CHAPTER 6 INITIAL ENVIRONMENTAL EXAMINATION

The overall objective of this Study is to carry out the investigation of the groundwater flow and recharge mechanism in the Stampriet Artesian Basin, and to formulate a groundwater management plan for sustainable groundwater development. The Study as such is in reality an environmental assessment, which should lead to achieving and maintaining sustainable groundwater utilization in the Area. In view of the paucity of environmental base line studies in the area, this Study will essentially comprise an environmental audit.

The detailed description of natural and social environment of the Study Area shall be elaborated in Chapter 2 of this report. The project proposed through this Study is not infrastructure development project in the usual sense, but rather a resource assessment. Therefore, in this chapter, the focus is placed on the examination of interrelationship between the groundwater management and the environmental issues, which potentially have impacts on the groundwater as a natural resource, and vice versa, have potential to receive impacts from activities related to groundwater management.

6.1 Screening and Evaluation

The Initial Environmental Examination was carried out in order to identify the environmental impacts on areas, which will be affected by the groundwater management plan, and in reverse, the potential impacts on groundwater resource imposed by environmental factors. The identification and screening were conducted in line with the “Environmental Management Act of Namibia (1988)” and the Guidelines prepared by JICA (1992). The examined environmental items were adopted from the JICA Guidelines, for each of which the degree of impacts was evaluated in five (5) categories. In Tables 6-1 to 6-3 these impacts are summarised and evaluated for the Social Environment, the Natural Environment, and potential Pollution, based on the information as described above. It is evident that the main study of the sustainable potential of the Stampriet Artesian Basin will provide the necessary basis for the environmental assessment.

The following section describes the environmental items, which was concluded in this IEE to have impacts at any level regarding the groundwater use and its management.

6.1.1 Social Environment

1) Economic Activities: Loss of production base (land etc.) and change of economic structure

Economic activities in this area are mainly related to farming, tourism and trading (at towns). The farming activities involve stockbreeding and agricultural crop production by irrigation. The alternative of groundwater management plan proposes the reduction of irrigation water by 30% of the current water use of the region. If this is applied, it is estimated that the agricultural yield shall accordingly be constrained and lead to the potential deceleration in the economic growth in the Area. One possible mitigation measure on this issue is to shift the crops to those with higher market values. In this regard, natural resource accounting (Lange, 1997) could be applied to determine the domain where a reduction in water use could possibly be effected with the least impact on the economy of the study area. The specific study of the Stampriet Artesian Basin (Lindgren, 1999) may serve as a guideline in this regard. The detail of this subject is included in Chapter 8, Conclusion and Recommendation.

(1) Causes of Impacts

- Constraints on the conventional water use

(2) Possible Environmental Impacts

- Change in agricultural productivity per unit farmland

(3) Factors for Evaluation

- Economic return per cubic meter of water used for each economic activity

(4) Measures

- Measuring of actual water use by means of water meters
- Generally allow most economical use of water resource (including the change of conventional irrigation scheme)
- Restrict least economical water use
- Improve the economic productivity per unit farm land by the conversion of crop species to cash crops

(5) Related Subjects for Study

- Socioeconomic impact of restricting water use(s)
- Possible repercussions of crop conversions

2) Water Rights and Rights of Common: Obstruction of irrigation and water rights

The legal situation with regard to water in Namibia is still regulated by the Water Act of 1956 (Act No 54 of 1956). Surface water is controlled by various clauses in the Water Act and permits are required for example for the removal of any water from a catchment, or for the construction of any water controlling structures in rivers. In terms of this legislation, groundwater can also be controlled by the proclamation of subterranean water control areas. Outside such proclaimed areas, landowners have full access and rights to the groundwater underlying their property. However, this is essentially in conflict with the Constitution of Namibia and a new Water Act is being drafted for giving the Government full control over groundwater.

The Stampriet Artesian Basin, described as the Windhoek - Gobabis - Mariental - Keetmanshoop Artesian Area, was proclaimed a Subterranean Water Control Area by Government Notice No 302 of 1 October 1955. Subsequently, adjacent areas, including most of the surface catchment areas of the rivers flowing through the Stampriet Artesian Basin, were declared subterranean water control areas: the Windhoek - Gobabis Subterranean Water Control Area (Government Notice No 189 of 6 February 1970) and the Windhoek - Gobabis Subterranean Water Control Area (Extension) (Government Notice No 47 of 26 March 1976). The upper reaches of the White and Black Nossob fall outside these subterranean water control areas, which imply that, at this stage, no control can be exercised over groundwater abstraction in this area.

At present, groundwater is abstracted without any particular control measure. The legislative control of water use itself does not have any legal conflict, but in practice, it may accompany a social conflict in the subject of water right. However, since the groundwater is a natural resource with highly public significance, the sustainable water use should be carried out all through. To achieve the goal, a step-wise implementation and public education on water use and taxation may mitigate the social impact in this regard.

(1) Causes of Impacts

- Obstruction in irrigation water use by the legislative control

(2) Possible Environmental Impacts

- Reduction of agricultural production
- Public opposition on taxation and regulation of water use

(3) Factors for Evaluation

- Long-term water level trend determination at several points
- Determine sustainable groundwater potential

(4) Measures

- Step-wise implementation of water use regulation & taxation
- Establishment of intensive regulation zone
- Public education/information on the water use and regulation

(5) Related Subjects for Study

- Most economical use of water (over and above drinking water needs), possibly making use of natural resource accounting (Lange, 1997)

3) Public Health Condition: Worsening of health and sanitary condition due to generation of wastes and appearance of harmful insects

Increased population numbers and the development of towns lead to increased water use and the generation of wastewater. Though the impact of wastewater on groundwater quality has not been reported so far, the wastewater discharge and treatment should be monitored for the public health aspect. Wastewater discharges are controlled and where available, permits for wastewater treatment systems are listed in the Appendix E in the supporting report.

According to the initial examination of the result of hydro-census conducted in this Study, the use of fertilizer is assumed to be very limited both in area and quantity. Accordingly, at present, the risk of groundwater contamination from the fertilizers has not been reported. However, certain agricultural chemicals that can be harmful reach these aquifers and enter the groundwater resource. Others, such as fertilizers, may cause eutrophication of surface water supplies. Further examination and monitoring is expected for the detection of long-term impact of these factors on the groundwater resource.

(1) Causes of Impacts

- Water pollution
- Use of potentially harmful agricultural chemicals

(2) Possible Environmental Impacts

- Increase in water-related illnesses

(3) Factors for Evaluation

- Present occurrence of potentially water-related illnesses, e.g. diarrhoea, malaria
- Present usage and usage trends of agricultural chemicals

(4) Measures

- Control of wastewater discharges for protection against groundwater pollution
- Control of potentially harmful agricultural chemicals

(5) Related Subjects for Study

- Water-borne diseases, e.g. malaria, may cause a minor problem from time to time and it is considered important to obtain statistics for considering the need for further actions.
- It is potentially possible that groundwater pollution from wastewater discharges may occur which could cause water-related illnesses.

4) Waste: Generation of construction waste, surplus soils, sludge, domestic waste, etc.

No Namibian guidelines could be found for (solid) waste disposal activities. Pollution derived from waste management and disposal will not be a consequence of groundwater development and its management, but of existing anthropogenic activities. Depending on the nature of the disposal sites, they may have an effect on groundwater quality in the phreatic aquifers, and could eventually impact on the use of groundwater. Though the adverse impact has not been reported so far, a through investigation and constant monitoring and management are necessary for the prevention of contamination impacts from waste disposal.

(1) Causes of Impacts

- Waste disposal activities and sites which do not comply with minimum requirements for environmental protection needs

(2) Possible Environmental Impacts

- Groundwater pollution
- Littering

(3) Factors for Evaluation

- Quantities of waste generated
- Types of waste (apart from domestic wastes)

(4) Measures

- Informing local authorities on hazards involved
- Providing minimum guidelines (from other countries)

(5) Related Subjects for Study

- Sewage sludge disposal

6.1.2 Natural Environment

1) Groundwater: Lowering of groundwater table due to overdraft and turbid water caused by construction work

The lowering of the groundwater table is already an established trend for a large part of the study area. This may be due to a multitude of reasons, including, inter alia, a reduction in groundwater recharge, and possible overexploitation. Once the sustainable potential of the Stampriet Artesian Basin has been determined, measures will have to be implemented to ensure that overdraft is eliminated. This aspect will need detailed investigation and already forms part of the general project brief. Should the sustainable management plan is established and effectively enforced, only positive impacts are expected on the groundwater recharge of the region.

(1) Causes of Impacts

- Control on overexploitation of groundwater
- Increased recharge of aquifers

(2) Possible Environmental Impacts

- Maintaining the groundwater table in phreatic and confined aquifers
- Repression of saltwater intrusion from overlying or underlying aquifers, into aquifers with good quality usable groundwater

(3) Factors for Evaluation

- Sustainable water resource potential of the whole aquifer system
- Water abstraction trends
- Water use for irrigation
- Water quality trends and saline water intrusion
- Areas of natural leakage

(4) Measures

- (Since the proposed management plan is expected to lead only positive impact on the Stempriet Artesian Basin, no further mitigation measure shall be

required except a regular monitoring and management)

(5) Related Subjects for Study

- Water-use situation study (economically and population induced)
- Water quality evaluation
- Isotope studies for determining aquifer recharge and sustainable yield
- Identify leaky boreholes and find solution for providing permanent casings

2) Fauna and Flora: Interruption of reproduction or extinction of species due to change of habitat condition

According to Griffin (pers. comm., 8 November 1999) a change in the natural vegetation will eventually affect the whole ecological chain. The Kalahari ecosystem in the area around the Auob and Nossob Rivers has been described by Leser (1971). Thomas and Shaw (1991) give a general description of the Kalahari environment.

The Giess Vegetation Map of Namibia (1971) is the only countrywide survey that exists for Namibia. Presently, the National Botanical Research Institute of Namibia is carrying out a project to update the Vegetation Map of Namibia at a scale of 1:1 000 000 (Strohbach and Sheuyange, 1999). The surveying has started in the Karas and Hardap regions during the 1997 growing season, and it has covered the part of the Stampriet Artesian Basin to the east of 18 ° E and south of 24 ° S. Although no quantitative data is available, it was postulated (Strohbach, pers. comm., 10 November 1999) that the Kalahari is a relatively young desert, as only 10 to 15 plant species were found per 1000 m^2 compared the Karas Mountains where approximately 60 species per 1000 m^2 were recorded. It has to be noted that the climate in the Karas Mountains varies considerably and would lead to a greater diversity of species.

