The impacts of pan quarrying on livestock watering in a semi arid region: case study of Kang pan in the Kalahari, Botswana

Samuel Mosweu[1] and Olusegun Areola
Department of Environmental Sciences, University of Botswana, Private Bag UB00704, Gaborone, Botswana
[1]Corresponding author. E-mail: mosweu@mopipi.ub.bw

ABSTRACT
Scenes of mass death of livestock inside a quarry and on the surrounding pan floor prompted this investigation on the impact of quarrying on livestock watering in the semi arid Kalahari region in southwest Botswana. This investigation was carried out at the Kang Pan at the end of the dry season when the water supply situation was at its worst. Samples of stagnant water from the quarry pit that form the major imprint of pan quarrying were collected for analysis of As, Ca, Cu, EC, Fe, Hg, K, Mg, Na, Pb, pH, TDS, and Zn in order to determine the pit water quality. The results show that the quarry pit water at the end of the dry season is highly concentrated not only with salts but also with solids and heavy metals including arsenic, lead and mercury. The water quality parameters are far below the internationally recommended standards for livestock watering. The extremely poor quality of the water collected in the pit is detrimental to livestock health and the pit itself is an environmental hazard to the animals. Pan quarrying without considering the possible environmental impacts has exacerbated loss of livestock in the area arising from severe drought. This, in turn, has affected the livelihoods of the communal farmers.
Key words: Arid regions, Environmental impacts, Kalahari, Livestock, Pan, Quarrying, Water quality

INTRODUCTION
Semi arid and arid regions are marginal areas for most forms of human activity. The phenomenon of aridity directly or indirectly constrains virtually every land use activity, most especially, agricultural and pastoral land use (Kassas, 1999). With regard to the quarrying of construction materials, aridity is important in two respects. Firstly, as is exemplified in the Kalahari region of Botswana, dry sandy soils, Arenosols, characterize the arid-to-semi arid landscapes. The Arenosols make very poor construction materials due to unfavourable physical properties. But, they are interspersed by patches of soils that exhibit varying proportions of calcic, silcrete and quartz materials. These occur in pans or playas which, consequently, have become the major sources of construction materials in these dry lands. This accounts for the concentration of quarrying activities in the pans which are scattered throughout the Kalahari region of Botswana. Secondly, the pans are the primary sources of water for both humans and livestock particularly in the dry seasons and drought years. Therefore, whatever happens to the terrain and the water resources of the pans automatically affects the rural livestock economy. In periods of water scarcity, both the quantity and quality of available water for livestock are adversely affected by the changes in the pan terrain and water bodies brought about by quarrying.

Pans began to play a critical role in the livelihoods of the Kalahari communities when they ceased from their nomadic lifestyle as hunters and gatherers by the end of the first quarter of the 20th century. This change in lifestyle came with the advent of pit wells (Fig 3) which they learnt to sink on the fringes of pans (Devit, 1971). Then, over time, hunting and gathering activities diminished due to recurrent drought and the migration of game animals to protected areas (Campbell *et al.*, 1991).The implementation of strict hunting regulations by the government also lead to a decline in hunting activities. Consequently, the Kalahari communities shifted toward livestock rearing. Livestock rearing still plays a pivotal economic role in the Kalahari area (Chanda et al., 2003). It has proved to be the most preferred economic activity in the area (van de Maas et al., 1994). The most limiting factor in livestock rearing is water. Therefore, any activity or development which perturbs the viability and sustainability of the pan systems is a threat to the livelihoods of the Kalahari communities. This is especially so because the Kalahari environment presents very limited economic opportunities that can sustain the communities. For instance, arable farming is practiced on a comparatively very small scale because of the dystrophic nature of the soils and the erratic pattern of rainfall.

Unfortunately, pan quarrying has increased in recent years with the increased road and housing construction in the semi arid regions of Botswana. The pans provide gravel, limestone, marble, gypsum and other materials. In spite of this, the impact of pan quarrying has received virtually no attention perhaps because the effects are highly localized in the vicinity of each pan. But, in the aggregate, these localized impacts constitute a major threat to rural livelihoods in the Kalahari region. The aim of this study is to analyze and describe some of the adverse effects of quarrying activities with particular reference to conditions in the Kang Pan during the dry season of 2007.

