the Kuiseb by 70\%, causing major problems for farmers living downstream and preventing recharge of aquifers that supply the coastal towns with water.

This part of the study aims to understand water supply and demand in the upper catchment and focuses on the influence of rainfall on the environment.
For the purposes of this study we had to make the assumption
that there was no subsurface flow from the upper Kuiseb to the
middle and lower compartments of the catchment. However, in
the diagramme we have indicated subsurface flow between
compartments, although this may be discontinuous at places.

Information was gathered mainly through a stakeholder
workshop that included commercial farmers, representatives
from water suppliers and agricultural extension officers. The
following points were raised.

**Vegetation and soil**
Most participants identified that there had been a change in the environment and blamed
low rainfall. *Faidherbia albida* trees were dying and density of grasses was higher 20 years
ago because there had been a change from perennial to annual grasses. The rainfall during
the past ten years has been substantially lower than the overall mean, which correlates with
stakeholder information that vegetation change is as a result of a decrease in rainfall. The
deleagtes felt that the construction of Freidenau dam had had a major impact on veld
conditions.

**Water**
Low rainfall has also led to the decrease in quantity and increased salinity of water from the
beginning of the 20th Century. One farmer reported that over the past 30 – 40 years, seven
springs on his farm dried up completely. He also indicated that the number of dry boreholes
on his farm increased from 35 – 40 during this period.

According to stakeholders, less rainfall and heavy abstraction of ground water has
increased salinity, which became detectable ten years ago and is increasing.

Runoff should show a comparable trend to rainfall figures, however records indicate that this
trend changed in the 1970s and runoff decreased by 60% while rainfall only decreased by
16.8%. As this was the time that many of the dams were built we could argue that the dams substantially decreased the runoff rate.

All the farmers in the upper Kuiseb are reliant on rainfall for their existence. If rainfall decreases, they will have to cut down on livestock and wildlife numbers. A number of tourism ventures have started recently which could take some pressure off the environment by lowering the pressure on water recharge and grazing. Tourism ventures are less vulnerable to variable rainfall.

Farmers indicated that they had always applied management practices such as rotational grazing. There is no bush encroachment in the upper Kuiseb and fire is not used as a management tool. Sheet erosion is more severe than wind erosion and causes siltation in the dams and rivers downstream.

Rainfall is the main variable that influences the state of the environment in the upper Kuiseb. The Friedenau dam in particular causes a significant decrease in the amount of runoff, especially in low rainfall years.

**Recommendations:**

- The number of dams and boreholes per farm should be registered with Ministry of Agriculture.
- The demand that a dam satisfies and the effect it has on the downstream flow should be assessed.
- The role of Friedenau Dam needs to be reviewed.

**State of the environment in the middle and lower Kuiseb**

The Kuiseb River is a vital linear oasis in the central Namib. The water table below the riverbed and floodplain, which is usually replenished by the annual floods, is a precondition for the growth of the riparian forest.

The Topnaars have inhabited the banks of the middle and lower Kuiseb for at least 300 years. Originally the riverine habitat provided nearly everything they required to meet their daily needs but in modern times, many have moved to Walvis Bay and the total number of settlements along the river has decreased.

The objectives of this part of the study are to determine the state of environment of the middle and lower Kuiseb with reference to the vegetation, soil and water, with emphasis on the following:

- Change in vegetation, particularly death and regeneration of trees
- Soil types and infiltration rates
- Availability of water to the Topnaar community and their livestock.
There is domestic stock in every Topnaar village, including donkeys, goats, sheep and cattle. Signs of intense use are indicated by a visible browseline along stretches of the river. Preferred browse species were *Faidherbia albida*, *Salvadora persica* and *Tamarix usneoides* in that order.

**Browsing impact on the three woody species:**
- All tree species tended to be grazed more around the villages
- Vegetation is heavily grazed near any water point and all new seedlings and pods are eliminated
- At villages east and west of Gobabeb, a vegetation study showed that the further one goes from a settlement, the more vigorous the vegetation.
- 68% of *F. albida* had pods on the branches or on the ground
- Of these, 70% only had pods on the trees.