The alien Prosopis sp. is responsible for destroying the habitat of the natural vegetation. The camel thorn trees (Acacia erioloba) are very sensitive for such invasions and they would seem to be affected in many places. Strohbach (pers. comm., 1999) has the impression that the Prosopis will grow in areas, which have ample supplies of water. In the Auob River, where such invasions occur, perennial grass, Sporobolus tenulus, was found which usually occur in marshy conditions, e.g. around a spring. The extent and success of attempts to control the invasions are unknown.

With regard to the fauna in the Stampriet Artesian Basin, no specific study has been

undertaken. The closest area where any study was done is the Hardap Dam National Park. Draft tables were compiled of the occurrence of amphibians, reptiles and mammals (Griffin, 1999). This type of study was carried out for all national protected areas under the control of the Ministry of Environment and Tourism. As the Hardap Dam National Park covers an area adjacent to the Stampriet Artesian Basin, the data obtained from Griffin (1999) is included in Appendix D.

(1) Causes of Impacts

- Alien vegetation invasions
- Potential overgrazing at stock watering points

(2) Possible Environmental Impacts

- Reduction in numbers of plants and species, followed by a decrease in the numbers of and species of fauna
- Desertification

(3) Factors for Evaluation

- Changes in vegetation determined by satellite imagery or aerial photography

(4) Measures

- Control of alien invasive vegetation
- Control livestock numbers

(5) Related Subjects for Study

- Occurrence of Phragmites sp in the Auob River bed on the farm Schilflage, R143, approximately 100 m south of the entrance road to the farm house (Strohbach, pers. comm., 1999)
- Over grazing near, and trampling of vegetation at watering points (DRFN, 1997).

6.1.3 Pollution

1) Water Pollution

This project in itself will not lead to any significant pollution impacts. Pollution is expected to occur through anthropogenic activities, existing and new, and that should be controlled by applying the necessary regulations and also by providing information to the local councils and the public.

The provisions of the Water Act, 1956 (Act No 54 of 1956) are intended to promote

the maximum beneficial use of the country's water resources, and to safeguard public water supplies from avoidable pollution. For this reason, permit applications are required for potential polluting activities, such as wastewater treatment and waste disposal (see application form in Appendix E). See also the attached list of Towns (Appendix F) and the list of Guest Houses and other establishments (Appendix G) within the area, some of which have applied for wastewater discharge permits in terms of the Water Act.

(1) Causes of Impacts

- Potential causes are solid waste and sewage sludge disposal activities
- On-site sanitation

(2) Possible Environmental Impacts

- Deterioration of water quality in the phreatic aquifers

(3) Factors for Evaluation

- Extent of disposal activities (population related) and likely impact
- Control of permits for potential polluting activities

(4) Measures

- Inspection by Government authorities
- Information dissemination to the local councils and the public

(5) Related Subjects for Study

- Effluent standards (see Appendix H)

In Tables 6-1 to 6-3 these impacts are summarised and evaluated for the Social Environment, the Natural Environment, and potential Pollution, based on the information as described above. It is evident that the main study of the sustainable potential of the Stampriet Artesian Basin will provide the necessary basis for the environmental assessment.

Table 6-1 Screening for Groundwater Development: Social Environment

No	Environmental Item	Description	Evaluation	Remarks (Reason)
1.	Resettlement	Resettlement by land occupation (transfer of rights of residence, land ownership)	D	No resettlement is involved in the project.
2.	Economic Activities	Loss of production base (land etc.) and change of economic structure	B	Implementation of sustainable groundwater management may cause a change in the economic structure due to a potential need for reallocation of water according to basic needs and economic guidelines
3.	Traffic and Public Facilities	Impacts on existing traffic, schools, hospitals, etc. (e.g., traffic jam, accidents)	D	No permanent impacts are foreseen.
4.	Split of Communities	Separation of regional communities by hindrance of regional traffic	D	No infrastructure will be installed to this effect
5.	Cultural Property	Loss or deterioration of cultural properties, such as temples, shrines, archaeological assets, etc.	D	No infrastructure is planned that will have such an effect
6.	Water Rights and Rights of Common	Obstruction of fishing rights, irrigation and water rights	B	For sustainable groundwater development, water abstraction rights for irrigation may need to be reconsidered
7.	Public Health Condition	Worsening of health and sanitary condition due to generation of garbage and appearance of harmful insects	C	No impact negative caused by the study itself is foreseen. Groundwater quality is deteriorating in some areas due to leaky borehole casings.
8.	Waste	Generation of construction waste, surplus soils, sludge, domestic waste, etc.	C	The project will not cause any impact but existing and future anthropogenic activities can potentially cause pollution
9.	Hazards (Risk)	Increase in risk of cave-ins, ground failure and accidents	D	No impacts are foreseen. Precautions will be taken at the drilling sites to prevent any problems

6 - 10

Table 6-2 Screening for Groundwater Development: Natural Environment

No	Environmental Item	Description	Evaluation	Remarks (Reason)
10.	Topography and geology	Change of valuable topography and geology due to excavation and earth fill	D	No large-scale construction is planned in the initial stage of the project.
11.	Soil erosion	Topsoil erosion by rainfall after land reclamation or deforestation	D	No large-scale construction is planned for the initial stage of the project.
12.	Groundwater	Lowering of groundwater table due to overdraft and turbid water caused by construction work	B	The lowering of groundwater levels is already an established trend, which could be related to the overdraft, reduced recharge of aquifers, and/or leaky borehole casings. The project is aimed at sustainable use
13.	Hydrological Situation	Change of discharge and water quality due to reclamation and drainage	D	Spring flow already negligible. Thus, no negative impact from this project is foreseen. However, changes in the catchments of the rivers entering the Stampriet Artesian Basin will affect the water balance in the area.
14.	Coastal Zone	Coastal erosion and sedimentation due to littoral drift and reclamation	D	The area is situated far from the coastline and the ephemeral rivers are only linked very indirectly with the coast via the Orange River system
15.	Fauna and Flora	Interruption of reproduction or extinction of species due to change of habitat condition	B	The study will not affect the fauna and flora. However, significant changes in vegetation may be taking place due to alien plant invasions. Overgrazing and desertification may also need to be evaluated.
16.	Meteorology	Change of micro-climate, such as temperature, wind, etc., due to large scale reclamation and construction	D	No impacts foreseen.
17.	Landscape	Deterioration of aesthetic harmony by structures and topographic change by reclamation	D	No large-scale construction is planned.

6 - 11

Table 6-3 Screening for Groundwater Development: Pollution

No	Environmental Item	Description	Evaluation	Remarks (Reason)
18.	Air Pollution	Pollution caused by exhaust gas or toxic gas from vehicles and factories	D	Short term limited exhaust gas generation during exploration drilling and test pumping only
19.	Water Pollution	Water pollution of river and groundwater caused by drilling mud and oil	C	Environmental pollution will be limited by employing proper drilling control and management
20.	Soil Contamination	Contamination caused by discharge or diffusion of sewage or toxic substances	D	Impact due to existing and new systems are not related to project activities
21.	Noise and Vibration	Generation of noise and vibration due to drilling and operation of pumping machines	D	Short term exploration drilling and test pumping only
22.	Land Subsidence	Deformation of the land and land subsidence due to lowering of groundwater table	D	Following completion of this project, groundwater exploration will be managed
23.	Offensive Odour	Generation of offensive odour and exhaust gases	D	Short term limited exhaust gas generation during exploration drilling and test pumping only
Overall Evaluation: Either IEE or EIA is necessary for the project implementation?			NO	However, the environmental impacts on the water quality and water balance of the Stampriet Artesian Basin may be significant

6 - 12

6.2 Discussion

The ratings of the various environmental items as defined by JICA (1992) are evaluated in the following categories:

- A: Serious impact is expected
- B: Some impact is expected
- C: Extent of impact is unknown
  (Examination is needed. Impacts may become clear as study progresses.)
- D: No impact is expected. IEE/EIA is not necessary

As set out in the introduction to this report, the Study as such actually constitutes an environmental assessment for the Stampriet Artesian Basin. Accordingly, the project in itself will not lead to an environmental impact, but would rather lead to mitigation of any existing impact. For this reason, none of the 23 environmental items in the tables were evaluated as having a potentially serious impact ("A"-rating). The ratings given should be considered as the existing or potential future situation due to anthropogenic and other activities. All environmental items with a "B" rating reappear in Table 6-4 below, detailing a brief study plan and a few remarks.

The main thrust of the project is to determine the hydraulic relationships in the various aquifers as defined by means of the newly interpreted geology, and particularly the associated flow regimes in each aquifer. These findings will be supplemented with interpretations based on the water quality (chemistry and isotope) data in those areas where other information is unavailable or insufficient. Against this background, the environmental factors will have to be reviewed as the project progresses. For example, depending on the findings of the project with regard to the sustainable potential of the aquifer, it may be required that water rights have to be reallocated to conform to such potential of the aquifer. This will have to involve a detailed economic value assessment of the various water uses in the area, and the associated impacts.

The overall evaluation as set out above is summarised in Table 6-4, giving the evaluation for each item and a brief indication of the planned actions. These actions will be reviewed as the project progresses and further information becomes available.

