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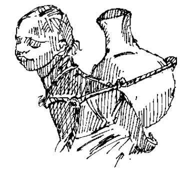
INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION



Groundwater resource assessment and development

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THE MAUN GROUNDWATER Development Project (MGDP) was initiated by the Botswana Department of Water Affairs (DWA) in 1995 following the Government's decision to terminate the Southern Okavango Integrated Water Development Project (SOIWDP) in 1992. SOIWDP was a large engineering study that proposed the utilisation of surface water to meet a number of water demands, including Maun's, on the southern fringe of the Okavango Delta.

The primary goal of the MGDP was to assess groundwater availability and development potential within a heretofore unexplored area to meet the projected year 2012 demand for the town of Maun estimated at 4 million cubic meters (MCM) per year.

Maun has experienced significant population growth over the past few decades that has resulted in increased pressure on existing water supplies. During this same period, surface water availability has been declining. The 1970's were generally a decade of above average outflow from the delta, the 1980's saw a decrease in outflow and the 1990's have experienced some of the lowest outflows on record.

Project area setting

The project area is located in Ngamiland District of north-western Botswana and covers an area of 12,500 km^2. Maun lies at the distal end of the Okavango Delta in the Kalahari Desert.

The climate in and around the project area is semi-arid to arid. Average annual rainfall is 455 mm at Maun and potential evapotranspiration usually exceeds 2,000 mm.

Long-term records of inflow into the delta at the Botswana-Namibian border and outflow from the delta in the Boro River indicate that, on average, 2 percent of the inflow is manifested as outflow with the average annual outflow being about 200 MCM/yr. The outflow occurs as an annual flood and during this 2-year project many of the delta outflow channels were dry for at least 8 months in a year.

The area geology consists of thick Kalahari Bed sediments underlain by bedrock units including the Karoo Supergroup of Carboniferous to Jurassic Age and the Damara Supergroup of Paleozoic to Proterozoic Age.

Methods

The project was implemented in three phases which included:

- Phase 1: Inception Period Study
- Phase 2: Field Exploration Programme
- Phase 3: Resource Assessment.

The principal focus of the Inception Period was to identify specific areas within the large 12,500 km^2 project area for field exploration. These activities involved the collection, review and interpretation of existing data, a borehole inventory and field reconnaissance, and a test airborne and ground geophysics programme.

During the Inception Period, multi-disciplinary technical studies including vegetation, geomorphology, hydrogeology, geophysics, surface water hydrology, remote sensing, structural geology and hydrochemistry were carried out and the data synthesised into a conceptual hydrogeologic model for the project area.

Shallow groundwater conductance maps, prepared from the airborne electromagnetic and initial ground geophysics surveys delineated areas of relatively low conductance, indicative of fresh groundwater, within the channels and flood plains of the main delta outlet river systems (flowing and dry). Areas of high conductance indicative of brackish and saline groundwater were noted between the river channels and at depth below the fresh water aquifer systems within the river channel and flood plain areas.

On the basis of the Inception Period work and with the results of an airborne electromagnetic geophysics study over the project area, six areas were identified for shallow Kalahari Bed exploration (Figure 1).

The field exploration programme included ground geophysics, test and production well installations and test pumping within the six exploration areas. The completed work quantities are summarised in Table 1.

The resource assessment phase involved: (a) an evaluation of groundwater availability and development potential for the six exploration areas, (b) the identification of additional data collection requirements and (c) recommendations for a development programme to meet the immediate (year 2000), medium term (year 2012) and longer term (year 2030) water supply needs for Maun.

Results

The fresh water aquifers identified in the six exploration areas are similar in nature and consist of multi-layered aquifer systems with semi-confining beds, underlain by saline aquifer systems. Aquifer units consist of fine to medium sands, and the semi-confining units of clays, sandy silts and sandy clays.

Table 1. Summary of field exploration

Programme	
Description of Work	**Quantity**
Geophysics	
TEM Soundings	690
HLEM (Line Km)	4
Magnetic Profiling (Line Km)	127
Boreholes	111
Exploration	40
Observation/Monitoring	65
Test Production	6
Aquifer Pumping Tests	46
Water Sampling (Major Ions and Isotopes)	
Boreholes	140
Surface Water	7
Rain Water	36
C-14/Tritium	6

Test pumping within middle semi-confined fresh water aquifers, with observation wells in the upper freshwater aquifers and the bottom saline water aquifers, indicated hydraulic interconnection between these three aquifer systems.

Under non-pumping conditions, the overall groundwater flux is downward. Under pumping conditions, the hydraulic heads are rearranged such that the flux is directed to the pumped aquifer system. The upper and middle semi-confined fresh water aquifer systems are characterized by transmissivities ranging from 10 to as much as 130 meters squared per day (m^2/d). The vertical hydraulic conductivity of the semi-confining layers is in the range from 10^{-2} to 10^{-4} meters per day (m/d)indicative of semi-confining layers through which significant leakage can and does occur.

Normal chemical evolution takes place with depth from low salinity, calcium-magnesium bicarbonate water in the shallow unconfined aquifers; to moderate salinity, sodium bicarbonate type water in the semi-confined aquifers; and eventually to sodium chloride-sulphate type water in the deeper semi-confined saline aquifers. This evolution indicates that the dominant recharge mechanism is the downward leakage of infiltrated surface water.

An analysis of deuterium versus ^{18}O for project samples indicated that rainwater plots along the meteoric water line (MWL). Groundwater and river water both plot along the evaporation line confirming that the predominant recharge source to the groundwater systems along the river valleys and flood plains is river water.

Conclusions

The MGDP findings indicated that adequate groundwater resources are available to meet Maun's 2012 water supply demand of 4 MCM per annum.

Numerical modeling simulations indicated sustainable development potential in all six exploration areas. Areas where annual delta floods (outflow) are still active and therefore receive regular recharge are more favorable for sustained resource development. Table 2 summarises the findings in four of the exploration areas that are practicable for near term development.

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Table 2. Summary of findings

Exploration Area Location	Area (Km^2)	Thickness of Fresh Groundwater (m)	Volume of Fresh Groundwater in Storage (MCM)
Lower Thamalakane River Valley	30	30 to 40	110 to 325
Upper Thamalakane River Valley	70	70 to 85	450 to 1,350
Upper Boro River Valley	170	40 to 110	1,200 to 3,600
Kunyere River Valley System	140	50 to 70	700 to 2,100
Exploration Area Location	**Recharge Mechanisms**	**Last Recharge Event**	**Nature of Principal Fresh Aquifer Systems**
Lower Thamalakane River Valley	Flood Infiltration	1998	Shallow Unconfined
Upper Thamalakane River Valley	Flood Infiltration	1998	Shallow Unconfined and Middle Semi-Confined
Upper Boro River Valley	Flood Infiltration	1998	Middle Semi-Confined
Kunyere River Valley System	Flood Infiltration	1992	Upper Unconfined/Semi-Confined, and Middle Semi-Confined