GROUNDWATER RESOURCE EVALUATION, MAUN, BOTSWANA, SOUTHERN AFRICA

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As so many interesting things happen, our project in Botswana was somewhat of a surprise in the way it came about from a meeting on a journey for a different purpose. During a trip to Mozambique and various other places in Southern Africa in 1992, I met an old Kashmiri friend with whom I had once worked on a large drilling project in India 20 years ago. This old friend, Tej Bakaya, had emigrated to Botswana in Southern Africa where he now has a consulting practice (Water Resources Consultants) specializing in groundwater supply projects. These projects rely heavily on geophysics for the siting of test and production wells. Tej was looking for new opportunities in the local arena and we in Pennsylvania were generally looking at foreign (subsurface saturated) soil to do something beneficial and different.

The project on which we successfully bid together in March of 1995 was large and complicated and required a meeting of our respective strengths; i.e. Tej's geophysics, pumping test team, contacts, and knowledge of the country, with my firm's capacity in drilling and hydrogeologic data analysis. We also contributed our very American can-do attitude and concentration on the bottom line.

Our location was the town of Maun in Ngamiland in northwest Botswana. Our purpose was to explore for groundwater to supply this rapidly growing town which currently holds 30,000 inhabitants and is expected to grow to over 75,000 by 2012. The expected water demand in the year 2012 is 4 million cubic meters per year (MCM/yr.) or about 3 million gallons per day (mgd). Maun is absolutely unique, situated both on the edge of the Kalahari Desert and the Okavango Delta. Not often has a town been so encouraged yet so constrained by its natural environment. Water is the key to the area's internationally-acclaimed beauty and to its survival.

The Okavango Delta is one of the world's largest inland river deltas. It is created by two parallel faults which serve to dam the Okavango River that spreads out into a fan-shaped pattern of perennial and seasonal swamps that are home to myriad wildlife including elephant, cape buffalo, big cats, hippo, kudu, countless small animals and birds. Maun is rapidly growing as the jumping off point for safari camps (generally reached by small chartered aircraft) in the verdant delta. At the same time, being located about 15 km southeast of the distal end of the delta, Maun is a dry dusty place most of the year where many people still spend much time and effort hauling water.

The river enters the delta in a large channel called the Panhandle at a substantial average annual flow rate of around 9,000 million cubic meters per year (MCM/yr.) or 2.4 x 10^6 million gallons per year. The average annual flow leaving the delta via the main delta distributary (the Boro River) is a trickle compared to this torrent, about two percent of the inflow, or 195 MCM/yr. (5.0 x 10^4 million gallons per year). The outflow is seasonal and the outflow channels are often dry for months at a time. In recent years (1990s), the water leaving the delta flows through Maun for just a short time each year during the annual flood, which occurs in the southern hemisphere winter (June-August). Photo 1 shows the 1996 delta outflow which reached the junction of the Boro and Thamalakane Rivers in early September. The mean annual flow for the 1990s at this junction is about 20 percent of what it had been during the 1970s. The 1995 and 1996 floods were the worst on record. No one knows whether this severe dry spell is permanent or will reverse itself in our lifetimes.

The groundwater exploration project for Maun's water supply was initiated by our client, the Department of Water Affairs of the Government of Botswana. This project followed on the heels of large-scale engineering schemes proposed by a large engineering firm working for the Department of Water Affairs for the region, which entailed dredging, dams and reservoirs.

These schemes were judged faulty by the International Union for the Conservation of Nature (IUCN) review team, who recommended that the conjunctive use of surface water and groundwater be examined. Local conservation organizations and residents also assisted in defeating these schemes which were contemplated with much consternation because of their extensive disturbance to the natural environment. During our time in Maun, we naturally heard much local lore and many colorful stories. Not the least of these were stories of attempts to change or clear the water channels of the delta which purportedly always ended in failure. The moral of the story was to not try to force changes, the consequences of which could not be understood or predicted, and which would undoubtedly be ill-fated. Groundwater was a possible and benign alternative.

Some of the stories we heard were strange indeed and amusing to our modern minds. One story was of a German engineer who was hired to build a small dam across one of

Photo 1: Delta Flood of 1996 Reaching the Junction of the Boro and Thamalakane Rivers.