Table 6-4 Overall Evaluation for Groundwater Development

No	Environmental Item	Evaluation	Study Plan	Remarks (Reason)
2.	Economic Activities	B	Determination of sustainable potential of artesian basin *(from main project)* Assessment of the economic value of groundwater for the different uses *(from DWA studies)* Possible reallocation scenarios *(DWA)*	Sustainable groundwater potential may be exceeded, requiring reallocation of water according to basic needs and economic guidelines
6.	Water Rights and Rights of Common	B	Water abstraction rights for basic uses, stock watering, irrigation and other purposes may need to be reconsidered *(DWA) (see item 2. above)*	If the sustainable groundwater potential is exceeded, water abstraction will have to be reduced
7.	Public Health Condition	C	Study use of potentially harmful agricultural chemicals Listing of permits issued by DWA for sewage and waste disposal Survey of sewage and waste disposal practices potentially harmful to health Establish potential impact of water quality deterioration due to leaky borehole casings	The JICA project will not create any health hazard, but existing health hazards in the study area which are identified during the study will have to be considered *(see also items 8. and 19. below)*
8.	Waste	C	Present and potential future anthropogenic activities producing waste need to be recorded *(see also items 7. and 19.)* Determine types and quantities of waste (apart from domestic waste)	The JICA project itself will not produce waste of any significance, but existing and future activities may present a hazard
12.	Groundwater	B	Evaluate abstraction trends and permanency of groundwater decline *(from main project)* Consider determining extent of impact of reduced piezometric heads on borehole leakage into/from artesian sandstones *(hydraulic modelling)* Estimate the extent of leakage due to corroded/inadequate borehole casings	Indications are that groundwater levels are receding, e.g. more and more boreholes, which were free flowing, stopped and are being pumped. Reducing/increasing water usage will affect piezometric heads and losses from the artesian aquifers
15.	Fauna and Flora	B	Estimate the role of the alien vegetation invasion with regard to groundwater losses, particularly in those areas directly affecting the natural recharge of the Karoo sandstones Consider the need for the regulation of overgrazing and desertification	Removal of alien vegetation should reduce groundwater losses and increase the recharge and sustainable potential of the artesian basin
19.	Water Pollution	C	Estimate the order of magnitude of waste generation, sewage treatment and disposal *(see items 7. and 8.)* Investigate the extent of water quality deterioration due to leaky borehole casings Develop guidelines for identifying leaky borehole casings and remedial measures, including the sealing/grouting of such boreholes	Impacts due to existing and new sewage and waste disposal systems do not related to this project but need to be recorded and managed. Leaky borehole casings may contribute significantly to water quality deterioration

6 - 14

6.3 Conclusions

As such, this project should only have a beneficial impact on the environment, as the outcome should indicate what measures are required for sustainable use of the groundwater and for resource protection. Aspects, which should receive attention, are, for example:

- the presumed long term lowering of the groundwater table
- the hydrological situation in the upstream river catchments and the effect on the water balance of the Stampriet Artesian Basin
- the natural recharge situation and the need for artificial groundwater recharge, in which case further environmental assessments will be needed
- alien vegetation invasions, particularly of the river valleys
- reconsideration of the usage of water for different economic purposes
- reconsideration of water abstraction rights
- considering environmental impact assessments where irrigation water use exceeds 100 000 m^3/a as proposed in the guidelines of the Department of Water Affairs
- leaky borehole casings and the associated water quality deterioration
- control over anthropogenic activities which potentially may pollute the soil and groundwater

6.4 Recommendations

It is recommended that the outlined study plans are followed for those four environmental items having a “B”-rating (see Table 6-4), viz. economic activities, water rights & rights of common, groundwater, and fauna & flora. The definitions of these items are as given in Table 6-1 to 6-3.

It is also recommended that the three environmental items with a “C”-rating (Table 6-4), i.e. public health condition, waste, and water pollution, is reviewed as the project progresses and further information becomes available.

CHAPTER 7 GROUNDWATER MANAGEMENT PLAN

7.1 Concept of Groundwater Management

The most desired form of groundwater use is to abstract the necessary volume of water without a groundwater level reduction or land settlement.

In the study area, the aquifers of Kalahari, Auob, and Nossob are used to abstract water for domestic, stock, and irrigation purposes. The total abstraction volume (0.015×10^9 m^3) is very small compared to the total groundwater storage (357×10^9 m^3). However, natural recharge cannot be expected to fill the aquifers due to the limited precipitation and complex hydrogeological features of the area. Therefore, as has been made clear by the long-term monitoring carried out by DWA, the groundwater level has continuously decreased, resulting in a negative water balance. Furthermore, the groundwater withdrawal in some areas shows a marked increase, causing a severe decrease in the groundwater level.

In the study area, the largest groundwater consumers are the irrigation farms. However, inefficient water use would not appear be the cause since the irrigation method has already been converted from flood irrigation, which involves a large water loss, to more efficient sprinkler methods and/or drip irrigation. The significant increase in the abstraction volume is therefore considered to be as a result in the increase of irrigation farming and over-extraction beyond the permitted rate.

As a result of the study, as examined in Chapter 3 of this report, groundwater levels in the Kalahari aquifer could be depleted in the area around the Auob River catchment in the next 30 years. In other words, groundwater will soon be dried up in the aquifer where the community has mostly depended on it so far. In order to maintain the groundwater level of the aquifer, a 50% reduction of the current water use is required (See Chapter 3). On the other hand, changes in the groundwater level in the Auob aquifer have not been estimated to be as drastic in this time span.

Considering that the current socio-economic system of the study area is dependent on groundwater, a sudden reduction of water use by 50% is therefore not practical.

Accordingly, the study shall propose that the groundwater management plan to contain both sustainable use and practical application aspects, which are acceptable to the government and the public of the area.

7.2 Optimum Groundwater Use in the Study Area

7.2.1 Target Groundwater Extraction

According to the groundwater simulation carried out in this study, it is estimated that a depletion of the Kalahari Aquifer would take a period of 70 to 80 years if current extraction is reduced by 30%. A 50% reduction in the pumping rate is required to maintain the current groundwater level. The groundwater model applied here is based on the existing data and information, and needs further improvement for future data compilation. When the model is upgraded in the future, the depletion period may change accordingly. The ultimate purpose of the groundwater management plan is to enable the sustainable use of the aquifer. However, in practice, agricultural production provides the basis for most livelihoods in the area. In this regard, as the first step of the management plan, it is recommended that there is a reduction 30% of the current extraction rate. This will be achieved upon the implementation of several action plans as described below. This is the adaptive management plan to achieve the target reduction rate of 30%, as well as adjusting the required reduction rate based on the continuous monitoring of the effectiveness of the extraction control.

7.2.2 Environmental Consideration

Although water abstraction is inducing the gradual decrease in the water table in the study area, no other environmental impact is evident. Besides, a groundwater management plan would not involve novel developments of the groundwater resource, but rather would mitigate the decreasing tendency of the groundwater level. As a result, it would be considered to have positive impacts on the environment.

7.3 Groundwater Management Plan

7.3.1 Alternatives to Mitigation Measures

The study area is designated as Subterranean Water Control Area by Government Notice No 302 of 1st October 1955. According to this, the following three activities are required upon extracting groundwater from the study area:

(i) To obtain permission for water extraction.
(ii) To obtain permission for the operation of irrigation on farms larger than 1 ha.
(iii) To report the total extraction volume per year.

Although the above subjects are the most essential parts in the groundwater management plan, they are hardly followed in practice. The actual situation regarding

items (i) and (ii) were made clear by the hydro census and DWA's data. The information regarding illegal wells and irrigation farms in the hydro-census data was provided on condition of penalty exemption. Therefore, the handling of these illegal water users needs careful consideration upon the formulation of groundwater management

For the sustainable use of the aquifers in the study area, a reduction in the current extraction rate is required. This is especially crucial in the Subterranean Water Control Area. In this area, as stated previously, countermeasures are necessary for the control of over-extraction beyond the aquifer capacity. In this regard, action plans for the reduction of groundwater extraction are proposed in Table 7.3-1. Both items for urgent implementation and for adaptive application are described. Not all the action plans are to be implemented, but mitigation effectiveness on the groundwater receding should be monitored for the feedback adjustment of the plans.

Table 7.3-1 Action Plans for the Reduction of Groundwater Use

No.	Priority	Action Plan	Contents	Remarks
1	◎	Enlightenment of sustainable groundwater use	To hold local explanation meetings in cooperation with Farmer Union	To allow understanding for the aquifer potential and the predicted depletion of groundwater under the current water usage.
2	◎	Observation of water extraction volume	To assure the through enforcement of reporting duty of well owners.	Compulsory installation of flow meter to all wells. The pumping rate shall be regularly reported. The reporting duty and meter installation shall be inspected.
3	◎	Review of permission system	To take back the current extraction permit and reallocate them to achieve the 30% reduction target	WW No. should be issued to all existing wells including illegal ones, and the reporting of extraction rate is made mandatory.
4	○	Reduction of irrigation area	To keep the permitted irrigation area	Present irrigation area; 546ha in Stampriet area (Area II in Fig.4-2) should be reduced to 399.5ha.
5	○	Conversion of cultivation crops	To promote the conversion of crops to those with higher market values with lower water demand.	In cooperation with Department of agriculture and Farmer Union, the possibility of crop conversion shall be discussed to allow understanding and cooperation of farm. The status of crop conversion shall be monitored.
6	○	Voluntary reduction by water users	To expect the farm operators to voluntarily conserve irrigation water as a result of public education.	Closely related with the public education (item No. 1), which require the cooperation with farmers organizations as Farmer Union.
7	△	Application of efficient irrigation method	To convert the irrigation method for promoting more efficient water use.	In cooperation with farms, irrigation area and method shall be studied. The annual pumping rate shall be monitored.
8	△	Pricing on groundwater	To charge on groundwater extraction to control the excessive water use.	Setting of a valid amount of water price should be examined based on the water value calculated in the study.

◎：Countermeasure for urgent implementation
○：Countermeasure for short-term implementation
△：Countermeasure for long-term implementation

7.3.2 Mitigation measures for the Reduction of Groundwater Extraction from Economic Aspects

A wide range of measures should be taken to control the water use such as raising awareness by education and information, legal measures and economic measures. However, considering the existing conditions of water use in the study area (refer to Chapter 4), this economic study focuses on the points mentioned below:

1) Conversion of cultivation crops
2) Application of efficient irrigation method
3) Reduction of irrigation area
4) Pricing of groundwater

1) Conversion of Cultivation Crops

To improve the water use efficiency from an economic perspective, reduction in the production of Lucerne and Cotton which require a lot more water than other crops and has lower added value compared to other crops is required. It is necessary to shift to high value added crops such as sweet melon, tomatoes, watermelon and other vegetables (Table 7.3-2).

