Groundwater for the North of Namibia

Volume I c

Summary Report on the Hydro-Census carried out for the Groundwater Resources in the Northern Namibian Part of the Cuvelai-Etosha Basin
Editor: Christoph Lohe (BGR)

Authors and contributing Persons (in alphabetical order):

Henry Beukes (MAWF), Arnold Bittner (BIWAC), Frank Bockmühl, Greg Christelis (former MAWF), Katharina Dierkes, Leonard Hango (DRFN), Mathews Katjimune † (MAWF), Prof. Jürgen Kirchner, Henk Labuschagne, Cecil Less, Falk Lindenmaier (BGR), Christoph Lohe (BGR), Gwendal Madec (BIWAC), Clarence Mazambani (DRFN), Victor Mufita (DRFN), Martin Quinger (BGR), Silke Rügheimer (Analab), Braam van Wyk (SLR), Harald Zauter (former BGR)

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Project: Groundwater for the North of Namibia (Cuvelai- Etosha Basin)

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Preface

Access to safe fresh water is the main limiting factor for the economic and social development of Namibia. Surface water is mainly restricted to 4 perennial rivers at the Northern and Southern borders. Therefore groundwater in Namibia, as it is true for most arid countries, plays a vital role for the supply of wide areas. As part of the technical co-operation between Namibia and Germany the Government of the Federal Republic of Germany provides financial and technical support through the BGR on the project “Groundwater for the North of Namibia.” Phase I commenced in January 2007 and was completed in the first half of 2010. Currently, Phase II is running until May 2014.

The goal of this project is “to improve access to safe drinking water and the project objectives are to provide well founded information concerning the groundwater resources in the Cuvelai-Etosha Basin (CEB) as a basis for Integrated Water Resource Management (IWRM).” Practically, this means a transition process from ongoing investigation and the resulting outputs into applied day to day management of the groundwater resources. To achieve this, the often very specific hydrogeologic knowledge has to be translated to widely understood principles which serve the protection and sustainable use of the different groundwater bodies.

It is exactly this approach that has been followed within this project and that will be perpetuated until a Decision Support System (DSS) has been developed that enables all decision makers and IWRM stakeholders with different educational background to simulate the effects of any possible planning decision on the water resources before implementation.

The first phase of the project however had to focus on the description of available resources in the intervention area CEB. Combining state of the art exploration technologies with intense use of classical hydrogeological field surveys, a formerly unknown deep-seated aquifer, the so called Ohangwena II aquifer, could be identified and described for the North Eastern part of the CEB as one of the main outputs. Being a transboundary aquifer system, this resource is shared with Angola in the North and holds a high potential for alternative supply and development of large areas in both countries. The investigation activities and the derived results which will be later on contained in and exchange through the Groundwater Information System (GWIS) which is under development in the current phase.

With a strong focus on capacity building additional staff will be enabled to independently plan and conduct groundwater investigations and link it to the management principles of IWRM. The impact of this project will thus enhance the Namibian Water sector in making the optimal use of all its water resources. By promoting the use of groundwater in combination with other resources it
will prepare Namibia to adapt to the challenges brought to the water sector through the negative impacts of a changing climate. It will thereby help to secure the social, environmental and economic development of Namibia.

The report at hand describes the outcome of a vital early step when investigating groundwater resources: the hydro-census. In principle it is a stocktaking of all of all existing and abandoned groundwater abstraction points and entails a description of water quality distribution through an intense sampling campaign. The results from the census deliver the baseline for all further investigation and management activities and are therefore of outmost importance.

Martin Quinger, Project Manager
Report Series, Project “Groundwater for the North of Namibia”:

Vol. I: Executive Summary: Groundwater for the North of Namibia, Phase I
Vol. I b: Kalahari Research Project: Results of Sample Investigation of Mud Rotary and Cored Drill Holes on the Cubango Megafan
Vol. I d: Groundwater for the North of Namibia: Groundwater Exploration with TEM-soundings in the Cuvelai-Etosha Basin
Vol. II: Executive Summary of Training Activities and Guidelines
Vol. II a: Hydrogeological Modeling Course September 2011

Reports in Preparation:
Vol. II b: Hydrochemical Sampling course
Vol. II c: Presentation on Interpretation of Hydrochemical Data for Groundwater Management 2012
Vol. II d: Delineation of Groundwater protection Zones
Vol. II e: Vulnerability Assessment in the Cuvelai- Etosha Basin
Vol. III: Executive summary of Investigation Measures and Modelling
Vol. III a: Overview of the Groundwater Resources in the Cuvelai- Etosha Basin, Namibia
Vol. III b: Overview of the Hydrochemistry in the Cuvelai- Etosha Basin
Vol. III c: Hydrochemistry in the Ohangwena Aquifer System
Vol. III d: Groundwatersituation in the Eiseb Graben Area
Vol. III e: Development of an Water Supply Decision Support System for the CEB

Vol IV: Executive Summary GROWAS II and GWIS

Vol. IV a: Workflow Analysis and Requirements for an Improved Groundwater Information System

Vol. IV b: GROWAS II Database Dictionary and Hydrogeological Key

Vol. IV c: Manual of GROWAS II and Training

Vol. V: Executive Summary Final Report Phase II

Vol. V a: Main Hydrogeological Report
# Table of Contents

Preface .......................................................................................................................... A  

Report Series .................................................................................................................. C  

List of Annexes ................................................................................................................. G  

List of Figures ..................................................................................................................... G  

List of Tables ....................................................................................................................... H  

Abbreviations ..................................................................................................................... I  

Summary ................................................................................................................................ 1  

1. Introduction ...................................................................................................................... 2  

2. Overview .......................................................................................................................... 3  

3. Previous Groundwater Investigations ...........................................................................4  

4. The DWAF Groundwater Database GROWAS ............................................................. 5  

5. Methodology ..................................................................................................................... 8  
   5.1 General .......................................................................................................................... 8  
   5.2 Steps undertaken prior to field survey ........................................................................ 8  

6. The Hydro-Census ........................................................................................................... 10  
   6.1 Scope of work ............................................................................................................... 10  
   6.2 Requirements for field teams .................................................................................... 10  
   6.3 Implementation .......................................................................................................... 12  
   6.4 Awareness campaign ................................................................................................. 13  

7. Results and Discussion ................................................................................................... 14  
   7.1 Identification of boreholes in the field ...................................................................... 14  
   7.2 Condition of water points ......................................................................................... 15
List of Annexes