OBJECTIVES

Field observations during the dry season of 2007 showed the Kang Pan littered with the carcasses of dead cows and donkeys. Some others were seen stuck in the mud in the erstwhile quarry pools which were now almost completely dried out. The remaining pool of water in some burrows looked so dark and heavily polluted. The objective of this study was, first, to document the physical evidence in the field of the direct and indirect impacts of the quarrying activities at the Kang Pan and secondly to analyze the chemical characteristics of the quarry pit water in order to assess the level of contamination. Thirdly, the study examined the implications of the aforementioned changes in the pan terrain and water resources for the livelihoods of the communities that depend upon pans, particularly as the only available natural surface water source.

Study Area

Pans or playas are small, closed basins containing ephemeral lakes (Thomas and Shaw, 1991). Their formation has been attributed to a variety of causes (Mabbutt, 1977; Goudie and Thomas, 1985). In the case of the Kalahari, Lancaster (1978a) concluded that the formation of pans is not linked to relict drainage systems; rather pan formation is associated with the process of deflation. However, other researchers pointed to the polygenetic nature of pans relating them to the concomitant action of ground water and aeolian excavation (Thomas and Shaw, 1991; Goudie and Thomas, 1985).

The Kang pan is located along the Sir Seretse Khama Trans Kalahari highway in

Kang village (Fig. 1). The pan is located approximately on Latitude 22° 38.789 S and Longitude 22° 43.554 E at an elevation of 1457m above sea level. It is one of many pans of varying sizes and shapes scattered throughout the Kalahari region (Lancaster, 1978a and b). The soils in the pan are predominantly calcisols underlain by strata of calcrete and silcrete which show some inter-layers of quartz-rich material.

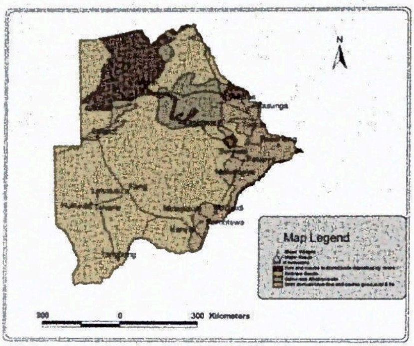

Figure 1: Map of Botswana showing the location of the study area

In the Kang pan, the ongoing quarrying of construction materials has created a hollow that is about 20m deep and roughly 2500m^2 in area. This is slightly larger than one of such pits created by the quarrying of the Hukuntsi Pan, which measured 15m in depth and about 2000m^2 in area in 2003 (see Fig. 2 Photo C). Hukuntsi lies 110km southwest of Kang and a few kilometers east of Tshane (Fig. 1).

The study area experiences an average annual rainfall of 350 mm (Department of Surveys and Mapping, 2001). As a result, water is a scarce commodity in the area and the pan systems are vital sources of both underground and surface water. Communal livestock depend on surface water in the wet season, while scarce water from wells (Fig. 3) is used in the dry season. Scarcity of water in the dry season exacerbates the vulnerability of communal livestock to the contaminated water which stagnates in the quarry pits that form the major imprint of quarrying of pans in the area.

MATERIALS AND METHODS

A Global Positioning System (GPS) was used to determine the elevation and geographical coordinates of the Kang Pan. The depth and area extent of the quarry were measured in the field. A walk round the quarry pit revealed the devastation caused by the severe dry season which led to the drying out of the quarry pool to form isolated ponds of mud and stagnant water. Photographs were taken of the quarry terrain and of the livestock, both the living and the dead.

Thereafter, water samples were collected from the quarry pit in standard water sampling plastic bottles. The pit is positioned within the pan close to the pan periphery. The water in the pit was what was left of the rainwater collected during the previous rainy season. Sampling was carried out at the end of the dry season when scarcity in water was at its height and the little remaining surface water in pits located in pans had reached its worst quality. The time of sampling was also chosen deliberately as it fell within the period in which the Kalahari communal farmers feel the greatest impact of quarrying of road construction material from pans.