The trees’ vigour decreased as we moved westwards towards the lower Kuiseb, indicating that land degradation is more severe there. This could be due to the heavier water abstraction, larger stock numbers and the fact that floods only reach that part of the Kuiseb in heavy rain years.

During workshops held at two Topnaar villages, participants said that the soil type had changed from clay to sandy soil over the past 10 years. Infiltration rate is higher in the riverbed than on the banks, although the higher levels of silt on the river banks will allow them to hold more water for longer, giving trees a chance to germinate.

The residents maintain that the changes along the river, especially the trees dying, allow sand from the dunes to be blown into the river and the silt in the river to be easily washed away by light floods. Desert sand is found in areas that once were said to be highly productive.

It is expected that under natural conditions an overall equilibrium is needed between groundwater recharge and discharge. Lowering of land levels usually associated with pumping of groundwater can result in poorly consolidated sediments which in turn can cause compaction. Once this occurs, the land cannot return to its former condition, even if an effort is made.

Before the 1980s, the Topnaar used hand dug wells of about 3m deep, which provided them with good quality water for human and livestock consumption. In the early 1980s the government had to drill boreholes as they could find no water, even at a depth of 18m. They have not decreased their numbers of stock despite lack of water and changing vegetation cover.
The two aquifers in the lower Kuiseb are essential sources of water for the two coastal towns of Walvis Bay and Swakopmund. The water supply for the latter is supplemented with water from the Omdel aquifer in the Swakop River. Presently water demand exceeds the supply potential of the Kuiseb aquifers.

The vegetation in the lower Kuiseb is in a bad condition, with trees observed to be dying. Three main factors cause the changes in vegetation:

• Water abstraction
• Agricultural practices
• Variable rainfall

Change in soil type is the result of erosion. Water supply in the river is less abundant than in the past and the drop in the water table has caused the changes in the vegetation.

**Recommendations:**

*Middle Kuiseb catchment*

• The effects of reduced flood rates on recharge and the environment should be monitored
• Abstraction should remain limited for local use only

*Lower Kuiseb catchment*

• NamWater should review their assessment of “sustainable yield” considering that this study determined the preliminary water reserve value at almost 30% lower than their value
• The effects of reduced flooding, abstraction and other factors need to be studied in detail and monitored closely
• A cost-benefit study on the impacts of abstraction on the aquifer and environment needs to be conducted.

**Natural resource economics**

**Case study: urban area attached to the Kuiseb catchment**

The increasing demands for water in the coastal towns of Walvis Bay and Swakopmund, largely driven by a high immigration rate in addition to the natural growth rate, means that over-abstraction of the available water sources, namely the Kuiseb and Omaruru aquifers will continue. This has led to a severe drop in groundwater level with accompanying negative ecological and socio-economic impacts on the surrounding environment. Economic growth will support this trend as more and more development takes place around the Economic Processing Zone (EPZ) and the harbour as well as within the fishing industry.
The main objective of this section of the study was to determine whether costing and pricing reflect the scarcity of water and to suggest means for improving aspects such as pricing policies. This study also aims to determine a water reserve to enable informed planning.

**Conventional determination of aggregate demand**

Two main ideas drive this definition:
1. Requirements
2. Needs
   - The current demand for water is assumed to be mostly determined by the numbers of users of different types
   - The future demand is estimated based on the projected growth rates of each user group
   - Usage requirements are derived from these estimates including additional water that is not accounted for.

Weakness of this method in practice:
The demand estimate frequently exceeds the actual pace of growth of sales and unaccounted for water for a longer period than expected. This leads to lower revenues than expected and leaves many utilities short of the necessary funds to meet their financial obligations.