Considering the farm size and the value added of crops, different scenarios of water reduction, all of which are realistic and efficient in the water use were simulated. It was examined how much water could be saved from conversion from Lucerne production into higher value added crops, while maintaining the same income of the farmers. In case farmers change their farming operation from Lucerne to Grape in Scenario 1-2 (changing ratio: 50 %) or from Lucerne to Maize in Scenario 2-1 (changing ratio: 100 %) the groundwater extraction will meet the short-term goal of a 30 % reduction in water use, which is the aim of this master plan. In Scenario 1-1 (changing ratio: 100 %) the groundwater extraction will attain the sustainable use level (68% reduction in water use).

Case 1 Lucerne → Grape

	Ratio of Changing Area	Reduced Water Volume (m^3)	Reduction Ratio
Scenario 1-1	100%	6,140,737	89 %
Scenario 1-2	50%	3,070,368	45 %
Scenario 1-3	20%	1,228,147	18 %

Case 2 Lucerne → Maize

	Ratio of Changing Area	Reduced Water Volume (m^3)	Reduction Ratio
Scenario 2-1	100%	1,917,569	28 %
Scenario 2-2	50%	958,784	14 %
Scenario 2-3	20%	383,514	6 %

Table 7.3-2 Value Added of Crops

Crops	Gross Income (N$/ha)	Total Cost (N$/ha)	Net Income (N$/ha)	Unit Water Consumption (m^3/ha)	Value Added (N$ /m^3)
Wheat	6,000	4,320	1,680	12,187	0.138
Lucerne	12,000	5,880	6,120	28,480	0.215
Maize	8,000	4,700	3,300	9,427	0.350
Cotton	11,000	5,360	5,640	16,507	0.342
Grapes	40,000	17,668	22,332	14,761	1.513
Sweet Melon	40,000	12,708	27,292	10,467	2.607

Source: MAWRD and Hardap Cooperative

2) Application of Efficient Irrigation Method

As Table 7.3-3 shows, micro irrigation methods such as Drip and Micro sprayer enable more efficient water use than with Sprinkler and Flood irrigation. Ideally irrigation water use can be saved by the application of more efficient methods.

Table7.3-3 Minimum Water Requirements for Different Crops and Irrigation Methods

Crop type	Minimum requirement (m^3/ha/year)	Irrigation methods		
		Micro (m^3/ha/year)	Sprinkler (m^3/ha/year)	Flood (m^3/ha/year)
Maize	5,656	6,284	7,070	9,427
Melon/Vegetable	6,280	6,978	7,850	10,467
Tomato	7,216	8,018	9,020	12,027
Wheat	7,312	8,124	9,140	12,187
Citrus	7,888	8,764	9,860	13,147
Grapes	8,857	9,841	11,071	14,761
Cotton	9,904	11,004	12,380	16,507
Lucerne	17,088	18,987	21,360	28,480

Source: MAWRD

Note: Sprinkler = Minimum requirement /0.8
Micro = Minimum requirement /0.9
Flood = Minimum requirement /0.6

As shown in Table 7.3-5, most of the farms have applied efficient methods such as drip, micro spray and so forth. In order to estimate exact water saving volume by alteration of irrigation methods, applicable irrigation methods should be considered based upon the information of irrigation areas and applied irrigation methods by each crop type. However, the hydro census data does not cover the detailed data of irrigation areas by crop type. Because of such data constraint, this study estimates a possible saving water volume considering the below cases which exclude the farms applying spray and flood irrigation methods mixed with other micro irrigation methods (refer to Table 7.3-4).

As Table 7.3-4 indicates, switching irrigation methods leads to a reduction of 215,500 m^3/year which amounts to about 3 % of the total irrigation water use in the study area. The figure does not meet the short-term goal as well as the sustainable water use level. However using a variety of efficient irrigation methods more reduction could be expected.

Table 7.3-4 Water Saving Volume with Application of Micro Irrigation Methods

	Cases applied with micro irrigation method	Saving volume (m^3/ year)	N.B.
Case 1	Flood → Micro (30% saving)	91,500	30.5ha x 10,000 m^3 x 30%
Case 2	Sprinkler→Micro (10% saving)	83,000	83ha x 10,000 m^3 x 10%
Case 2	Pivot → Micro (10% saving)	15,000	15ha x 10,000 m^3 x 10%
Case 4	Flood, Sprinkler →Micro (20% saving)	26,000	13ha x 10, 000 m^3 x 20%
Total		215,500	

Note: 10,000 m^3 = averaged water consumption per ha
20% is the average of Case 1 and 2

An important aspect to be noticed as Table 7.3-3 and Fig. 7.3-1 indicates is that the application of micro irrigation methods does not always contribute to water saving. Water consumptions of some farmers are far more than 28,480 m^3 per year which is almost maximum water requirement of crops, although they have applied efficient irrigation methods which require much less water than that.

The main reason for this is that water saving highly depends upon the way which the farmers use the technologies and groundwater. For instance, some farmers may not have adequate knowledge about how to use the efficient irrigation methods properly and, furthermore, may not be aware of the scarcity and the importance of ground water. To improve their knowledge and awareness, education for the farmers should be initiated in

parallel with the application of more efficient irrigation methods.

Table 7.3-5 Irrigation Areas and their Employment of Various Irrigation Methods

Unit: ha

Irrigation method \ Area	I	II	III	IV	VII	Total	%
Drip		98.5		2.0	4.1	104.6	23.8
Sprinkler		56.0	1.0	20.0	6.0	83.0	18.9
Sprinkler, Flood, Drip		77.0				77.0	17.5
Sprinkler, Drip	2.0	62.5				64.5	14.7
Flood	3.0	17.5	4.0		6.0	30.5	6.9
Flood, Drip					21.0	21.0	4.8
Pivot		15.0				15.0	3.4
Micro sprayer	1.0	12.0			1.0	14.0	3.2
Sprinkler, Flood	1.0	10.0			2.0	13.0	3.0
Sprinkler, Drip, Micro sprayer	12.5					12.5	2.8
Flood, Micro sprayer	2.0					2.0	0.5
Micro sprayer, Drip					2.0	2.0	0.5
Hose				0.5		0.5	0.1

Source: JICA analysis based upon Hydro-census data

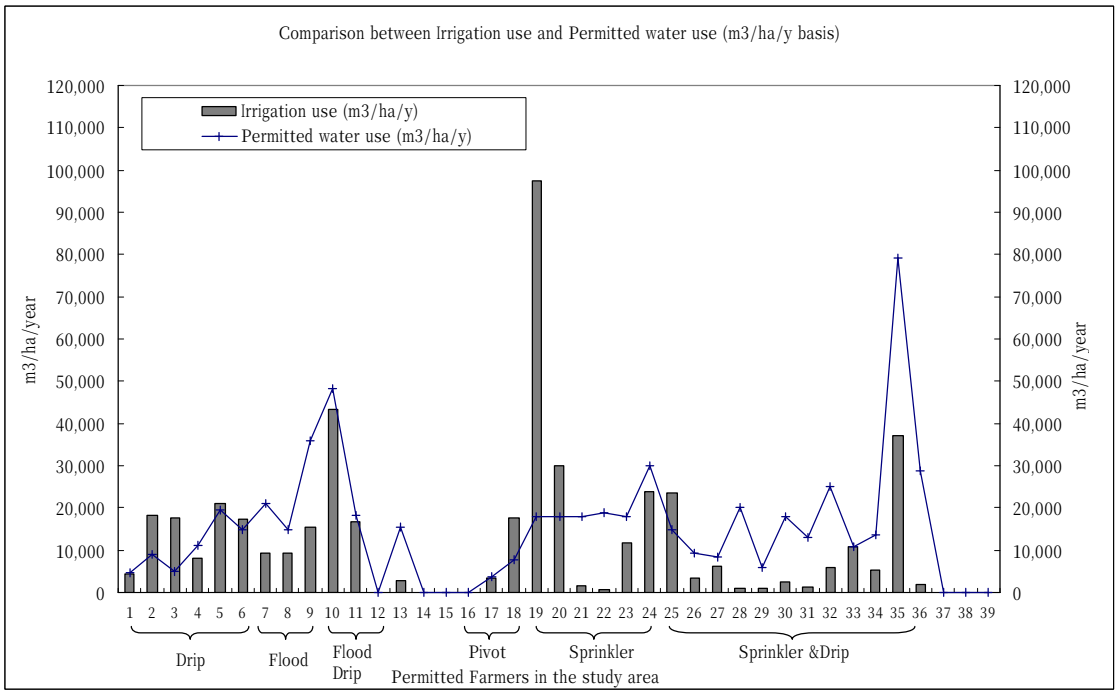

Fig 7.3-1 Water Consumption by Irrigation Methods

Source: JICA analysis based upon DWA data

3) Reduction of Irrigation Area

As mentioned in Chapter 4, farmers especially in Area II have exceeded their irrigation quotas and therefore a reduction in the irrigation area is one of the efficient ways to reduce groundwater extraction.

If the current irrigation areas (432 ha) of permitted farmers in Area II are scaled down to the permitted level by 30% reduction, then simply the same ratio of water consumption can be reduced. In this case groundwater extraction in the study area would almost meet the sustainable level.

4) Pricing of Groundwater

Enhancement and promotion of more efficient water use by education and campaign are basically conducted at the initial stage of the water reduction implementation program. However, such a policy may face some difficulty in persuading the farmers to change their behaviours. This is because currently ground water is not charged in the study area. Also it could be expected that farmers will not agree to pay for ground water. However, charging for groundwater is a useful tool for providing incentives to the farmers. As an ultimate economic measure pricing or taxing can be applied considering affordability and acceptability to farmers.

This study considers the crop conversions with pricing policies as one of recommendations (refer to 7.3.2 1)). Based upon the generalised data of costs, benefits and required water volumes for crop productions, value added per cubic meter for main crops in the study area were calculated. The figures basically indicate how efficient crop productions use groundwater.

According to Scenario1-2, changing of crop production from Lucerne to Grape enables a reduction of 34% of current water usage. However, this is quite difficult without sufficient motivation to farmers, because such a shift requires some additional costs and physical efforts on the part of the farmers.

Basically farmers change their farming activities based upon costs and benefits with the aim to get more profit with less investment. Due to the economic principle, they tend to change their activities from irrigation farming with low value added to livestock farming with high value added.