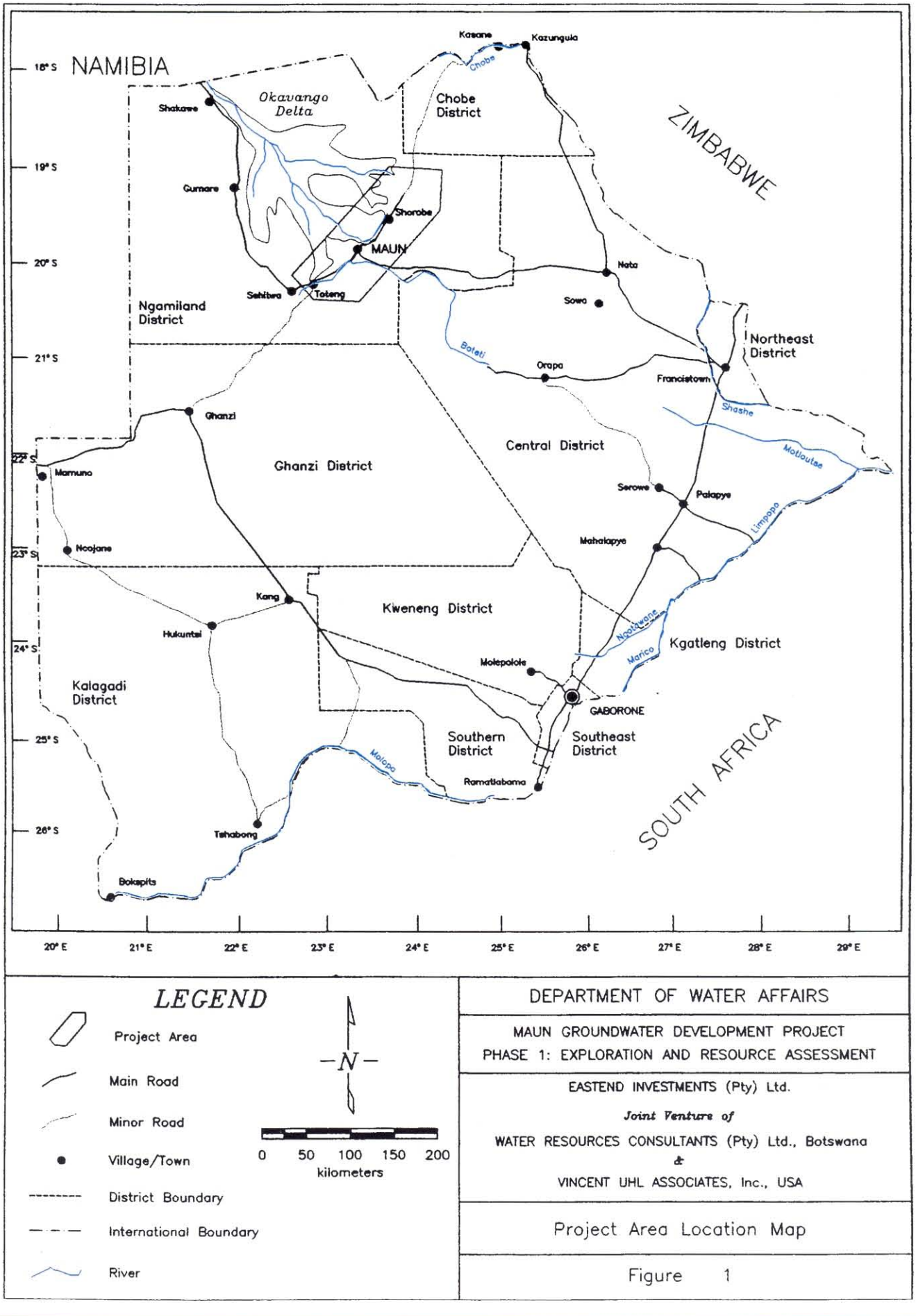
the water channels in the Delta sometime in the early part of the century. When the dam was partially built and water was flowing fiercely through the opening, he reportedly convinced a colonial government official that partially built dams increased the flow of water and was allowed to construct many of these monuments. Certainly a story out of another time!