**Alternative determination of demand**

An international water conference held in Ireland in 1997 endorsed the idea that:
Water is an economic as well as a social good and should be managed as such.
Thus water demand is based primarily on:
1. *The value of water to the users*
The more valuable the water, the more will be purchased.
2. *The price of water to be paid by the users*
The higher the price, the less will be purchased.
3. *The users’ income*
The greater the income, the more will be purchased.
4. *The availability and price of water from other sources*
If water is equally accessible but lower in price from the utilities than from alternative sources, the more water will be purchased from the utilities.
The alternative method is useful in the case of Walvis Bay, where the demand for water is increasing in the face of water scarcity and thus it would be useful to look at the demand over the years from the coastal area.

Water consumption in Walvis Bay in cubic meters

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<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Water demand</td>
<td>3906310</td>
<td>4192449</td>
<td>4668488</td>
<td>4728067</td>
<td>4571496</td>
<td>4436786</td>
<td>4651386</td>
<td>4722425</td>
</tr>
<tr>
<td>% change</td>
<td>2.7</td>
<td>3.2</td>
<td>4</td>
<td>3.8</td>
<td>3.1</td>
<td>2.7</td>
<td>2.8</td>
<td>2.73</td>
</tr>
</tbody>
</table>

Source: Municipality of Walvis Bay 2000

Unaccounted for water in Walvis Bay varied from 13.9% to 18.2% over a period of six years.

The cost of water for Walvis Bay in Namibian Dollars

<table>
<thead>
<tr>
<th>Years</th>
<th>Increase</th>
<th>0-15m³</th>
<th>16-25m³</th>
<th>25-85m³</th>
<th>+85m³</th>
<th>Business</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>93/94</td>
<td>45%</td>
<td>0.58</td>
<td>0.7</td>
<td>1.04</td>
<td>2.2</td>
<td>1.32</td>
<td>1.17</td>
</tr>
<tr>
<td>94/95</td>
<td>32%</td>
<td>0.85</td>
<td>1.14</td>
<td>1.51</td>
<td>2.92</td>
<td>1.81</td>
<td>1.65</td>
</tr>
<tr>
<td>95/96</td>
<td>32%</td>
<td>1.11</td>
<td>1.5</td>
<td>1.99</td>
<td>3.85</td>
<td>2.38</td>
<td>2.17</td>
</tr>
<tr>
<td>96/97</td>
<td>40%</td>
<td>1.33</td>
<td>1.89</td>
<td>2.77</td>
<td>5.87</td>
<td>3.14</td>
<td>3.12</td>
</tr>
<tr>
<td>97/98</td>
<td>54%</td>
<td>2.16</td>
<td>2.8</td>
<td>4.27</td>
<td>8.54</td>
<td>4.27</td>
<td>4.41</td>
</tr>
<tr>
<td>98/99</td>
<td>25%</td>
<td>2.7</td>
<td>3.5</td>
<td>5.34</td>
<td>10.68</td>
<td>5.34</td>
<td>5.51</td>
</tr>
<tr>
<td>99/00</td>
<td>30%</td>
<td>3.51</td>
<td>4.55</td>
<td>6.94</td>
<td>13.88</td>
<td>6.94</td>
<td>7.16</td>
</tr>
</tbody>
</table>

With price increasing, water is currently priced only for its production cost and subsidised for domestic use. For the water budget to break even, a 65% increase in tariffs is required for this current year.

According to the municipality of Walvis Bay, the purchase price of water from bulk suppliers increased by 120% in 1999/2000, so even with a 65% increase in tariffs the municipality will only be able to cover its supply cost and none of the external costs such as damage to the environment and downstream ecosystems and opportunity costs. These latter costs are carried by the taxpayers and the economy of the country.