As Table 7.3-6 indicates in the case where the government charges a price between

N$ 0.4 to 1.5/m^3 for ground water, farmers who cultivate Wheat, Maize and Cotton etc which produces lower value added than N$ 0.4/m^3 will encounter a deficit with this charging. According to economic theory we would then expect to observe farmers to change their cultivating crop type from the lower value added ones to the higher value added ones like Grapes and Sweet melon. As a result of this charging policy and consequently change of crop type water consumption is expected to be reduced and should approach the sustainable level of water use.

Table 7.3-6 Value Added of Crops

Crops	Gross Income (N$/ha)	Total Cost (N$/ha)	Net Income (N$/ha)	Unit Water Consumption (m^3/ha)	Value Added (N$ /m^3)
Wheat	6,000	4,320	1,680	12,187	0.138
Lucerne	12,000	5,880	6,120	28,480	0.215
Cotton	11,000	5,360	5,640	16,507	0.342
Maize	8,000	4,700	3,300	9,427	0.350
Grapes	40,000	17,668	22,332	14,761	1.513
Sweet melon	40,000	12,708	27,292	10,467	2.607

Source: MAWRD and Hardap Cooperative

7.3.3 Groundwater Monitoring Plan

1) Purposes of Groundwater Monitoring

Monitoring is required to assure the proper implementation of the above suggested action plans, and the effectiveness of achieving the target . In case one action plan does not seem to improve the situation, other actions may need to be applied in order to reach the targets. Also, as a consequence of data compilation from the constant monitoring, the accuracy of groundwater level estimation should be also improved. Accordingly, a groundwater monitoring plan is proposed as follows.

2) Target Area of Monitoring

This study targets the entire area of Southeast Kalahari Artesian Groundwater Basin. The continuous nature of groundwater also requires a monitoring plan for the entire basin. On the other hand, however, the receding of groundwater level is not uniform in the study area. In this regard, the most significant water decrease is observed in the limited area around Stampriet along the Auob River and its eastern region. Accordingly, the above area is tentatively called as the Special Groundwater Control Area. The groundwater monitoring after the study should have special attention to the area, while the entire area of the basin has been already established as the “Groundwater Control Area” in the Water Act.

3) Monitoring Item and Method

The monitoring items are divided into either technical or administrative aspects. Table 7.3-7 shows the outline of monitoring contents.

Table7.3-7 Monitoring Item

Item	No.	Importance	Monitoring Item	Method	Responsibility
Technical Item	1	◎	Groundwater level	Automatic hydrograph, manual measurement	DWA
	2	◎	Water quality	Sampling and analysis	DWA
	3	◎	Precipitation	Automatic rain gauge	DWA
	4	◎	Flow rate	Automatic flow meter	DWA
Administrative Item	5	◎	Extraction rate	Flow meter, inspection	Well owners (DWA)
	6	○	Irrigation improvement	Reporting, inspection	Farms (DWA)
	7	○	Crop conversion	Reporting, inspection	Farms (DWA)

Remark ◎：Item for urgent implementation
○：Item that implementation is preferred

(1) Technical Monitoring Items

(i) Groundwater Level

The monitoring wells targeting the Kalahari aquifer exist at 14 sites, but there are none in the special monitoring area. For this reason three new observation wells should be installed in the area as shown in Fig.7.3-2. The existing wells owned by DWA and the newly drilled ones arising from the JICA study should cover the other area.

As for the Auob and Nossob aquifers, the monitoring shall be continued in the existing monitoring wells of both DWA and JICA.

The distribution of existing and newly planned observation wells is shown in Table 7.3-8 and Fig. 7.3-2.

Table7.3-8 List of Monitoring Wells

Category	Well No.	Location	Kalahari	Auob	Nossob
JICA Borehole	J-1	Christiana	-	◎	-
	J-2	Olifantswater West	-	◎	◎
	J-3	Steynsrus	◎	◎	◎
	J-4	Okanyama (Aminuis)	◎	◎	◎
	J-5	Maritzville (Stampriet)	-	-	◎
	J-6	Cobra	◎	◎	◎
	J-7	Jackalsdraai	◎	-	◎
	J-8	Tweerivier	◎	◎	◎
	J-9	Klein Swartmodder	-	◎	-
DWA Borehole	JO-1N	Neu Simmern	-	-	◎
	JO-2A	Gumchab Ost	-	◎	-
	JO-3A	Neumark	-	◎	-
	DWA-4,5,6,7	Olifantswater West	△	○	△
	DWA-3A	Stampriet	-	○	-
	DWA-2A	Boomplaas			
	JO-4A	Tugela	△	-	○?
	JO-5N	Gochas	-	-	◎
	JO-6N	Dagbreek	-	-	◎
	JO-7A	Glencoe	-	◎	-
	JO-8A	Cobra	-	◎	-
To be drilled		(Near Stampriet)	◎ or ○		
		(East to Stampriet)	◎ or ○		
		(North to Stampriet)	◎ or ○		

Remark) ◎：automatic hydrograph (Seba) ○：automatic hydrograph (record paper) △：manual

The monitoring shall be conducted in the intervals as shown in Table 7.3-9. The result of monitoring should be organized as the groundwater graphs as shown in Fig. 3.7-4 of Chapter 3 to describe the fluctuation of the piezometric head.

Table 7.3-9 Interval of Measurement and Data Collection of Groundwater Level

Measurement Method	Interval	Data Organized as
Automatic hydrograph (Seba)	Consecutive measurement, data collected every three months	Daily fluctuation of Piezometric Head
Automatic hydrograph (record paper)	Consecutive measurement, data collected every months	Monthly fluctuation of Piezometric Head
Manual	Monthly regular measurement	Monthly fluctuation of Piezometric Head

Besides, there are many natural springs in the Auob catchment around Stampriet. At the time when the study was started, all the springs had stopped. After the intensive rainfall in the rainy season of 1999/2000, some of the springs resumed

in places such as Hoachanas and Klein Swartmodder. Among these springs, five to ten of them should be selected for the monitoring. The owners of these springs will be entrusted for the monitoring of the flow behaviour of these springs.

(ii) Water quality

There is an area called salt block that has an extreme level of salinity in the study area. Saltwater intrusion, however, is not anticipated because the water abstraction is very small compared to the total groundwater storage. Therefore, it is not necessary to uniformly monitor the entire area, but only in the Special Groundwater Control Area, where further groundwater receding and accompanying water quality deterioration is anticipated. Accordingly, for water quality, the following items shall be monitored at the designated boreholes as shown in Table 7.3-10.

Table 7.3-10 Intervals for Water Quality Monitoring

Area	Monitoring Interval	Monitoring Item
Special Control Area	Once a year	Major cation & anion, NO_2, NO_3, SiO_2, F, pH, TDS
Others	Once every two years	

Remark: Among the boreholes shown in Table 7.3-8, J-3N, J-6N, and J-8A are excluded from the monitoring plan because the recovery from groundwater abstraction is extremely slow at these boreholes.

(iii) Precipitation

For the examination of groundwater recharge, the precipitation data is important as well as the data of the piezometric head. The observation points are required in the groundwater recharge area and in the upstream area. At present, the Meteorological Agency is conducting the observation at and around the study area; however, the data is often missing, resulting in the provision of insufficient data for the groundwater analysis. Therefore, it would be desirable to build the DWA's own observation system. DWA has currently installed several rain gauges in and around the study area under IAEA project. Further installation of water gauge is required in other recharge areas to augment the existing observation points. The proposed installation points are as follows: Uhlenhorst area, Hoachanas area, Christiana area, Weissrand area.

(2) Administrative Monitoring Items

(i) Extraction Rate

At present, the reporting duty prescribed by the Water Act is not completely fulfilled. Especially, item 2 in Table 7.3-1 is hardly reported due to insufficient installation of the flow meter. The grasp of extraction rate is essential for understanding the groundwater balance in the study area. Therefore, the installation of flow meter and reporting should be promoted in consent with water users.

The monitoring of the pumping rate is an indispensable subject in future groundwater management. The installation of flow meter and regular reporting should be enforced by the DWA inspections.

(ii) Improvement of Irrigation Method

In the study area, the majority of farmers have already introduced sprinkler or drip irrigation method. Therefore, the effectiveness of water conservation by the conversion of irrigation is limited. The action plan is to further promote the improvement of irrigation method to every farmer in the study area.

As far as the irrigation water is concerned, the minimum pumping for the efficient water use is desired. For this to be achieved, a thorough provision of information and education is necessary to obtain understanding and cooperation of the farmers. The monitoring of the improvement status is also essential to ascertain the application of the conversion.

(iii) Conversion of Cultivation Crop

Most of the crops cultivated in the Special Groundwater Control Area are cash crops. If crop conversion is applied without proper measures, there could be it may a decrease in the income of the farmers. Crops with higher market values with lower water demand should be introduced with the consent of farmers. The execution of this action plan is expected to make a great impact on the total extraction rate, thus a proper monitoring would be required.

7.3.4 Institution and Organization

While some part of the action plans may require cooperation with other relevant divisions, the major part of the discussed groundwater monitoring plan assumes the main input from Geohydrology Division in the DWA. Here an examination is attempted for the institutional and organizational aspects.

Table 7.3-11 shows the posts and tasks of the monitoring engineers. The Geohydrology Division has vacant posts for almost half of the total quota. Therefore it is anticipated that insufficient staffing may lead to improper conduct of monitoring activities. The major factor in the of lack of personnel is the outflow of engineers to NamWater. This tendency is not expected to change for the moment, therefore, the proposed personnel organization incorporate the rather fixed technicians and supple the other posts to strengthen the organization. The following table shows the required posts and numbers of engineers only for the groundwater monitoring activities.

Table 7.3-11 Monitoring Item, Contents and Required Engineers

Required Engineer	Required Number	Tasks	Remarks
Senior Geohydrologist or Geohydrologist	1-2	- Management of groundwater level, analysis of observation data - Water sampling for quality analysis, analysis and interpretation of data	Urgently needed
Groundwater Simulation Expert	1	- Improvement of groundwater simulation model	5 years after monitoring is started
Technician (A)･(B)	2	- Collection and processing of groundwater observation data - Collection and processing of precipitation observation data - Collection and processing of observation data of extraction rate - Water sampling for quality analysis and data processing	The task volume of the technicians may vary depending on the season. A system is required for the technicians to support each other
Technician (C)	1	- Inspection survey of irrigation method improvement and crop conversion. Organization of the survey	
	-	- Collection of river flow rate data	In cooperation with Hydrology Division

The Senior Geohydrologist and Geohydrologist post are important posts to take charge of the management of the groundwater monitoring. However, at present, the employment of proper personnel is assumed to be difficult. For this reason, one possibility would be to hire the domestic consultants or expert engineers dispatched by international donors.