Separate Folder:
Annex 2: Hydro-Census Field Questionnaire Template
Annex 3: Summary of Hydro-Census Field Sheets
Annex 4: Summary of Water Analysis and Water Quality Parameters
Annex 5: Terms of Reference for conducting the Hydro-Census Campaign
Annex 6: Consultancy Report, K. Dierkes: Implementation of a Hydrocensus in Parts of the Oshana, Omusati, Oshikoto and Ohangwena Regions, Hydro-Census Results in the Ohangwena and Oshana Region
Annex 8: List of Categorization of Boreholes
Annex 9: Borehole Photo-Documentation with WW Identification (incomplete)
Annex 10: Borehole Photo-Documentation without WW Identification
Annex 11: Borehole Documentation, CuveWaters Project in Omusati
Annex 12: Water Analysis Reports
Annex 13: Hydro-Census Field Sheets, Consultancy C. Less
List of Figures

Figure 1: Shaded relief view (SRTM DEM) of the Cuvelai-Etosha Basin and the Hydro-Census Area.............................................................................................................................. 3
Figure 2: Classification of boreholes according to field observations........................................ 15
Figure 3: Example of production borehole with blocked access to the inspection port.............. 17
Figure 4: Water quality classifications within hydro-census study area. .................................. 19
Figure 5: Numbers of boreholes with class D water quality in relation to limiting constituent and region................................................................................................................... 20

List of Tables

Table 1: Water quality guidelines (WATER ACT, ACT 54 OF 1956). ........................................ 18
Table 2: Comparison of columns of the hydro census with possible import tables and columns of Growas database. .......................................................................................................................... 22
## Abbreviations

### General Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>BGR</td>
<td>Federal Institute of Geosciences and Natural Resources of Germany</td>
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<td>BMZ</td>
<td>German Federal Ministry for Economic Cooperation and Development</td>
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<td>CEB</td>
<td>Cuvelai-Etosha Basin</td>
</tr>
<tr>
<td>CuveWaters</td>
<td>Scientific IWRM-Project in Northern Namibia (ISOE Germany)</td>
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<tr>
<td>DRFN</td>
<td>Desert Research Foundation Namibia</td>
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<tr>
<td>DWSSC</td>
<td>Directorate of Water Supply and Sanitation Coordination</td>
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<tr>
<td>DWAF-BGR</td>
<td>Short form for the project “Groundwater for the North of Namibia” of the Federal Institute of Geosciences and Natural Resources of Germany (BGR) and the Department of Water Affairs and Forestry (DWAF)</td>
</tr>
<tr>
<td>DWAF</td>
<td>Department of Water Affairs and Forestry</td>
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<tr>
<td>GROWAS</td>
<td>Database at DWAF, Geohydrology (till 2013)</td>
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<tr>
<td>GROWAS II</td>
<td>The National Groundwater Information System at DWAF, Geohydrology</td>
</tr>
<tr>
<td>ISOE</td>
<td>Institute for Social-Ecological Research, Germany</td>
</tr>
<tr>
<td>IWRM</td>
<td>Integrated Water Resources Management</td>
</tr>
<tr>
<td>KfW</td>
<td>German Development Bank</td>
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<tr>
<td>LLSU</td>
<td>Large Livestock Units</td>
</tr>
<tr>
<td>MAWF</td>
<td>Ministry of Agriculture, Water and Forestry</td>
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<tr>
<td>MLR</td>
<td>Ministry of Lands and Resettlement</td>
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<tr>
<td>RWS</td>
<td>Short for Rural Water Supply, the official abbreviation is DWSSC</td>
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<tr>
<td>TOR</td>
<td>Terms of Reference</td>
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### Technical Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>a</td>
<td>year</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>EC</td>
<td>Electric Conductivity in mS/m or µS/cm</td>
</tr>
<tr>
<td>m asl</td>
<td>Meter above sea level</td>
</tr>
<tr>
<td>m bgl</td>
<td>Meter below ground</td>
</tr>
<tr>
<td>meq</td>
<td>Milliequivalent</td>
</tr>
<tr>
<td>mg/l</td>
<td>milligram per liter</td>
</tr>
<tr>
<td>µS/cm</td>
<td>micro Siemens per centimeter</td>
</tr>
<tr>
<td>N</td>
<td>North</td>
</tr>
<tr>
<td>SRTM</td>
<td>Shuttle Radar Topography Mission</td>
</tr>
<tr>
<td>TDS</td>
<td>Total dissolved solids</td>
</tr>
<tr>
<td>TEM</td>
<td>Transient Electromagnetic Method</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Trans Mercator</td>
</tr>
<tr>
<td>W</td>
<td>West</td>
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<tr>
<td>WGS 84</td>
<td>Geographic Coordinate System</td>
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</table>
Summary

The DWAF database GROWAS contains a large amount of data concerning groundwater extraction points; it is the main source of information for the determination of water used from groundwater resources. However, databases need constant improvement of their content. Groundwater extraction wells last for a while but deteriorate at some point, usage of wells change and new wells might be drilled without an entry in the registration system GROWAS. This means that a regular investigation of existing and abandoned water extraction points has to be conducted, hence a Hydro-Census was conducted for the Northern parts of the Cuvelai-Etosha Basin (CEB).

Information of about 1050 boreholes was extracted from the database. They were visited to determine the actual status of their condition. During this campaign 230 water samples were taken and water analyses were carried out to determine the spatial distribution of water quality. Many coordinates found in the database needed to be corrected. In total 233 boreholes were not found at all during the visits. Out of 822 found boreholes 278 are in good working condition while for exact the same number it was found that condition and usage needs to be improved. Thematic maps and reports were compiled, the improved datasets have been used to update the database GROWAS.

The hydro-census results revealed that referring to the objectives of the investigation some essential parameters needed for the assessment of hydro-geological properties of aquifers in the CEB either were not or could not be gathered. These data are for example well installation information which can be used in combination with borehole completion reports for the interpretation which aquifer is tapped by a borehole. If such information is not available additional technical methods should be included into the field work of the hydro-census campaign.

However, the hydro-census results will be used in future to roughly estimate an approximate amount of extracted water from groundwater reservoirs and their water quality. The findings will furthermore support the design of a groundwater monitoring network in the Cuvelai-Etosha basin and identify the need for further drillings in the area to concretize freshwater bearing aquifers. This information is essential to determine the water balance and usability in terms of quality of reservoirs and hence a part of sustainable groundwater management. The improved and new GROWAS II database is currently under development in Phase II of the Project.
1. Introduction

In January 2007 the project “Groundwater for the North of Namibia” commenced as a 3 year project in the framework of the Namibian-German Technical Cooperation. This project is carried out by the Department of Water Affairs and Forestry (DWAF) in co-operation with the Federal Institute of Geosciences and Natural Resources of Germany (BGR) and it is referred to as the DWAF-BGR Project within this text. Funding agencies are the German Federal Ministry for Economic Cooperation and Development (BMZ) and the Ministry of Agriculture, Water and Forestry (MAWF). The main objective of the project is that: The Namibian institutions of the water sector use well founded information concerning the groundwater resources in the Cuvelai-Etosha Basin (CEB) as a basis for Integrated Water Resources Management (IWRM). Therefore the project activities undertaken are to provide reliable data about the quantity and quality of groundwater resources in the CEB. Furthermore this information has to be presented to relevant planners and stakeholders in a way that allows them to use it appropriately. As an overall goal the project will contribute to enhanced water supply for the population living in the CEB.