Water samples were collected and subjected to standard preservative measures. The parameters that were investigated were pH, conductivity, Total Dissolved Solutes (TDS), calcium, potassium, sodium, magnesium, lead, mercury, Iron, cooper, arsenic and Zinc. Direct determination by means of atomic absorption analysis as outlined in Fresenius *et al.* (1988) was used to analyze for cations. The HANNA pH 210 pH meter was used to measure pH and the inoLab cond 730 WTW series EC meter was used to determine EC and TDS.

RESULTS AND DISCUSSION

Livestock at the Quarry Pools

The Kalahari environment presents no water source alternatives for livestock in the winter season apart from wells (Fig 3) and boreholes which are available mainly in the commercial ranches. Consequently, the communal livestock farmers are the main victims of the water scarcity that occurs year after year during the winter season. It is during this season that communal livestock do not get enough water from wells due to a fall in the water table. As a result, communal livestock are compelled to converge on the quarry pits (Fig. 2) lured by the smell of water.

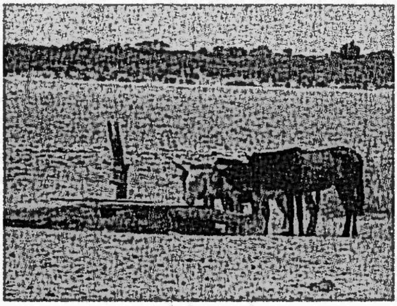

Figure 3: Hand dug well located within the pan used for livestock watering

Over-concentration of livestock soon depletes the limited water in the quarry pools which also becomes heavily polluted with animal dropping. The result is the tragic death of livestock (Fig. 2) and heavy losses to the communal farmers. Although loss of livestock by communal farmers has been a recurrent experience in the Kalahari, pan quarrying has exacerbated the situation. Available water during the winter season is now confined to a narrower space within the quarry pits rather than in the more open, undisturbed flat pan floor. The quarry pits become mud holes as the water is depleted and, indeed, many cows get stuck in the mud and die there (Fig. 2 Photo e-g). Furthermore, the high level of pollution is due obviously to the very confined nature of the quarry pools (Fig. 2 Photo d). Carcasses of livestock that die in the pool of water exacerbate the deterioration of water quality as they get decomposed. As a result, water quality worsens day after day (Fig 2 Photo d). Eventually, many livestock become too stressed to venture into the quarry pools to drink. They stand in the blistering sun on the open pan floor, some lying down out of exhaustion (Fig 2 Photo a). Worse still many of the animals are unable to move about to forage for feedstuff. The communal livestock farmers look on helplessly as the animals die off one after the other because they have no alternative water source to which they could transfer their flock. Owners of the dead livestock are not keen to salvage the remnants of their animals because of the poor nutritional quality of the carcasses at the time of their death. Consequently, carcasses accumulate in and around the burrow pit causing more undesirable environmental impacts. Indeed, the national television, recently reported that in some other areas like Ghanzi, some boreholes that supply the township with potable water have been shut down due to the pollution of the aquifers arising from the impacts of pan quarrying (Botswana Television News, 2007)