Although the current supply for Maun came from a wellfield (Shashe Valley), very little was known about groundwater occurrence and availability in our 5,000 square mile study area, roughly half the size of New Jersey (Figure 1). Much of this area was absolutely unexplored in terms of groundwater occurrence and availability. During the project inception period, we used all available tools and the technical expertise around us in several disciplines to synthesize a conceptual picture of the area and identify areas for exploration in the drilling program. We hired professors at the University of Botswana to study and report on vegetation, geomorphology, geologic structure, surface water hydrology, and remote sensing (satellite imagery). An Australian firm conducted an airborne electro-magnetic (EM) survey over a large chunk of the project area, and we conducted ground geophysical surveys. We did a reconnaissance of existing wells (called boreholes in Botswana). The wells we found included those for private residences and ostrich farms, for remote villages and cattle posts, in addition to the supply systems for Maun and the outlying village of Matlapaneng, which was our home (base camp) during the project.

Our conceptual picture evolved from the research during the inception period. The river channels came into high focus as the areas to target for groundwater exploration. The airborne geophysics indicated areas of fresh water beneath and, in certain cases, extending far beyond the boundaries of these channels. Vegetation analysis from the satellite imagery showed freshwater loving species in extensive riparian forests bordering these channels and extending far beyond their boundaries in the same areas as the geophysics. Analysis of all the data indicated that the chance of finding significant freshwater supplies in the vast interfluves between these channels was minimal. In addition, the available data for valleys such as the Shashe with its existing wellfield indicated that the freshwater underlying these channels was underlain by brackish and then saline water within a few tens of meters. The freshwater layer in this aquifer was being depleted.

Therefore, at the start of the exploration drilling program, we were faced by several challenges. Not the least of these was our uncertainty that we would be successful in finding sufficient overall freshwater resources, which, given the hydrogeologic setting, seemed a formidable task. In addition, there was the need to find areas where wellfields would be feasible; i.e. where the aquifer conditions could support pumping without depletion or significant upconing of water of unacceptable quality, and would permit decent well yields.

During the drilling program, we installed and pump-tested about 50 exploration and test wells, many in remote areas reached by sand tracks in four-wheel drive vehicles. A number of these wells were installed in wildlife areas where encounters with elephants were not uncommon. We were very grateful to our young Botswanan scientists and technicians; not just for their technical input, but for their guidance in this wild part of the planet where getting lost or stuck or making


NAMIBIA
ZIMBABWE
SOUTH AFRICA
Okavango Delta
Chobe District
Ngamiland District
Ghanzi District
Central District
Northeast District
Kweneng District
Kgatleng District
Kalagadi District
Southern District
Southeast District
Kasane
Kazungula
Chobe
Shakawe
Gumare
Shorobe
MAUN
Sehitwa
Toteng
Nata
Sowa
Orapa
Francistown
Boteti
Shashe
Motloutse
Limpopo
Ghanzi
Mamuno
Ncojane
Kang
Hukuntsi
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Palapye
Mahalapye
Ngotwane
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LEGEND
Project Area
Main Road
Minor Road
Village/Town
District Boundary
International Boundary
River
N
0 50 100 150 200
kilometers
DEPARTMENT OF WATER AFFAIRS
MAUN GROUNDWATER DEVELOPMENT PROJECT
PHASE 1: EXPLORATION AND RESOURCE ASSESSMENT
EASTEND INVESTMENTS (Pty) Ltd.
Joint Venture of
WATER RESOURCES CONSULTANTS (Pty) Ltd., Botswana
&
VINCENT UHL ASSOCIATES, Inc., USA
Project Area Location Map
Figure 1

a mistake can be fatal. The discharge end of pumping test pipes encouraged locals to collect water during these tests (Photo 2) and on occasion, lions and other animals.

The freshwater aquifers encountered in the exploration program were all similar in nature and consisted of multi-layered, fine-to medium-sand aquifer systems with semi-confining beds of clays, sandy silts and sandy clays, overlying a brackish/saline aquifer. Test pumping in the middle semi-confined freshwater aquifers with observation wells indicated that these aquifers and confining beds are interconnected. The individual aquifers exhibited a range of hydraulic characteristics with well yields from 5 to 220 gpm.

Even back at base camp, the project could never be far from our thinking. We leased a non-working tourist camp on the banks of the Thamalakane (pronounced Tom-a-la-con-ee) River with thatched cottages, a kitchen and a cook which sometimes swelled to 30 people during the busiest phases of the project. The Thamalakane River is the channel that runs through Maun, and a main group of the Delta outlet channels are tributary to this river. The primary Delta outlet channel at present, the Boro River, meets the Thamalakane within walking distance of our base camp (see Photo 1).