In accordance with the project proposal (MAWF 2004), CEB desk study (BIWAC 2006), and the project planning workshop (MAWF-BGR, March 2007) a comprehensive hydro-census of boreholes in the CEB had to be implemented as one of the first steps of the groundwater investigation.

This report gives a detailed description of the activities and results related to the hydro-census activity. It also summarizes the results of a water sampling campaign that was part of the hydro-census fieldwork.

Chapter 1 and 2 of this report give an introduction to the project background and hydro-census objectives. Chapter 3 numerates the status on the groundwater investigations with a short description of the activities carried out. The starting point of the activities was the groundwater database GROWAS in the Department of Water Affairs and Forestry. A short overview on the history of data storage right up to the status of the database (2007/2008) is briefly summarized under Chapter 4.

The Methodology of the hydro-census campaign is described in detail under Chapter 5 and 6, followed by a discussion of the results under Chapter 7.

The collected information was used to update and synchronize the groundwater database. The procedures and results of the import are summarized under Chapter 8.

The outcomes and benefits of the hydro-census campaign and as well lessons learned during the process are shown under Chapter 9.
2. Overview

The endorheic Cuvelai-Etosha basin (CEB) lies between the perennial rivers Cunene in the west and the Okavango in the east.

The CEB is an extensive sedimentary basin in North Central Namibia. In turn, the CEB is part of the greater Owambo Basin, which stretches from northern Namibia to southern Angola. The extension of the CEB is about 97600 km\(^2\), from S17°-20° latitudes and E14°-18° longitudes. It is divided into four sub-basins: Tsumeb, Olushandia, Iishana and Nipele. The extent of the basin and sub-basins were defined by different hydrological and physiographic parameters, water supply and consumption, population density and political regions.

This basin is the most densely populated area of Namibia, nearly fifty per cent of Namibia’s total population of about 2 Million live here.

It is a flat area and part of the Kalahari basin system that stretches from Angola, Namibia and Botswana to South Africa. The basin consists of a thick sequence of Kalahari and younger sediments that rest on Karoo strata. Soils are predominantly sandy and vegetation is largely wood- and shrub land.

Figure 1: Shaded relief view (SRTM DEM) of the Cuvelai-Etosha Basin and the Hydro-Census Area.
Groundwater resources are generally scarce and especially in the lishana region of more or less poor quality. Traditionally water is collected in shallow hand-dug wells or in so-called “gat” dams, i.e. large excavations into which shallow groundwater seeps slowly. Large parts of the north-western and central parts of the area are supplied with water through a canal- and pipeline system that obtains water from a pumping scheme withdrawing water from the Cunene River at Calueque in Angola.

3. Previous Groundwater Investigations

Several groundwater investigation projects were conducted in the past focussed partly or entirely on areas in the Cuvelai-Etosha Basin.

Specifically are to be mentioned:

1992-1995: as part of a German-Namibian Technical Cooperation Project between DWA and BGR a helicopter flight from Ondangwa to Tsumeb was carried out. During this flight electromagnetic (EM), magnetic and radiometric data were recorded. This investigation has been accompanied by correlations between aerogeophysical data and existing borehole data as well as an isotope hydro-geological study. As a result detailed regional studies for the Tsumeb Area and for Oshivelo were recommended (Ploethner, 1997).

1999-2002: Funded by the German Development Bank KfW the Tsumeb Groundwater Study was implemented by a joint venture of the consulting companies GKW (Mannheim, Germany) and BICON (Namibia). The investigation area covered the commercial farm areas in Southern Oshikoto Region and some adjacent areas that already fall into Otjozondjupa Region. About 300 commercial farms were visited in the context of a hydro-census. Further the study conducted exploratory drillings, pumping tests, hydro-chemical and isotope water analysis and the development of a 3-D Groundwater Flow Model (GKW Consult & BICON, 2003).

2002-2005: in the framework of a German-Namibian Technical Cooperation Project between DWAF and BGR groundwater investigations were conducted in three target areas: Oshivelo Area, Eastern Caprivi, Eiseb Graben. Concerning the Oshivelo Area the following investigation methods were employed: helicopter electromagnetic (EM) survey, time-domain electromagnetic (TEM) ground measurements, drilling of investigation boreholes including pumping tests, borehole geophysical measurements, hydro-chemical and isotope hydrological analyses (Margane & Schildknecht 2005).
4. The DWAF Groundwater Database GROWAS

In the late 1970s the Geohydrology Division started electronic borehole data capture in spread-sheet form on a single desktop computer. Basic borehole data were entered together with an abbreviated geological formation description, where available, and four chemical parameters of the CSIR water quality maps. Together with this spread-sheet one set of topographical maps at the scale of 1:50,000 indicating the borehole positions constituted the “Master map” collection of the Geohydrology Division.

Borehole positions were identified either from the description on the “Borehole Completion Forms”1; and/or from the positions shown on the 1:400,000 CSIR maps that identified the sample positions. Where possible the information of the two data sets was consolidated and the borehole positions then plotted on the “Master maps”; the geographical coordinates (format DD.DDDD°, Geographical System, Schwarzeck Datum) were calculated from the respective position on these maps and each borehole was given a unique “Site ID code” consisting of the 1:50 000 map number plus a 4-digit number starting with “0001” on each map, e.g. 2217CA0001. Hard copy files of this data bank showing 10 records on one page exist in the Geohydrology Data Room.

In the middle 1980s the spread-sheets were transferred to a main frame computer of the Department. The “hanging files” in the record room of Geohydrology Division are hard copies of this database.

In the late 1980s or early 1990s this data bank was split into a number of spread-sheets on a “NCR” server of the Department containing more information but the link between the “Borehole Completion Form” data and the CSIR data (the CSIR analysis number) was lost. The NCR was DOS based. Following the collapse of the NCR database in 1998 there has not been any data entry or updating. No hard copies of these data sets exist. There were, however, electronic “Printer files”.