The socio-economics of the Topnaar community

**Recommendations:**

1. Demand Management: this strategy creates incentives for more efficient and conservative water-use
2. Water policy: pricing policy should be considered as an important element of water demand management – consumers respond to price changes.
3. Water tariff adjustments: water should be priced at its replacement cost in order to stress its true value and reflect its scarcity.
4. Subsidy removal: charges should adequately cover the cost of water supplied to those who can afford it. In fact, prices should be charged for the water itself as well as the cost of the infrastructure to provide it.
There is evidence of hunter-gatherers inhabiting the lower Kuiseb catchment area for the past 2,000 years. Over the last thousand years, the economy of these early inhabitants diversified to include domestic farming. By the mid 19th Century the Kuiseb delta people were known as the Topnaar - a translation of the Nama name #Aonin, meaning people of a marginal area. A few of the early accounts by settlers describe the !Nara melon as an essential source of food and water for the Topnaar.

This section of the study outlining the socio-economic situation of the Topnaar community living along the Kuiseb, who are entirely dependent on available resources to meet their basic daily needs, concentrates on four main aspects with water as a cross-cutting issue:

- Demographics
- Agricultural practices (mainly livestock)
- Overview of natural resources
- Overview of other resources e.g. pensions and employment.

No reliable data on population mobility, birth or mortality rates are available. In 1966, researchers at Gobabeb estimated that the total population of the lower Kuiseb was about 130 people in eight settlements. However, the 1991 census recorded 313 people living in nine villages. A 1994 study showed that there were 13 settlements with 428 people spaced between two and 15km stretching 130km along the northern bank of the river. There are more males than females living along the river, especially those between the ages of 20 and 45.

As in all other rural areas in Namibia, the Topnaar communities depend on natural resources for the livelihoods. During two workshops, participants identified the following resource ranking for Soutrivier and Rooibank.

<table>
<thead>
<tr>
<th>Resources</th>
<th>Soutrivier</th>
<th>Rooibank</th>
</tr>
</thead>
<tbody>
<tr>
<td>!Nara</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Livestock</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wood/trees</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Pension</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Maize meal</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Although !Nara was ranked second in importance, residents of Rooibank indicated that they are expending more energy on livestock farming as it was more practical. One resident though, said !Nara seeds were his only source of income and the plants were thus very important to him.

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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>78</td>
<td>105</td>
<td>123</td>
<td>160</td>
<td>161</td>
<td>163</td>
</tr>
<tr>
<td>Goats</td>
<td>1442</td>
<td>1615</td>
<td>2413</td>
<td>2507</td>
<td>2231</td>
<td>2374</td>
</tr>
<tr>
<td>Donkeys</td>
<td>63</td>
<td>64</td>
<td>90</td>
<td>118</td>
<td>116</td>
<td>120</td>
</tr>
<tr>
<td>Horses</td>
<td>0</td>
<td>215</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Sheep</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>22</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Pigs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Number of livestock kept by Topnaars
Goats are the most important livestock as they are used for meat, milk and income (mats and belts are sold in Walvis Bay). Some participants mentioned that they also farm with chickens and sheep. Livestock has become more important as the use and availability of !Nara plants decline.

Indigenous !Nara melons have been used in different ways for many years, although they can no longer be used as a subsistence food because of the increasing inaccessibility of the plants. Presently only a handful of individuals move to the Kuiseb delta each summer and are driven by the cash incomes earned from selling the pips in Walvis Bay. Only sufficient melons are collected to make a few hundred dollars to use as cash for school fees or to buy goats. The decline in the use of !Nara plants was perceived as being caused by the fields moving away from the people.

*Euclia pseudebene* is the main species of tree used for firewood, while *Faidherbia albida* and *Acacia erioloba* are important for livestock fodder.

The Topnaar indicated that they would like to live with wildlife as their forefathers did but that this was made impossible by the proclamation of the Namib-Naukluft Park, which prevented them from hunting. Tourism, while residents were aware of it, was not considered an option for income generation.

Formal employment generates income for Topnaars working at Gobabeb, the NamWater facility at Rooibank and in Walvis Bay. Those employed formally, send remittances home to those remaining in the villages.

The decrease in groundwater level affects the Topnaar in many different ways. As they use a very small amount of water – less than 0.1% of the water abstracted from the lower Kuiseb – they have no significant effect on the groundwater levels.