As for Technicians, at present, they are in charge of data collection and reading, but not for processing. However, accuracy of monitoring could be assured if the same technician makes the graphs after the reading the groundwater level.

Table 7.3-12 Personnel Allocation in DWA as of October 2001

Post	Quota	Occupied	Vacancy
Deputy Director: Geohydrology	1	1	0
Senior Geohydrologist	3	1	2
Geohydrologist	9	1	8
Technician	10	2	8
(Drilling Section)	-	-	-
Driller	2	2	0
Foreman	3	2	1
Technical & Clerical Assistant	6	5	1
<Total>	34	14	20

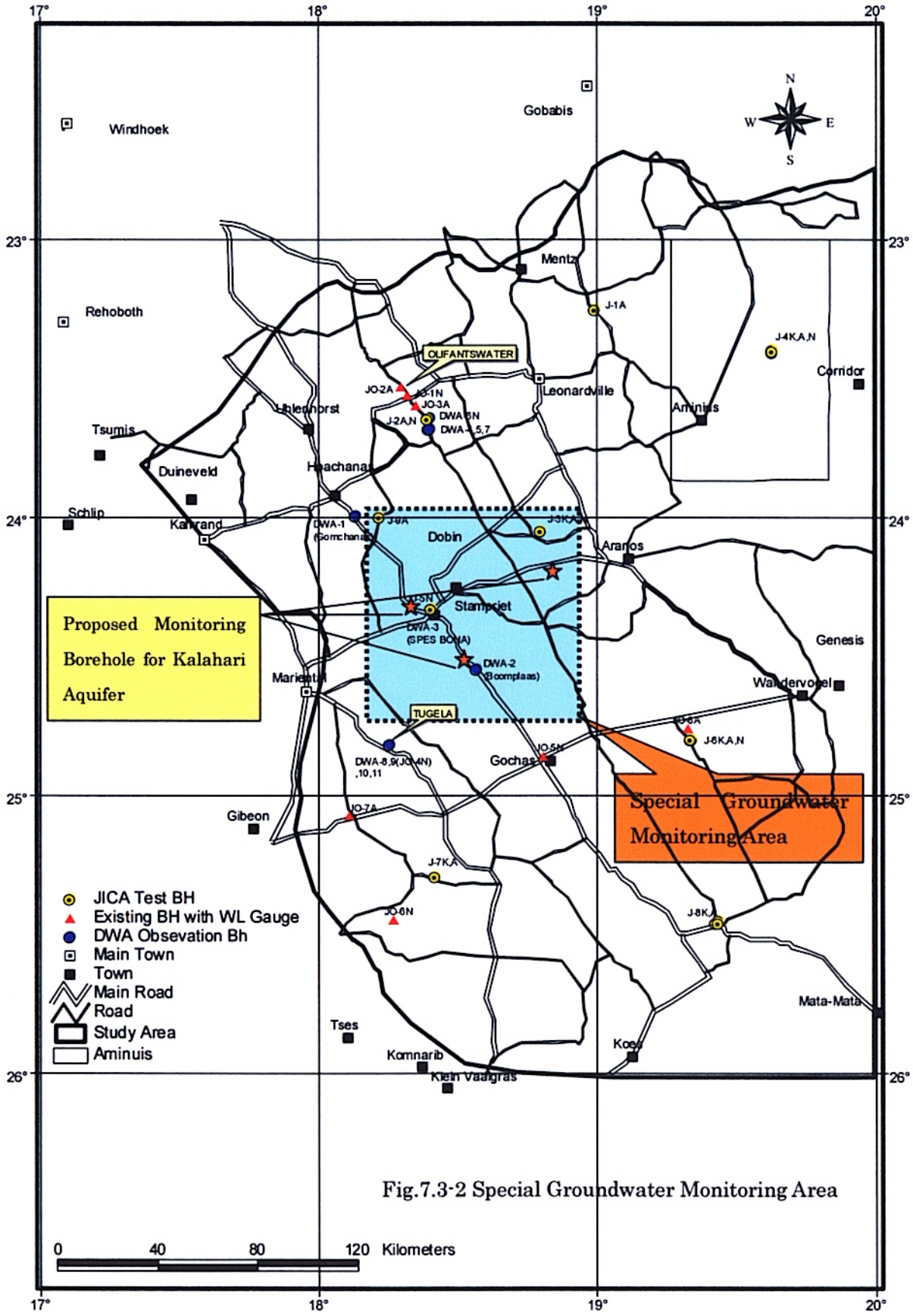

Fig.7.3-2 Special Groundwater Monitoring Area

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

1) Hydrogeological Structure

The Kalahari, Auob and Nossob Aquifer do not a simple monoclinal feature but a considerably complicated structure. Redefinition of the aquifers was also done through this study (See Fig.3.6-1).

2) Groundwater Potential Evaluation

The Auob Aquifer has the highest potential, followed by the Kalahari Aquifer, while the Nossob Aquifer shows the lowest potential. (See Fig.5.3-9 to 11)

3) Groundwater Flow and Recharge Mechanism

a) Groundwater Flow

Groundwater into each aquifer flows from NW to SE and it was estimated that it takes several thousand years to flow through the whole basin. (See Fig.3.7-1 to 3).

b) Recharge

The major recharge into the basin occurs via direct rainfall feeding the rivers and the fractures as well as the karstic sinkholes that are situated on the rim of the basin. Recharge via these features and structures feed the Kalahari Aquifer directly and this amounts to $105\times10^6 m^3$/year in an average rainfall year and 1,550 x $10^6 m^3$/year during an exceptional rainfall event (on average 1/50 years). Recharge into the Auob Aquifer via the Kalahari Aquifer and the Kalkrand Basalts does occur but this is mainly during the exceptional rainfall events. Recharge into the Nossob Aquifer is negligible and most of the resource in the Nossob Aquifer can be regarded as fossil water.

4) Water Balance

a) Under average rainfall conditions, the water level of the Kalahari Aquifer decreases by 5cm/year on average. Even though a 1/50 year heavy rainfall event does reverse the drawdown to some degree for a limited period, it does not prevent the longer term water-level decline under the present conditions.

b) Groundwater recharge volume is up to 0.5% of total rainfall during a normal rainfall event

and 3% during a 1/50 year heavy rainfall event. Most of the rainwater is lost by evapotranspiration. This is exacerbated by the large amount of alien vegetation and attention should be paid to solving this problem.

5) Groundwater Demand

a) Of the total groundwater abstracted from the Basin, approximately one half of the volume of $15\times10^6 m^3$/year is used for irrigation ($6.88\times10^6 m^3$/year). Approximately 78 % of the total irrigation use is concentrated in the Stampriet area. (See P.4-12 and Table4.1-3)

b) Of the total groundwater abstraction from the Basin annually, 66% is from the Kalahari Aquifer, 33% from the Auob Aquifer and only 1% from the Nossob Aquifer respectively.

6) Groundwater Simulation

a) Within a 60km square area around Stampriet the drawdown of the groundwater level is remarkable. (See Fig.5.3-12 to 17)

b) Some wells within the Kalahari Aquifer around the Stampriet area may dry up within the next 30 years if the present condition of water use prevails. (See Table3.3-2, 3 and Fig.5.3-18) In view of the present over abstraction taking place, mitigating measures as part of a water demand management plan as described in Chapter 7 of the report should be adopted.

7) Groundwater Management Plan

a) Water Demand Management

It is proposed that the irrigation use be reduced by 30% for the short term and that the following countermeasures are suggested:

i) Start of an awareness campaign regarding the sustainable use of groundwater.

ii) Proper monitoring of water abstraction volumes.

iii) Review of permit conditions for water allocation.

iv) Reduction of over irrigated areas.

v) Switch to higher value crop cultivation.

vi) Voluntary reduction in water use by users.

vii) Application of more efficient irrigation methods.

viii) Pricing of groundwater.

b) Aquifer Management Plan

An aquifer management plan was set up as follows.

i) A regional groundwater monitoring plan was set up covering the entire basin as shown in Fig.7.3-2 and groundwater levels should be monitored on a continuous basis.

ii) A special groundwater monitoring area was also proposed in an area covering approximately 90km square around Stampriet. (See Table5.3-2, 3 and Fig.7.3-2) Here three additional observation boreholes should be drilled and installed with recorders.

c) Personal Recruitment

DWA staff should be increased to fill the approved posts in order to do the necessary follow-up work of this study and to implement the groundwater management plan.

8) Initial Environmental Evaluation

The proposed groundwater management plan is expected to have positive environmental impacts as the groundwater potential in the Stampriet Artesian Basin will be positively affected.

9) Counterpart Training

During this study, transfer of technical know-how to counter-part personnel was conducted between JICA study members in each field in the form of on-the-job training. The Director of Resource Management and the Deputy Director of Geohydrogy also took part in the counterpart-training course in Japan.

8.2 Recommendations

1) This report be accepted in principle.

2) The mean groundwater recharge into the aquifer is limited to 135 Mm^3/a, subject to future monitoring management and adjustment.

3) An appropriate aquifer management plan, as described in Section 7 of the report, be implemented.

4) The criteria for all allocation of water for irrigation should be adjusted as suggested in paragraph 7-1 to ensure that the benefits of using the available water resources are maximized.

5) In view of the present over abstraction taking place, mitigating measures as part of a water demand management plan as described in Section 7 of the report should be adopted in cooperation with all water users to reduce the water demand and the local Water Committee should play a major role in this regard.

6) Further studies must be done to improve borehole construction and reduce the leakage from the existing groundwater abstraction wells. Furthermore attention must be given to assess and rectify the suspected contamination of groundwater taking place in the Basin, to reduce the loss of artesian pressure and to enhance aquifer recharge from surface runoff in areas where this can be done. The problem of alien vegetation should be addressed.

7) The technology used and the results obtained in this study should be utilized to manage other groundwater basins in Namibia.