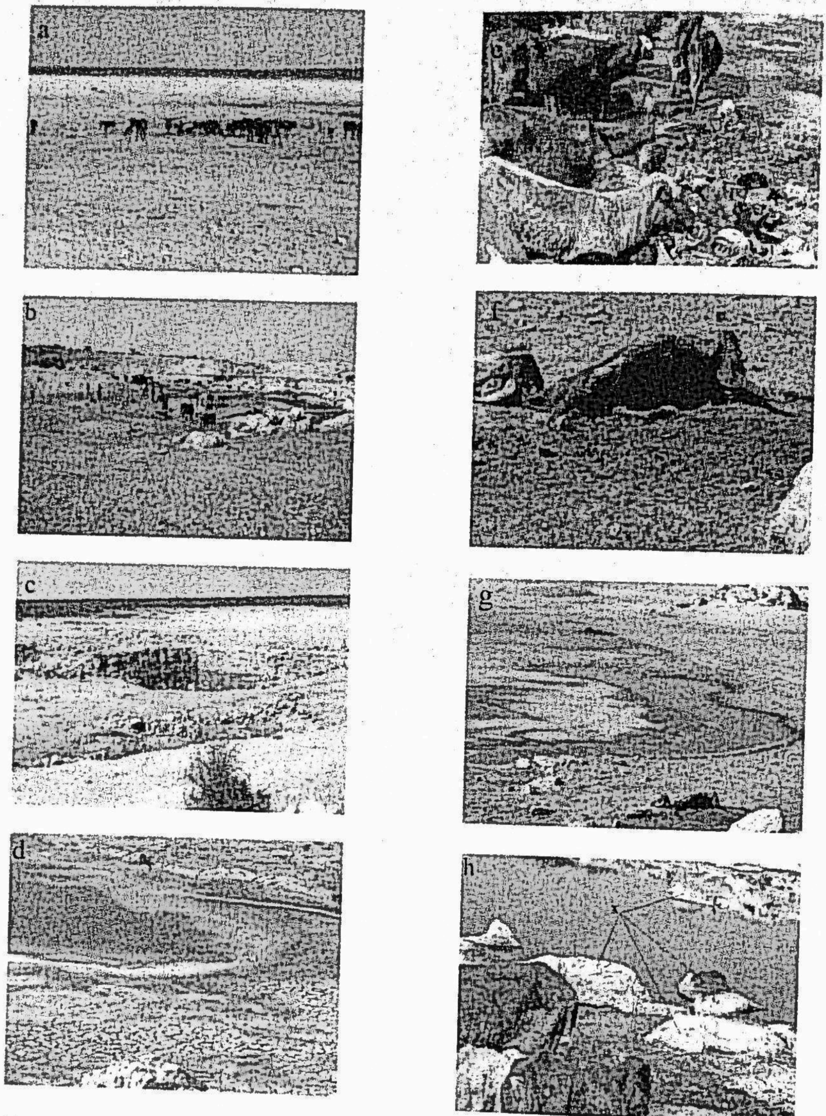

Figure 2: Figures showing the scenes in the Kang pan at the end of the dry season just before the first rains of the rainy season.

Quarry Pit Water Quality Analysis

Table 1 shows the results of the analysis of the quarry pit water at the end of the dry season set against the internationally recommended quality standards for watering livestock (see Hem, 1959, Petersen, 1999, McDowell, 2003). High salinity is a characteristic feature of water that accumulates in the Kalahari pans due to the salt rich soils and sediments associated with the pans (IDRC, 1997). Animals can tolerate highly saline water for a few days without harm, but they refuse to drink water with very high salt concentrations. Table 1 clearly shows that the quarry pit water at the end of the dry season is highly concentrated not only with salts but also with solids and heavy metals including arsenic, lead and mercury.

Petersen (1999) reported that waters with 7000-10,000 mg/L total solids are unfit for poultry and probably for swine and that considerable risk may exist in using them for pregnant or lactating cows, horses, sheep, the young of these species, or for any animals subjected to heavy heat stress or water loss such as the livestock in the Kalahari region experience. In general, the use of such waters should be avoided although older ruminants, horses, and even poultry may subsist on them for long periods of time under conditions of low stress. The quarry pit water total solids content is 4 to 6 times greater than the 7000-10000 upper tolerance limit recommended for livestock watering. Petersen (1999) states clearly that any water with more than 10,000mg/L holds such great risks for livestock that it cannot be recommended for use under any conditions.