**Setting the reserve**

An environmental reserve for ephemeral and perennial rivers can be set according to different criteria. It is essential that we know the reference conditions and present status of the reserve. In setting a reserve in this study we tried to strike a balance between the environment on one hand and development on the other so that they could complement one another.

**Present status assessment of the resource**

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<thead>
<tr>
<th>Resource</th>
<th>Lower Kuiseb</th>
<th>Middle Kuiseb</th>
<th>Upper Kuiseb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level (below surface)</td>
<td>0-4m</td>
<td>0-3m</td>
<td>Unknown</td>
</tr>
<tr>
<td>Water quality</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Flora</td>
<td>Figs</td>
<td>Figs</td>
<td>Perennial grassland, narrow riparian vegetation, woody forest</td>
</tr>
<tr>
<td></td>
<td>F albida</td>
<td>F albida</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A erioloba</td>
<td>A erioloba</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E pseudebene</td>
<td>E pseudebene</td>
<td></td>
</tr>
</tbody>
</table>
Rooibank A aquifer is made up of varying proportions of reworked aeolian and fluvial sands, gravel and silt. The maximum capacity of the aquifer is estimated to be 20Mm$^3$.

Rooibank B aquifer is composed predominantly of aeolian sand with extensive intercollations of impermeable fluvial silts with a maximum capacity estimated at 126Mm$^3$.

Assessment of the resource in terms of land use, water use and socio-economic conditions.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Lower Kuiseb</th>
<th>Middle Kuiseb</th>
<th>Upper Kuiseb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use</td>
<td>Livestock farming</td>
<td>Livestock, Naukluft Park, Gobabeb</td>
<td>Livestock farming, guest or tourist lodges, small scale cropping</td>
</tr>
<tr>
<td>Water use</td>
<td>Domestic use including livestock</td>
<td>Domestic use including livestock</td>
<td>Domestic use including livestock</td>
</tr>
<tr>
<td>Socio-economic conditions</td>
<td>Income from goat sales, !Nara sales, pensions, NamWater jobs and money from those working in coastal towns.</td>
<td>Income from goat sales, !Nara sales, pensions, Gobabeb jobs and money from those working in coastal towns.</td>
<td>Productivity of farms is decreasing leading to a reduction in the employment of the local inhabitants of the area.</td>
</tr>
</tbody>
</table>

The total capacity of the Kuiseb aquifer is 280Mm$^3$. Of this, 150 Mm$^3$ is from Roobank B and Dorop south. In 2000 the abstractable water and the ground water table are again declining and now stand near 38Mm$^3$. The capacity of the Rooibank aquifer for abstraction depends upon recharge. Abstraction increased from 6.7Mm$^3$ to 9.9Mm$^3$ between 1987 and 1998. If this rate of abstraction continues, the aquifer will be exhausted by 2014 if a recharging flood does not occur (a 23% chance).

The current rate of abstraction is 7.3Mm$^3$, exceeding the sustainable yield of the aquifer by 3.1Mm$^3$.

**Recommendations**

- Reduce the abstraction rate to 4.2 Mm$^3$ per year in order to reduce the rate at which the water table is dropping, which will allow the aquifer to recharge during floods, benefitting the woody vegetation in the river.
- Alternative sources of supply, such as a desalination plant, must be found while the aquifer recharges.
- Undertake an in depth study of the water reserve. Our results suggest that by reducing abstraction to 40% of the recharge rate, the water level could recover to reference level of 5m below surface.
- A sustainable water use policy should be implemented, suitable to the Kuiseb catchment.
• The Kuiseb directly above Swartbank should be declared a non abstraction zone.
• Establish a Water Demand Management Committee with all stakeholders that use and manage water from the lower Kuiseb aquifer.
• Cost water according to real “price” including environmental value.

**Bibliography and references**

Desert Ecological Research Unit of Namibia. *Gobabeb general questions and answers* Pamphlet. DERU. Gobabeb.