1 Until 1977 the Hydrogeology fell under the responsibility of the Geological Survey. For farmers the services of a Government geologist or technician for borehole site selection were free of charge if farmers supplied borehole information and samples. Subsidised drilling also required borehole information and samples. Government therefore had a rather complete record set of all boreholes drilled in the country and comparatively good borehole logs, as these were all logged by Geological Survey personnel. After 1977 governmental drilling responsibilities were split into 1st, 2nd and 3rd (National, Regional und Local) tier. Different numbers were allocated by the different authorities and central record keeping of the drilling activities in the country didn’t take place.
In 2004 the GROWAS database was launched. This new database runs on Microsoft SQL Server 2000.

Considering that

1. Data entry in the NCR data base was not up-to-date when it broke down; and
2. Numerous borehole surveys were carried out shortly after Independence in 1990 (see hydro-census history above); followed by
3. Extensive drilling campaigns, some of them known as “Draught Relief” programs,

it is evident that a considerable data entry backlog existed. During the course of the hydro-census in the CEB there has been an attempt to let students enter hard copy data from reports etc.. Due to the lack of experience and capacitating the personnel in advance quality of newly entered data is questionable. Before all borehole and aquifer related data of the hydro-census have been captured the breakdown of the database server as from April - May 2009 delayed the process. In the second half of 2009 new server hardware had been acquired. The final installation of the upgraded system took place in January 2010. Subsequently the finalization of the data entry took place from February to April 2010, involving hydro-geological consultants and project personnel.

In 2011 the Geohydrology Division started again the data entry of hard copy information into the GROWAS database. Due to a significant staff shortage the tasks were adjourned midyear 2012.

Besides the backlog there exist other challenges in data comparison and identification: In the GROWAS database the unique “Site ID code” identifier of earlier data banks was replaced by a “WW-number”. This created a number of complications:

- There has been insufficient control in the allocation of WW numbers. Probably different people have allocated the same number to different boreholes.
- At times it has been the practice to allocate WW numbers with A, B, C, etc. suffixes to indicate first, second, or third, etc. drilling attempt. GROWAS does not accept these suffixes. Suffix X often was given to unsuccessful boreholes. Thus in the field a sealed “X” borehole can be found in vicinity of a production borehole having the same WW number but without suffix X.
- Sometimes WW numbers have been issued without sufficient control: Whenever an official could not establish the original (or the latest) WW number the borehole is given a new WW number. Amongst others this has been the case for all “Site ID code” holes in the old data base that did not have or could previously not be linked to a WW number.
This practice has resulted in boreholes having two and more WW numbers which can often not be linked.

- Some hundreds of WW numbers in Ohangwena, Oshikoto and Omusati Region were given to hand-dug wells according to a specific survey in the 1990s. Many of them are represented by WW numbers of the 90000 series.

Apart from the positions on the “Master Maps” boreholes have in pre-GPS days been hand-plotted on various thematic maps. These positions were often based on distances and approximate directions from known points or they were copied from other maps. Therefore borehole positions can vary significantly from map to map, even duplication of boreholes with identical numbers but different positions on the same map occurs.

From the foregoing it is obvious that only field surveys can identify the correct position of a borehole. However, a borehole may be (i) difficult to find if the database positions are somewhat incorrect and (ii) there may be insurmountable difficulties to link that borehole to the correct hard copy or database information.
5. Methodology

5.1 General

Field observations and data collection are the basic tools of any earth related science. The term “Hydro-Census” in relation to groundwater investigation has been used in recent times to describe a survey that strives (i) to completely capture borehole and well data in an area together with (ii) related socio-economic data.


Conducting a hydro-census on regional or national scale demands the elaboration of a comprehensive questionnaire referring to the needs of a national groundwater database. Personnel conducting the census must be trained in advance to enter forms and questionnaires in the proper way. While some data, e.g. the GPS coordinates of a borehole (provided the same datum is used), is unambiguous, other parameters require the judgment of the census personnel. For instance, whether it is an observation or a production borehole, whether a borehole; the equipment; the reservoir; or the protective fencing need repairs or not; what type of pump is installed; or how reliable the water use information might be needs to be assessed by the observer.

According to the CEB desk study (BiWAC, 2006) the existing borehole data in GROWAS (Namibian Groundwater Database, hosted in Division of Geohydrology, MAWF) are described as incomplete and outdated. Thus there was need to verify unreliable data sets, to update old borehole information and to find out about boreholes that were not yet included in GROWAS.

5.2 Steps undertaken prior to field survey

In preparation of the hydro-census project members supported by 3rd and 4th year geology students from the University of Namibia (UNAM) systematically went through reports on groundwater issues in the CEB. Through this activity certain data sets in GROWAS could be
adjusted. The updating of GROWAS according to hardcopies of reports, maps, archived borehole completion reports and other documents took many months and continued during the hydro-census.

In order to clearly define the procedures a short hydro-census test run was implemented by project members and an extension officer of the Department of Rural Water Supply in April 2007 in the Oshikoto Region. Know-how from formerly conducted hydro-census activities in other parts of the country (mostly in areas of commercial farmland) and experiences of the test run helped to anticipate potential difficulties and to formulate terms of reference for the implementation. It was obvious that the assessment had to be planned carefully and that it should be accompanied by an information campaign. Project members elaborated a specific questionnaire that should help to carry out interviews with the water users (Annex 2: Hydro-Census Field Questionnaire Template).

Special attention must be given to:

1. A well planned questionnaire corresponding with the database requirements where the number-, unit-, or code format of each field is predetermined. As far as possible text fields should be replaced by YES/NO or code fields\(^2\) to ensure maximum conformity. Fields indicating the accuracy of the data should also be included\(^3\).

2. As the coordinates are the only unambiguous identifier of a site care must be taken that (i) the same GPS System and Datum and format is used by all surveyors and that (ii) the same coordinate pair and locality description is used on questionnaires; sample sheets; and labels of sample bottles, etc.

3. There should be some guidelines regarding what photos of the sites should show. The list of the photos or the individual photos themselves should be labelled identical to the questionnaires, etc.

4. Provision should be made for fields where ambiguities exist within the GROWAS database.

\(^2\) Examples would be: Water-level status **Static**, **Pumping**, **Recovering Influenced by nearby pumping**; Borehole status **Used**, **Not used**, **Destroyed or Abandoned**. A written definition of the terms should also be provided.

\(^3\) Such as the reported but not measured water level or yield.
6. The Hydro-Census

6.1 Scope of work

The field personnel conducting the hydro-census field work were required to:

(i) visit all boreholes in the project area in the Cuvelai-Etosha Basin (CEB) and interview owners or users capturing data according to a questionnaire;

(ii) document technical details in the questionnaire and take photographs of the water points; and

(iii) measure temperature, pH, conductivity (EC), dissolved oxygen (DO) and take water samples.