The Thamalakane channel was dry for 10 out of 12 months per year during the project (1995 to 1997) and comprised a wide and grand pathway for parading groups of horses, wandering herds of cows and goats, villagers, children on donkeys, and certain hydrogeologists out for a stroll in the early evening. There is something slightly askew in the picture; concrete balustrades, floating docks, big motor boats sitting, that are peculiar reminders of the wet 1970s and 1980s, when tourists could be ferried up into the Delta along this wide and fast flowing river. Now the boats are piled up by the side of the channel, and all of the camps including ours, are hurting for water.

The project resulted in the identification of at least five areas along the river channels that could be utilized for future groundwater development for Maun into the 21st century and delineated over 10,000 million cubic meters (MCM) of fresh groundwater in storage. Three of these areas are located where the annual delta floods are still active. A phased development program was recommended. In addition, a successful pilot test indicated that artificial recharge basins could be used to restore the existing depleted Shashe wellfield during the annual flood in nearby channels, if wetter conditions return and sufficient surface water were to be available.

In the long term, the sustainability of the water resource will depend on continued recharge to these aquifer systems from the annual flood from the Delta. The volume of these flood waters as well as the preservation of the Delta itself will require international cooperation. Already, plans by Namibia to divert water from upstream points of the Okavango River to its capital city area (Windhoek) are undergoing intense scrutiny by interested parties in Botswana. The future of the Delta will be determined by how these issues are resolved in conjunction with the naturally shifting hydrology in this region.

Although we finished the 2-year project and headed home due to domestic obligations, we look forward to practicing again at some future time in this lovely and interesting country. This project was the largest groundwater contract to date awarded by the Government of Botswana, and was the first time an American firm was selected. As newcomers to Maun, we very quickly attracted attention as the water people who were consulted by many different people (entrepreneurs, tour operators, reporters, school founders), both local and passing through from all over the world. The Batswana people were charming hosts. We would love to return.

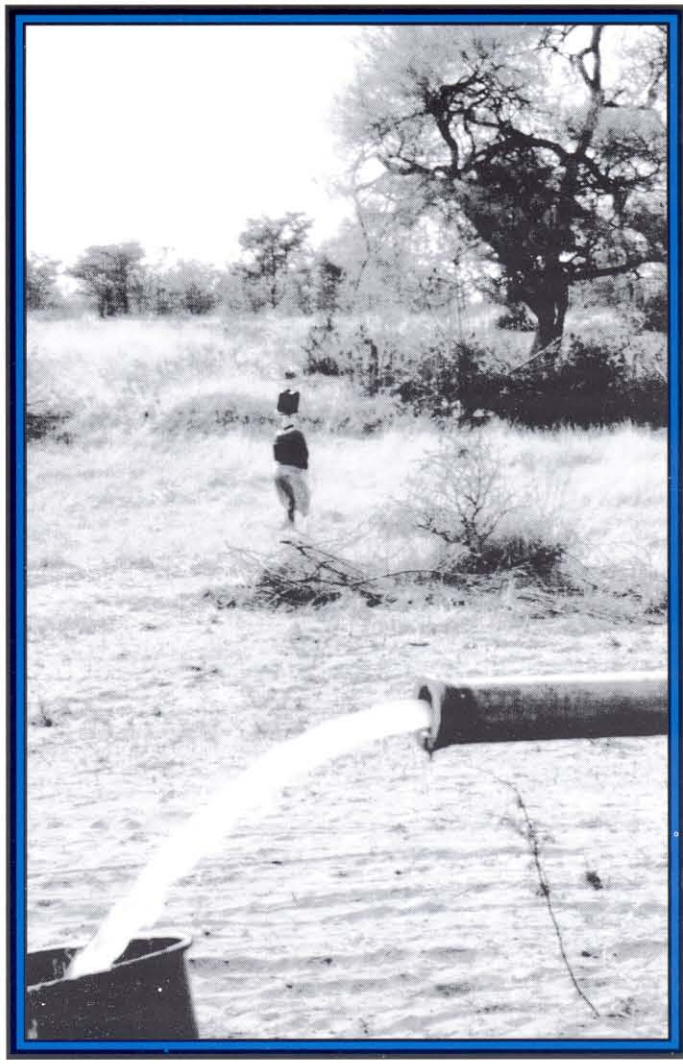

Photo 2: Pumping Test Discharge Pipe and Water Collection.

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