References

No	Author	Published Year	Title	Publication
1	Central Bureau of Statistics, National Planning Commission	–	1991 Population and Housing Census Basic Analysis with Highlights	Central Bureau of Statistics, National Planning Commission
2	Central Bureau of Statistics, National Planning Commission	–	1991 Population and Housing Census Report B, Statistical Tables, Volume I	Central Bureau of Statistics, National Planning Commission
3	Central Bureau of Statistics, National Planning Commission	–	1991 Population and Housing Census Report B, Statistical Tables, Volume II	Central Bureau of Statistics, National Planning Commission
4	Central Bureau of Statistics, National Planning Commission	–	1991 Population and Housing Census Report B, Statistical Tables, Volume III	Central Bureau of Statistics, National Planning Commission
5	Central Bureau of Statistics, National Planning Commission	–	1992 Population and Housing Census Report C, Statistics on Enumeration Areas	Central Bureau of Statistics, National Planning Commission
6	Central Bureau of Statistics, National Planning Commission	April, 1977	1994/1995 Namibia Agricultural Census: Basic Analysis of Communal Agriculture	Central Bureau of Statistics, National Planning Commission
7	Central Bureau of Statistics, National Planning Commission	April, 1977	1994/1995 Namibia Agricultural Census: Basic Tables of Commercial Agriculture	Central Bureau of Statistics, National Planning Commission
8	Central Bureau of Statistics, National Planning Commission	April, 1977	1994/1995 Namibia Agricultural Census: Basic Tables of Communal Agriculture	Central Bureau of Statistics, National Planning Commission
9	Central Bureau of Statistics, National Planning Commission	April, 1977	1994/1995 Namibia Agricultural Census: Technical Report	Central Bureau of Statistics, National Planning Commission
10	Government of Nmaibia	–	A Digest of the Water Supply and Sanitation Sector Policy of the Government of Namibia	Gamsberg Macmillan
11	Tredoux G	1981	A geohydrochemical investigation of the Stampriet Artesian Basin (Namibia/South West Africa) (in Afrikaans)	Ph.D-dissertation, University of the Orange Free State, South Africa
12	McDonald, M.G. and A.W.Harbaugh	1988	A modular three-dimensional finite-difference ground-water flow model, U.S.G.S. Open-File Report 93-875, Book6, Chap.A1, 576p.	U.S.G.S.
13	–	1956	An Approach to Sustainable Water Management Using Natural Resource Accounts	RSA / 1956
14	P.S. Meyer	1999	An Explamation of the 1:500000 General Hydrogeological Map Oudtshoorn 3320	Department of Water Affairs and Forestry, Republic of South
15	P.S. Meyer	1998	An Explamation of the 1:500000 General Hydrogeological Map Port Elizabeth 3324	Geohydrology Department of Water Affiars and Forestry, Republic of South Africa
16	Meat Board of Namibia	1990-1998	Annual Report 1990-1998	Meat Board of Namibia
17	Bank of Namibia	Mar.	Annual Report 2000	Bank of Namibia
18	The Survey-General	1977	Aranos State Water Scheme Memorandum of Drilling and Test Pumping	The Survey-General
19	K.E.L. Schalk and W.Hegenberger	1991	Bibliography of Namibian Earth Science Volume 2	Geological Survey, Ministry of Mines and Energy
20	P.J.Hugo,K.E.L.Schalk and Salaha-Jane Barnes	1983	Bibliography of South West Africa/Namibian Earth Science Volume 1	Geological Survey, Ministry of Mines and Energy
21	D J Huyser	1982	C WAT 50 Chemiese Kwaliteit van die Grondwater in Suidwes-Afrika/Namibie Volume 1	–
22	D J Huyser	1982	C WAT 50 Chemiese Kwaliteit van die Grondwater in Suidwes-Afrika/Namibie Volume 2	–
23	H D Goetze	1982	C WAT 50 Chemiese Kwaliteit van die Ondergrondse in Suidwes-Afrika/Namibie Volume 4 - Benaderde Geografiese Posisies van die	–
24	D J Huyser	1982	C WAT 50 Finale verslag oor die Chemiese Kwaliteit van die Ondergrondse in Suidwes-Afrika/Namibie Volume 3 - Deel I - Onverwerkte Data	–
25	D J Huyser	1982	C WAT 50 Finale verslag oor die Chemiese Kwaliteit van die Ondergrondse in Suidwes-Afrika/Namibie Volume 3 - Deel II - Onverwerkte Data	–

No	Author	Published Year	Title	Publication
26	C.S. Kingsley	1985	CDM Minerak Surveys, Sedimentological Anaysis of The ECCA Sequence in the Kalahari Basin, South West Africa/Namibia,	Gamsberg Macmillan Publishers Ltd
27	C.S. Kingsley	1985	CDM Mineral Surveys Sedimentological Analysis of the Ecca sequence in the Kalahari Basin, South West Africa / Namibia	CDM
28	Geological Survey, Ministry of Mines and Energy	-	CDM Mineral Surveys: Open File Report EG 087 (Aranos Basin) SWA coal project	Geological Survey, Ministry of Mines and Energy
29	C.S. Kingsley	1985	CDM Mineral Surveys: Sedimentological Analysis of the ECCA Sequence in the Kalahari Basin, South West Africa/Namibia	CDM
30	Klaus Dierks	1999	Choronology of Namibian History From Pre-Historycal Time Idependent Namibia	Namibia Scientific Soiety, Windhoek Namibia
31	-	-	Constituency and Regional Boundary Changes	Geological Survey, Ministry of Mines and Energy
32	Central Bureau of Statistics, National Planning Commission	2001	Consumer Prices and Inflation Interim Consumer Price Index: Windhoek	Central Bureau of Statistics, National Planning Commission
33			Deep Borehole Sections, Namibia-Botsuwana	-
34	Jan Davis and Gerry Garvey, with Michael	1993	Developing and Managing Community Water Supplies	Oxfam
35	G.Tredoux, J.C.Vogel J.Kirchner	1978	Die Geohidrologie van DIE ARTESIESE KOM STAMPRIET Deel III : Data	Department of Water Affairs, Ministry of Agriculture, Water and Rural Development
36	G.Tredoux, J.C.Vogel J.Kirchner	1979	Die Geohidrologie van DIE ARTESIESE KOM STAMPRIET Deel II : Kaarte	-
37	Domenico, P A & Schwartz, F W	1990	Domenico, P A & Schwartz, F W, 1990. Physical and chemical hydrogeology	John Wiley & Sons, New York.
38	-	-	Drilling of a Deep Fresh Water Borehole In the Eehnana Area Applying the EDL-Technique, 1998	Namwater
39	Water Reseach Commision	-	Enhanced of the National Groundwater Data Base Facilities -Extended Executive Summary-	Department of Water Affairs, Ministry of Agriculture, Water and Rural Development
40	Ian Clark, Peter Fritz	1997	Environmenal Isotopes in Hydeogeology	CRC Press LLC
41	-	-	Environmental Management Act Act x of 1998 (Final draft)	-
42	Shibasaki, T. et al.	1995	Environmental Management of Groundwater Basins,202p.	Tokai Univ. Press,
43	D.J.L Visser	-	EXPLANATION" GEOLOGICAL MAP, The Geology of the Republics of South Africa, Transkei, Bophuthatswana, Venda and Ciskei and the Kingdoms of lesotho and Swaziland	GeologicalSurvey Repubic of South Africa
44	-	-	Feasibility Study on measures to secure water supply to the Central Areas of Namibia Vol.I	-
45	-	1997	Feasibiliy Study on the Okavango River to Grootfontein Link of the Easterin Nationl WaterCarrier Volume 1-6	Ministry of Agriculture, Water, Republic of Namibia
46	Eugene J. Wilson	1965	Final Geological Report and Summary of Operations	-
47	-	-	First National Development Plan (NDP1) Volume 1	-
48	-	-	First National Development Plan (NDP1) Volume 2	-
49	Central Bureau of Statistics, National Planning Commision	Sept. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin April to June 2000	Central Bureau of Statistics, National Planning Commision
50	Central Bureau of Statistics, National Planning Commision	Jun. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin January to March 1999	Central Bureau of Statistics, National Planning Commision
51	Central Bureau of Statistics, National Planning Commision	Dec. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin January to March 1999	Central Bureau of Statistics, National Planning Commision
52	Central Bureau of Statistics, National Planning Commision	Jun. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin January to March 1999	Central Bureau of Statistics, National Planning Commision
53	Central Bureau of Statistics, National Planning Commision	Nov. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin July to September 2001	Central Bureau of Statistics, National Planning Commision