A complete list (TOR) of the duties of the contracted consultants and an example for the field sheet used for the hydro-census is attached in the Annex (Annex 5 and Annex 2).

The Project provided data in the GROWAS database and requested that the content of databases in the Directorate of Rural Water Supply (RUWIS database, DWSSC) and in the Directorate of Agriculture (NARIS database) should be consulted.

Topographical maps at scales of 1:250,000 and 1:50,000 covering the entire investigation area have been made available.

6.2 Requirements for field teams

Census personnel must have sufficient knowledge and experience to sample and measure what is required and to judge the correctness and accuracy of the data collected. Optimally they would have a good knowledge of the database in which the data will be stored.

For the activity of collecting data in the field consultants should be appointed and supervision be done by project staff. On 1st of August 2007 selected hydro-geological consultants were invited to a meeting with the project management to prepare the hydro-census field work. Requirement was that the hydro-census would be carried out during the period August to October 2007 (dry season) and the final report submitted not later than December 2007. Some of the candidates did not apply for the implementation of the hydro-census due to limited availability. Finally four consultants were chosen to conduct the survey.
The Project area was subdivided into four parts. For the delineation of the investigation area the geological setup was prioritised over administrative borders. Obviously the officially defined borders of the four Sub-basins of the Cuvelai-Etosha Basin do not exactly correspond to the extension of the basin in terms of a groundwater system. Thus in the Western part some boreholes had to be assessed that officially fall into Kunene Region. In the Eastern part of the basin the assessment covered some area of the Kavango Region. As Northern limitation of the investigation the border to Angola had to be respected, although from a scientific point of view the investigation of the Angolan part of the basin would be most useful to describe the transboundary aquifer system. The Southern parts of the basin were covered by earlier hydro-census activities. For this reason the areas of commercial farmland south of the veterinary fence and of the Etosha National Park were excluded from the 2007 hydro-census.

Four different consultants with hydro-geological background conducted the field work: Frank Bockmühl, Katharina Dierkes, Hannes Grobbelaar (subcontracted by Henk Labuschagne), Cecil Less.

Simon Wurdak investigated Uuvudhiya Constituency during his MSc Project in the framework of the CuveWaters project (Annex 11: Borehole Documentation, CuveWaters Project in Omusati).

Due to the fact that most of the people living in the rural areas of the CEB do not speak English it was decided that each of the hydro-census teams had to consist of a hydro-geologist and a technical person, at least one of them having good language skills in Oshiwambo. Ideally a staff member of the regional office of the Directorate of Rural Water Supply should join the consultant, thus facilitating the field work and contributing knowledge about water point locations, road access and customs of local population.

Water points such as traditional hand dug wells or even shallow concrete walled wells should not be assessed as there would have been a huge number of points to be visited. This would have increased enormously the costs of the measure without gaining a lot of reliable information. Traditional wells generally don’t exist over many years. Their position can be shifted from year to year. Also water levels and water quality are supposed to be changing from season to season.
6.3 Implementation

The hydro-census covering the Namibian part of the northern CEB was planned to be undertaken in 2007.

Two of four consultants started early enough to finalise their field work during the dry season 2007. Due to intense workload through commitments with mining industries and other clients and partly due to health problems the two other consultants commenced field work very late in 2007, thus being forced to conduct an important portion of their field work during the rainy season 2007-2008 that provided over-average rainfalls. The above mentioned circumstances lead to considerable delays of two field teams. Finally the last field visits were conducted in May 2008.

The presence of a member of the Regional Office of RWS (DWSSC) during the field visits proved to be very fruitful. Often the decision which sand road to use to reach remote villages was very much facilitated by field-experienced RWS staff. It also facilitated conducting the interviews with the caretaker or any other responsible person of the local water point committee.

In areas visited during the dry season significantly more water samples were taken as in areas that were assessed in the wet season. Consultants doing field work during the rainy season often had difficulties to find water users close to the water points. As animal herds could easily find water anywhere in the months January to May 2008 a lot of installed water points were found unused in this period and taking water samples was not possible. In many cases no member of a local water committee was available for an interview; sometimes not a single water user could be found.

The way in which some fields in the questionnaires were filled in reflects the different background and experience of the respective consultants, e.g. in the technical detail of pumps and engines. Unfortunately the documentation of the hydro-census lacks many field sheets or photos. Annex 9, 10 and 13 include only boreholes were field sheets and photos were available and represent therefore not a comprehensive documentation.
6.4 Awareness campaign

A further component facilitating the communication with water users was the awareness and information dissemination campaign conducted before and during the field work by members of the Desert Research Foundation Namibia and staff members from DWAF. Prior to hydro-census field work key stakeholders in the region (Regional Councilors, Traditional Authorities and Rural Water Supply Offices) were visited and informed about the project aims and activities using explanatory letters and the project flyer, printed in English and Oshiwambo.

During the field work period broadcast announcements were disseminated to inform people living in the investigated areas in which constituencies and villages the project should visit boreholes and questionnaire water users. Therefore the consultants had to be in regular contact with DRFN that coordinated the information flow.

At many places where the field teams interviewed water users it was noted that communities were already aware of the hydro-census activities prior to the arrival of the field teams as a result of the broadcast campaigns conducted.

The DRFN report is attached to this report under Annex 7: Report on the Hydro-Census Awareness Campaign, DRFN 2008.
7. Results and Discussion

7.1 Identification of boreholes in the field

In total the consultants were requested to visit approximately 1051 borehole sites in the Cuvelai-Etosha Basin according to the content of GROWAS database in midyear 2007.

822 boreholes were found, whereas at 233 sites no borehole could be located.

92 boreholes were found in the field but could not be correlated with existing data sets in GROWAS. For these new WW numbers were allocated and the relevant data entered into GROWAS. Reasons why certain boreholes didn’t yet exist in the database are:

- Some boreholes drilled on behalf of private individuals or organisations have never been reported to DWAF.

- Some boreholes drilled in the past were reported to DWAF through official borehole completion reports but without geographical coordinates. In these cases the detailed borehole information might exist in the hardcopy archive but integration into GROWAS is impossible as coordinates are indispensable requirement for data entering.

- In many cases borehole numbers inscribed on the stand pipe differ from the data sets in GROWAS that plot on the same location. A reason for this could be the fact that drilling companies request free WW numbers before they start a drilling campaign. These numbers become allocated in the field, but sometimes a renumbering could be done by the supervising consultant or DWAF staff members. For persons taking water samples or conducting any other type of fieldwork geographical coordinates should always be the main identifier and are even more relevant than WW numbers that are indicated at the borehole or in an old map.

- In one case the borehole found in the field showed a WW number that didn’t appear in GROWAS. Searching in the hardcopy archive a series of borehole completion reports from boreholes in the Cuvelai-Etosha Basin (WW 34364 to WW 34383) was found, all of them not yet appearing in the database. As coordinates were available this valuable information about borehole depth, lithology and more was entered into GROWAS.
In the past a considerable amount of borehole numbers was created by DWAF officers through procedural errors. Thus duplication of data sets occurred; especially many WW numbers in the range of 70000 are concerned. Often the hydro-census revealed that one instead of two or two instead of four boreholes do exist at one specific location. Subsequently numbers that are obviously wrong could be eliminated.

Considering the fact that the consultants did only search for boreholes in the surrounding of the 1050 sites in GROWAS it must be assumed that many more unregistered boreholes exist, making a water balance calculation far more difficult.

### 7.2 Condition of water points

Figure 2 represents a summary and classification of the condition of boreholes visited during the hydro-census campaign. This information provides a picture about functionality and need of maintenance or repair.

The rate of boreholes that are well maintained or need simple maintenance is only 34%. A relatively high number of boreholes are in disrepair, either still working under critical circumstances (27%) or already broken and currently not contributing to water supply (36%).

<table>
<thead>
<tr>
<th></th>
<th>boreholes and wells</th>
<th>monitoring boreholes</th>
<th>probe installed</th>
<th>A1</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>boreholes and wells</td>
<td>installed</td>
<td>functional</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td></td>
<td>installed</td>
<td>needing maintenance</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td></td>
<td>installed</td>
<td>needing major repair</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td></td>
<td>no installation</td>
<td>abandoned</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>boreholes and wells</td>
<td>no installation</td>
<td>not in use</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td>no installation</td>
<td>destroyed</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>boreholes and wells</td>
<td>unknown</td>
<td>not found</td>
<td>233</td>
<td></td>
</tr>
</tbody>
</table>

**Total of boreholes found:** 822

Figure 2: Classification of boreholes according to field observations.
Another aspect influencing water quality is the issue of fencing. 189 boreholes of the 498 installed boreholes and wells (B1, B2 and B3) were found with sufficient fencing. In 102 cases fences are reported to be in need of repair. 149 of the boreholes were not fenced at all allowing cattle to approach directly to the standpipe of the borehole. No information on fencing was given for 52 boreholes. Unfenced boreholes results in undesirable high risk of faecal pollution of the groundwater through animal excrement.

Action is needed to improve water supply for the population. DWSSC and MLR as main responsible bodies for water supply installations need to be informed to intensify rehabilitation or replacement of boreholes in disrepair.

7.3 Remarks on borehole information

The hydro-census results revealed that referring to the objectives of the investigation some essential parameters needed for the assessment of hydro-geological properties of aquifers in the CEB either were not or could not be gathered. These data are for example well installation information which can be used in combination with borehole completion reports for the interpretation which aquifer is tapped by a borehole. If such information is not available additional methods included into the hydro-census campaign would be desirable. For example, the use of borehole cameras and conducting simple hydraulic tests at boreholes, like slug tests or short term draw-down tests, would provide valuable information. The information collected in this hydro-census campaign gives only limited options for further evaluation of aquifer characteristics.

It has furthermore to be mentioned that the borehole documentation from the field personnel is not complete. Especially the photo-documentation and the field sheets are not representing the entire field work. The quality of work strongly differs between the different consultants.

7.4 Socio-economic findings

Some of the questions of the standard questionnaire targeted at socio-economic issues like number of households, utilisation of the water, number of large livestock units (LLSU), and existence of water point committees.

For the quantitative parameters of number of households and number of LLSU the reliability of data must be estimated to be relatively low. Nevertheless starting a discussion about these issues during the interview led to a deeper understanding of the local situation. The question for
instance how far people would have to walk to reach the next water point revealed that addi-
tional water points could be needed.

Interviews revealed details about the acceptance of the official RWS installations. In many cas-
es community members reported that they prefer to use traditional wells or pan water as source
for drinking water and use borehole water for stock watering. Depending on seasonal varying
availability of traditional water sources the existing boreholes often serve as backup water sup-
ply systems only.

Information about LLSU should be considered as unreliable as this question often raised suspi-
cions about potential governmental control and future tax obligations of cattle owners. Certainly
some LLSU numbers were intentionally underestimated. In some cases cattle herds might have
been counted at more than one water point, as some farmers move around with their livestock
and use different boreholes.

Concerning the question of existence of water point committees the answers might be different
according to the perception of the interview partner. Generally it can be stated that the rate of
existing committees is higher in Oshikoto and Ohangwena than in Omusati. One of the reasons
could be the fact that Omusati Region is more dominated by cattle posts populated by paid
workers. Typical villages with inhabitants who permanently live at a place are rare in Omusati
and more common in Oshikoto and Ohangwena. The higher number of water committees re-
flects increased ownership for the water points.

7.5 Water level measurements

The possibility of water level measurements was restricted by the fact that many of the installa-
tions did not allow to insert a dipmeter. According to the standard design of a RWS borehole
installation boreholes generally have been equipped with ports (screwed 2” caps) for
accessing the water table with a water level dipmeter. However, contrary to the plans in the design sheet, pumps and dis-
charge pipes often have been installed in such a way, that these ports cannot be
opened (see Figure 3).

Figure 3: Example of production borehole with blocked access to the inspection port.
The creation of a reliable groundwater level contour map of the northern CEB was not possible due to the fact that only few water-level-information could be collected during the hydro-census.

The possibility of taking water samples was often hampered by the fact that the pumps were not operating at the moment the field team visited a water point. According to the local arrangements some pumps were operating during night hours, others during specific operation hours only.

### 7.6 Results of Groundwater Analysis

A total of 225 water samples were taken during hydro-census field work and analysed at Analytical Laboratory Services cc in Windhoek. Some samples were analysed at the BGR. These samples enlarge significantly the amount of reliable water quality data in the Cuvelai-Etosha Basin. It is envisaged to use these data together with existing chemistry data for a detailed hydro-chemical assessment to be conducted as a further step of the groundwater investigation project. The groundwater analysis results are summarized under Annex 4. The detailed analysis reports are attached as Annex 12.