No	Author	Published Year	Title	Publication
54	Central Bureau of Statistics, National Planning Commision	Dec. 2000	ForeignTrade Statistics: Quaterly Trade Statistics Bulletin October to December 2002	Central Bureau of Statistics, National Planning Commision
55	A.M. Altebaeumer F.J. Altebae	Sep, 1990	Geochemical Evaluation of the PCIAC-GSD Masetlheng Pan-1 Well, Botsuwana and an Oil-Sheep Sample From Namibia	-
56	Weaver, J M C, Talma, A S & Cave, L C	1999	Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group	Report to the Water Research Commission, WRC Report No 481/1/99.
57	November A. Mthoko, Norbert H. Noisser, Matthias W. Rebentisch	1992	Geography of Namibia, 1990	Gamsberg Macmillan
58	Tredoux	1981	Geohidorochemiese Ondersoek van die Artiese kom Stampriet, Suidwes-Afrika	-
59	Geological Survey, Ministry of Mines and Energy	1979	Geological Map 1 : 1,000,000	Geological Survey, Ministry of Mines and Energy
60	Geological Survey, Ministry of Mines and Energy	-	Geological Map 1:250,000 KOES	Geological Survey, Ministry of Mines and Energy
61	Geological Survey, Ministry of Mines and Energy	-	Geological Map 1:250,000 LEONARDVILLE	Geological Survey, Ministry of Mines and Energy
62	Geological Survey, Ministry of Mines and Energy	-	Geological Map 1:250,000 ARANOS	Geological Survey, Ministry of Mines and Energy
63	Geological Survey, Ministry of Mines and Energy	1981	Geological Map, 1/250,000 GOBABIS	Geological Survey, Ministry of Mines and Energy
64	J.N.Carney D.T.Aldiss N.P.Lock	1994	Geological Survey Department Bulletin Series The Geology of BOTSUWANA	Department of Water Affairs, Ministry of Agriculture, Water and Rural Development
65	-	-	Glacial Temperature and Moisture Transport Regimes Reconstructed from Noble Gases δ 18, Stampriet	-
66	-	-	Government Gazette, General Notice, Office of the Prime Minister	-
67	-	1997	Government Gazette, General Notice, Water Supply Regulations (Windhoek Municipality)	Friedrich Ebert Stiftung / 1997
68	Ake Nilson	1988	Groundwater Dams for Small-scale Water Supply	IT publications
69	-		Groundwater Information System - User Manual, 1992	CSIR / RSA
70	Research Group for Water Balance ed	1973	Groundwater Resources Research, Kyoritsu Shuppan Co., Ltd., 397p. (in Japanese)	-
71	Bear, J	1979	Hydraulics of Groundwater,210p	McGraw-Hill
72	Vogel, J C	1967	Investigation of groundwater flow with	Isotopes in Hydrology, IAEA,
73	Germanov, A I, Volkov, G A, Lisitsin, A K & Serebrennikov, V S	1959	Investigation of the oxidation-reduction potential of ground waters	Geokhimiya, 3, 322 - 329.
74	-		Isotopic Composition of Groundwater In Semi-Arid Regions of Southern Africa, 1974	-
75	Central Statistics Office, National Planning Commission	1996	Living Condition in Namibia Basic description with highlights the 1993/1994 Namibia Household income and expenditure survey Main Report	Central Statistics Office, National Planning Commission
76	-	1999	Meat Board of Namibia Annual Report 1998	Meatboard of namibia Establishment in terms of the
77	Gerald & Marc Hoberman	1999	NAMIBIA	Gerald & Marc Hoberman Collection Ltd.
78	Dr. Mary Seely	1991	Namibia Drought and Desertification	Gamsberg Macmillan Publishers
79	Nicole Grunert	2000	Namibia Facination of Geology, A travel Handbook	Klaus Hess Publishers
80	-		Namibia Regeonal Resources Manual	Geological Survey, Ministry of Mines and Energy
81	-	1999	Namibia Trade Directory: A preview of Namibian Trade and Industry	-
82	-		Namibia Water Corporation Bill	The Survey General
83	Ginger Mauney	1997	Namibia, Environment, Volume 1	-
84	Christed Stern, Brigitte Lau	1999	Namibian Water Resources and Their Management, Preliminbary History	Brigitte LAU and Christel Stern

No	Author	Published Year	Title	Publication
85	DWA	Jan. 1995	Namibia's Environmental Assessment Policy – For Sustainable Development and Environmental Conservation	–
86	Piet Heyns, Sharon Montgomery,John Pallett, Mary Seely	1998	Namibia's Water A Decision Makers' Guide	DWA and the Desert Research Foundation of Namibia
87	Central Bureau of Statistics, National Planning Commission	Aug. 1999	National Accounts 1983-1998	Central Bureau of Statistics, National Planning Commission
88	Ministry of Agriculture, Water and Rural Development		National Agricultural Policy	Ministry of Agriculture, Water and Rural Development
89	Ministry of Agriculture, Water and Rural Development	Aug. 2000	National Water Policy White Paper: Policy Framework for Equitable, Efficient, and Sustainable Water Resources Management and Water Services	Ministry of Agriculture, Water and Rural Development
90	Harold Fullar (ed) J.L. Earle (ed)	1996	New Visual Atlas	George Philop & Son Limited, London
91	Harold Fullard, M.Sc.	1996	New Visual Atlas, New Syllabus	JUTA & CO, LTD, Kenwyn 7790
92	G. Dolby	1989	Palynological Analysis of Core Samples from the VREDA 281 No. 1 Well, Namibia	–
93	Shibasaki, T.	1972	Permissive Capacity in Groundwater Pollution	Environmental Information Science
94	Domenico, P.A. and F.W. Schwatrs	1998	Physical and Chemical Hydrogeology, 2nd ed., John Wiley and Sons, 506p.	Inc.
95	Hill, M.C.	1990	Preconditioned Conjugate-Gradient 2 (PCG2), A computer program for solving ground-water flow equations, U.S.G.S. Water-Resour. Invest. Report 90-4048, 43p.	U.S.G.S
96	–	1986	Progress Report No.1 on the Stampriet Artesian Basin, Results of the Borehole Survey within the Stampriet – Gochas Area, Report No. 3100/9/G21, 19p	Department of Water Affairs, South West Africa/Namibia
97	–	1987	Progress Report No.2 on the Stampriet Artesian Basin, Results of the Borehole Survey within the Aranos – Leonardville Area, Report No.	Department of Water Affairs, South West Africa/Namibia
98	–	1989	Progress Report No.3 on the Stampriet Artesian Basin, Results of the Borehole Survey in Area 3, the North-Western Intake Area, Report No. 12/9/G3, 17p.	Department of Water Affairs, South West Africa/Namibia
99	–	1999	Publicatation and Open File. Price List	Ministry of Mines and Energy
100	Bank of Namibia	Jun.	Quarterly Bulletin June 2001 Volime 10 No.2	Bank of Namibia
101	–		Regional Geoscience Division	Geological Survey, Ministry of Mines and Energy
102	–	1999	Republic of Namibia 1998/1999 Annual Agricultural Survey, Basic Amaysis of Communal Agriculture	Central Bureau of Statistics National Planning Commission, Windhoek
103	National Planning Commission/UNDP/NEPRU/XFAM		Section throuth the Kalahari between Auob & Nossob rivers	National Planning Commission/UNDP/NEPRU/XFAM
104	The Survey-General	1976	Simplified Geological Map of Namibia 1 : 2 000	The Survey-General
105	Geological Survey, Ministry of Mines and Energy	1998	Some notes on the Geohydrology and Hydrochemistry of the Salt Block whithin the Stampriet	Geological Survey, Ministry of Mines and Energy
106	Piet van Wyk	1993	South Africa, Trees, A photographic Guide	Struik publishers, Ltd, Cape
107	The Water and Environment Team	1998	State of the Enivironment Report Water in Namibia (DRAFT)	Milano, Agip C.
108	Office of the President, National Planning Commision, Central Bureau of Statistics	Oct. 1999	Statistical Abstract 1999 No.6	Office of the President, National Planning Commision, Central Bureau of Statistics
109	Mannheim, F T	1961	Stockholm Contributions in Geology, 8, p 27.	Mannheim, F T, 1961. Stockholm Contributions in Geology, 8, p 27.
110	World Bank United Nations Development	Apr. 1995	Sub Saharan African Hydrological Assessment SADC countries Country Report: Namibia (Draft Report)	World Bank United Nations Development Programme
111	Center for Development Cooreration Services, Vrie Universitiet Amstedam	1996	Successful natural resource management in South Africa	Gamsberg Macmillan publishers Ltd

No	Author	Published Year	Title	Publication
112	-	Jan.1990	Technical Cooperation Hydrocarbon Exploration	Department of Water Affairs, Ministry of Agriculture, Water and Rural Development
113	Stephen Devereux Martin Rimmer Devie LeBeau Wade Pendleton	Dec. 1993	The 1992/1993 Drought in Namibia: An Evaluation of its socio-economic impact on affected household	Social Sciences Division, Multi-Displinary Research Centre, University of Namibia
114	Vogel, J C, Talma, A S & Heaton, T H E	1982	The age and isotopic composition of groundwater in the Stampriet Artesian Basin, SWA	Final report to the Steering committee for Water Research in SWA. NPRL, CSIR, Pretoria, Project 400/90615.
115	-	-	The Age and Isotopic composition of Groundwater in the Stampriet Artesian Basin, SWA (April,1982)	-
116	-	1977	The Age and Isotopic composition of Groundwater in the Stampriet Artesian Rasin. SWA	The Survey-General
117	Geological Survey, Ministry of Mines and Energy	1980	The Artesian Area in South West Africa	Geological Survey, Ministry of Mines and Energy
118	G. Dolby	Aug, 1990	The Biostratigraphy of the G.S.D. P.C.I.A.C. Masetlheng Pan-1 Well, Botsuwana	-
119	Tredoux G & Kirchner J	1981	The evolution of the chemical composition of artesian water in the Auob Sandstone (Namibia/South West Africa)	Trans. Geol. Soc. S.Afr., 84, 169 - 175
120	Drever, J I	1988	The geochemistry of natural waters. Second Edition.	Second Edition. Prentice Hall, New Jersey.
121	Tredoux G & Kirchner J	1979	The geohydrology of the Stampriet Artesian Basin	Report submitted to the Steering Committee for Water Research in South West Africa (Namibia).
122	World Trade	1998	The Namibian Development Services Directory	World Trade Organization / 1998
123	W. Hegenberger	-	The Regional Geology of Northeast South West Africa/Namibia (1982)	Geological Survey, Ministry of Mines and Energy
124	-	-	The Stampriet Artesian Basin, with Special Reference to the Salt Block	Geological Survey, Ministry of Mines and Energy
125	Kirchner J & Tredoux G,	1975	The Stampriet Artesian Basin, with special reference to the Salt-block: The chemical composition of the ground water with respect to Geological Formations	Presented at SARCCUS Meeting, Bulawayo, Zimbabwe, May
126	-	1995	The United Nations Development programme, Sub Saharan Africa Hydrological Assessment, SADC Countries	The World Bank
127	Schalk, K	1961	The water balance of the Uhlenhorst cloudburst in South West Africa	The water balance of the Uhlenhorst cloudburst in South West Africa
128		1994	Understaindg the Oshana Environment	Gamsberg Macmillan Publishes
129	Harbaugh, A.W. and M.G.McDonald	1996	User' s documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model, U.S.G.S. Open-File Report 96-485, 56p.	U.S.G.S
130	The Department of Water Affairs and	1998	Waste Management and the Minimum Requirements, First Edition	-
131	Geological Survey, Ministry of Mines and Energy	-	Water Act No.54 of 1956	Geological Survey, Ministry of Mines and Energy
132	-	1994	Water In Namibia, 1994	Department of Water Affairs, Ministry of Agriculture, Water and Rural Development