Table 1 shows the water quality thresholds in Namibia based on the **WATER ACT (ACT 54 OF 1956)**.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Livestock watering</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC [mS/m]</td>
<td>150</td>
<td>300</td>
<td>400</td>
<td>&gt; 400</td>
<td>&gt; 6000</td>
</tr>
<tr>
<td>Sulphate as SO₄ [mg/l]</td>
<td>200</td>
<td>600</td>
<td>1200</td>
<td>&gt; 1200</td>
<td>&gt; 1500</td>
</tr>
<tr>
<td>Sodium as Na [mg/l]</td>
<td>100</td>
<td>400</td>
<td>800</td>
<td>&gt; 800</td>
<td>&gt; 2000</td>
</tr>
<tr>
<td>Fluoride as F [mg/l]</td>
<td>1.5</td>
<td>2.0</td>
<td>3.0</td>
<td>&gt; 3.0</td>
<td>&gt; 6.0</td>
</tr>
<tr>
<td>Nitrate as N [mg/l]</td>
<td>10</td>
<td>20</td>
<td>40</td>
<td>&gt; 40</td>
<td>&gt; 100</td>
</tr>
</tbody>
</table>

Table 1: Water quality guidelines [*WATER ACT, ACT 54 OF 1956*].
Of 225 water samples only 34 (≈ 15%) correspond to drinking water of class A quality. The main components responsible for poor water quality are fluoride, sodium and EC. High concentrations of sulphate, nitrate and other components were found in a relatively small number of samples.

- 54 samples showed fluoride content corresponding class D
- 26 samples showed sodium content corresponding class D
- 21 samples showed EC content corresponding class D
- 12 samples showed sulphate content corresponding class D
- 3 samples showed nitrate content corresponding class D.

Figure 4: Water quality classifications within hydro-census study area.

Regarding the regional distribution of boreholes with poor water quality the following patterns can be observed:

- In Oshikoto Region Fluoride, Sodium and EC are responsible for poor water quality,
- In Ohangwena Region mainly Fluoride and EC are responsible for poor water quality; Sodium plays a minor role,
- In Omusati Region EC and Sulphate are responsible for poor water quality; Fluoride plays a minor role,
The feature of high Fluoride concentrations in samples of Ohangwena Region and Oshikoto Region also extends into Western Kavango Region.

Figure 5: Numbers of boreholes with class D water quality in relation to limiting constituent and region.

In the majority of the cases the residents living in the surroundings of water points fully depend on the borehole water during the dry season or during the whole year. In general there is no knowledge about the health risks of the low-quality water among these communities. No examples for water treatment installations could be found at the visited water points.
8. Import of Hydro-Census Data to the GROWAS Database

8.1 Borehole data

The first quality-check of data stored in the GROWAS database, regarding the CEB borehole information, has been realized already prior to the field campaign 2007/2008. A plausibility check determined un-realistic datasets.

Datasets removed from GROWAS or not included in the hydro-census campaign were:

- a. datasets with diameters greater than 1000mm,
- b. datasets with final drill depths of less than 3m,
- c. datasets with almost no corresponding data, i.e. only a number and coordinates.

These datasets were assumed to be incomplete or may represent traditional wells, as the main aim of the hydro-census was to only investigate existing boreholes.

In June 2011, SQL-scripts for an import of the hydro-census data to the GROWAS database were written at BGR in Hannover. The import of hydro-census information needed to be done step by step to avoid import mistakes since the GROWAS database does not have import functionalities for bulk data. Several adjustments and manual additions had to be made via the GROWAS graphical user interface.

The first step prior to the upload of new data was the identification of datasets which can be imported or updated in GROWAS. Not all data gathered during the hydro-census find a matching field in GROWAS.

Table 2 shows hydro-census data and comparable target fields in GROWAS for the import procedure. Mainly, latitude and longitude and the borehole status could be re-imported.

It was discussed to import the information “location” as well but no fields are defined in GROWAS for this information. This and other shortcomings will be amended in the new database GROWAS II and the information will be added at a later stage. The information “region” and “constituency” can be imported but the question was raised whether the entries should be re-checked using a geospatial relation tool and the reference tables stored in GROWAS need to be checked and completed first. Information like “Topo_Sheet_Id”, “Topo_Ref_No”, “casing_diameter” and “casing_material” were not imported as information is probably extracted from GROWAS and was not updated during the hydro-census.
Table 2: Comparison of columns of the hydro census with possible import tables and columns of GROWAS database. (The comment field gives information of why import is conducted or not.)

<table>
<thead>
<tr>
<th>Hydro-Census data Excel-Tables</th>
<th>GROWAS-Tables</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All column names from Hydro-Census (shortened)</td>
<td>Fields that exist in tables of GROWAS, syntax is following: <code>name_of_table.name_of_column</code></td>
<td>import key</td>
</tr>
<tr>
<td>WW_ID_(present)</td>
<td>mt_BORHOLE.BoreholeNo</td>
<td>import key</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>Region</td>
<td>mt_borehole.fk Region</td>
<td>maybe import</td>
</tr>
<tr>
<td>Location</td>
<td>mt_borehole.Location</td>
<td>maybe import</td>
</tr>
<tr>
<td>Constituency</td>
<td>mt_borehole.FK_CONSTITUENCY</td>
<td>no import, constituencies not defined in look-up table</td>
</tr>
<tr>
<td>Topo_Sheet_No</td>
<td>mt_borehole.fk_TopoSheet50</td>
<td>no import</td>
</tr>
<tr>
<td>Topo_Ref._ID</td>
<td>mt_borehole.OldWellNumber</td>
<td>no import</td>
</tr>
<tr>
<td>RWS_Borehole_No.</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>New_WW_ID</td>
<td></td>
<td>No data, column empty</td>
</tr>
<tr>
<td>Lat.</td>
<td>mt_borehole.Latitude</td>
<td>import</td>
</tr>
<tr>
<td>Long.</td>
<td>mt_borehole.Longitude</td>
<td>import</td>
</tr>
<tr>
<td>BH_status</td>
<td>mt_borehole.fk_BoreholeStatus</td>
<td>needs to be defined in look-up table</td>
</tr>
<tr>
<td>Water_committee_existing_Y/N</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>Contact person water committee</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>Responsible_for_borehole</td>
<td></td>
<td>maybe equivalent to Permit holder, no import</td>
</tr>
<tr>
<td>Casing_diameter</td>
<td>subt_construction.diameter</td>
<td>is likely an export field of GROWAS, no import</td>
</tr>
<tr>
<td>Casing_material</td>
<td>subt_construction.fk_ConstructionMaterial</td>
<td>is likely an export field of GROWAS, no import</td>
</tr>
<tr>
<td>Bh_depth</td>
<td>MAX(subt_DIAMETER.ToDepth)</td>
<td>import not possible, field generated automatically</td>
</tr>
<tr>
<td>Source for bh depth</td>
<td></td>
<td>no import</td>
</tr>
<tr>
<td>RWL</td>
<td>mt_borehole.LatestWaterLevel</td>
<td>no import</td>
</tr>
<tr>
<td>measurement_from_collar/parapet/other</td>
<td></td>
<td>no import</td>
</tr>
<tr>
<td>Collar_height</td>
<td>mt_borehole.CollarHeight</td>
<td>no import</td>
</tr>
<tr>
<td>Date(year)ofcompletion</td>
<td>mt_borehole.DrillEndDate</td>
<td>no import</td>
</tr>
<tr>
<td>Bh_rehabilitation?Y/N/when</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>Rehabilitation_necessary?</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
<tr>
<td>PID</td>
<td></td>
<td>No information on dataset</td>
</tr>
<tr>
<td>PID_measurement</td>
<td></td>
<td>No information on dataset</td>
</tr>
<tr>
<td>Taking_of_water_samples_possible?</td>
<td></td>
<td>no field in GROWAS</td>
</tr>
</tbody>
</table>
Table 2 continued: Comparison of columns of the hydro-census with possible import tables and columns of GROWAS database. (The comment field gives information of why import is conducted or not.)

<table>
<thead>
<tr>
<th>Hydro-Census data Excel-Tables</th>
<th>GROWAS-Tables</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water_meter_installed?_Y/N</td>
<td>no field in GROWAS</td>
<td></td>
</tr>
<tr>
<td>Storage_facilities/reservoir_x_m3</td>
<td>no field in GROWAS</td>
<td></td>
</tr>
<tr>
<td>Installed_pump_type</td>
<td>no field in GROWAS</td>
<td></td>
</tr>
<tr>
<td>Remarks</td>
<td>subt_inspection.comment</td>
<td>No import</td>
</tr>
<tr>
<td>Date of survey</td>
<td>subt_inspection.DateOfInspection</td>
<td>import, not all dates available</td>
</tr>
<tr>
<td>Suvey conducted by</td>
<td>subt_inspection.fk_Subject</td>
<td>import</td>
</tr>
<tr>
<td>Photo_1</td>
<td>mt_BOREHOLESKETCH.SiteSketch</td>
<td>No important, no pictures available for import</td>
</tr>
<tr>
<td>Photo_2</td>
<td>mt_BOREHOLESKETCH.SiteSketch</td>
<td></td>
</tr>
<tr>
<td>Bh_original</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>Dip_meter</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>Reservoir_m3</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>Engine no</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>Long_wgs84</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>Lat_wgs84</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>WW_indi</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
<tr>
<td>WW_susp</td>
<td>very sparsely data available, no import</td>
<td></td>
</tr>
</tbody>
</table>

After the identification of hydro-census data which can be imported to GROWAS the data import was conducted as previously described.

During the hydro-census 1055 boreholes were checked:

- 233 boreholes do not have coordinates, it is considered that these boreholes were not found and hence will get a remark “location not found” in GROWAS (subt_inspection).
- Several boreholes are not in the GROWAS database, these boreholes have been added to the main table borehole (mt_borehole).
- Several boreholes are not in the GROWAS database and have no coordinates: these boreholes were ignored at all.
- Several boreholes were inspected twice by different consultants, partly both consultants did not find the borehole and hence there are no coordinates.
8.2 Chemistry Data Import

During the preparation of the import scripts each water chemistry value was checked in Excel on its prefix and was extracted to a separate field. For each water-chemistry value the specific method number was extracted and added as column name. This procedure was necessary to reassign the values in GROWAS.

The hydro-census campaign delivered for 232 boreholes water quality information. For some boreholes two water samples were taken. Major and minor ion content and field parameters were the main quality parameters gathered by the hydro-census.
9. Conclusions and Recommendations

The procedure of realizing a hydro-census can be seen as one step in a series of activities that aim at a comprehensive understanding of a complex hydrogeological situation. In this regard the results of the hydro-census contributed important elements to further steps of the groundwater investigation:

- To identify the need for observation borehole drillings and the spatial density of drillings to establish a groundwater monitoring network in the CEB.
- To choose existing locations and boreholes where water sampling for a detailed chemical water quality survey should be carried out.
- To choose locations at which geophysical measurements might be specifically promising.
- To see where severe water supply gaps exist in rural areas.

Some of the outcomes of the hydro-census went beyond the collection of hydrogeological information. Thus this exercise gave an overview about the water supply situation in the Cuvelai-Etosha Basin and pointed out some critical issues in the water supply situation.

As an example the chemical water analyses showed clearly that many of the boreholes used for human drinking water and livestock water supply produce water that shouldn’t be consumed without further treatment. It’s obviously an urgent challenge to find out in which cases which type of water treatment can be the appropriate response to poor water quality. The main quantity of water is used for livestock watering and domestic purposes and does not require class A water quality. A smaller amount of water needed as drinking water for humans could be treated before given to the user. Specific emphasis in this regard must be given to Fluoride as a widespread contaminant. A feasibility study for defluoridation techniques under the existent circumstances is recommended and already under way in phase II of the project. Adapted solutions could be elaborated under responsibility of the Department of Water Affairs and Forestry (Directorate of Rural Water Supply and Directorate of Resource Management).
The hydro-census revealed also some shortcomings. The main are listed in the following as lessons learned:

Lessons learned:

a. Prior to the field campaigns a detailed analysis of existing data needs to be conducted. This includes not only the existing data in the groundwater database. Essential for the understanding of the aquifer systems and the identification of the demand for observation boreholes is the comparison of information in the existing database and information which is only available in hard-copy format in the archive of the DWAF and DWSSC.

b. A hydro-census campaign should include a more detailed description of well-installations. On-site methods like hydraulic tests and the use of borehole cameras are essential if borehole completion reports are not available.

c. Collection of water samples from boreholes should be realized even access is limited due to installations. With adequate equipment the installations could be temporarily removed, samples taken and e.g. hydraulic tests conducted. Sometimes only some screws need to be removed and access for a dipmeter for example is already granted.

d. Conducting a hydro-census campaign needs to go hand in hand with an analysis of the existing database. The hydro-census in the CEB revealed that the existing database is not capable to handle much of the information collected in the field. Especially the usage of specific data, e.g. socio-economic information, should be discussed prior to the investigations.

e. Partners should be identified beforehand to discuss the quality of the information needed for other projects regarding water points (e.g.: Water point remediation projects).

f. The documentation of the personnel conducting the field campaign need be handed over for all boreholes. The field work documentation is an important part and should be made available completely with all field sheets and photodocumentation.
10. References

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