Table 1: Properties of the Quarry Pit Water

Parameters	Sample 1 (mean ± S_f)	Sample 2 (mean ± S_f)	Recommended concentration limits (mg/L)
Arsenic	>1µg/L	>1µg/L	0.5[c]
Calcium	153.00±0.46mg/L	55.00±0.60mg/L	1000[s]
Copper	5.50±0.04mg/L	7.30±0.03mg/L	0.5[s]
Iron	1.29±0.01mg/L	1.97±0.01mg/L	2.0[e]
Magnesium	11.29±0.04mg/L	4.06±0.01mg/L	500[s]
Mercury	>1µg/L	>1µg/L	0.01[s]
Lead	>1µg/L	>1µg/L	0.1[c]
Potassium	12.40±0.30mg/L	17.30±0.07mg/L	20[ck]
Sodium	13 282±90mg/L	18 226±25mg/L	2000[s]
Zinc	0.97±0.03mg/L	2.12±0.05mg/L	25[s]
pH	9.30±0.04	9.80±0.01	5.6-9.0[s]
TDS	43 750±125mg/L	67 000±125mg/L	7000-10 000[n]
Conductivity	53.70±0.09mS/cm	74.00±0.21mS/cm	10.94-15.62[s]

[c] : Council for Agricultural Science and Technology (CAST), [n] :National Academy of Sciences (US, Texas), [s] :www.spectrumanalytic.com, [e] :US Environmental Protection Agency, [ck] :Castillo & Kirk (2004)

Table 2, extracted from Petersen (1999), shows data on the recommended concentrations for the selected chemicals analyzed in this study and provides information on the consequences of exceeding the recommended limits. The quarry pit water falls well below the recommended critical upper limits only in respect of the concentrations of calcium, magnesium, sodium and zinc. The iron and potassium levels are very close to the recommended critical limits. But, the concentrations of arsenic, lead, copper, mercury are all higher than the recommended limits. Arsenic, lead and mercury are all health hazards for both livestock and humans (see Table 2). Chronic lead poisoning may occur at levels of 0.5 to 1.0 mg/L. Low levels of some chemicals are not necessarily good; they may be detrimental to livestock. For example, low levels of zinc (e.g. below 20 mg/L) can reduce the ability of cattle to digest their feed. Exceeding the critical limits set for various chemical elements may not necessarily result in death of livestock; but it does affect the health and productivity of livestock and the quality of the animal products such as the meat and milk. No biological or microbial analysis was done on the water samples collected from the quarry pits. But, it was clear that the pools were heavily polluted with animal droppings. The dark green colour of the water indicated the growth of blue-green algae. According to Petersen (1999), most blooms of blue-green algae contain either brain toxins (neurotoxins) or liver toxins (hepatotoxins). A 100 kg (220 lb) calf need only consume just over 1 L of water to produce death, depending on the toxin present in the blue-green algae bloom. It is not surprising then that many livestock die at the quarry pits during periods of severe drought.

Table 2: Recommended maximum concentrations for selected chemicals in livestock drinking water. *Information from CCREM 1987, Australian Water Quality Criteria 1974, BCMOELP 1994, NRC 1974, NRC 1998, Manitoba Agriculture 1992.

Chemical Name	Guideline	Units	Application
Arsenic (As)	500	µg/L	If arsenic levels in feed are low, up to 5 mg/L can be tolerated (arsenic is used as feed additive to enhance growth in poultry and pigs).
Calcium Ions (Ca)	700	mg/L	Guideline value when magnesium is present.
	1,000	mg/L	Guideline value when magnesium is absent.
Copper (Cu)	1,000	µg/L	Guideline value for cattle. Copper is essential to animal health and is often a feed additive. Revise levels downwards if supplements are given or feed is high in copper.
	500	µg/L	Guideline value for sheep.
	5,000	µg/L	Guideline value for pigs and poultry.
Hardness (as $CaCO_3$)	No guideline		Hardness has no effect on water safety, but can result in the accumulation of scale in water delivery pipes. The scale mainly consists of magnesium, manganese, iron and calcium carbonates. Water with more than 120 mg/L as $CaCO_3$ is considered hard.
Iron (Fe)	300	µg/L	No toxicity guideline established. Veal calves will have increased coloration of meat at iron levels as low as 0.1 mg/L; this level can also give milk an oxidized flavour. Iron can present problems in restricted flow drinking water lines where iron precipitation may plug the line. Iron will also present problems when water is disinfected and can encourage bacterial slime growth in water supply lines.
Lead (Pb)	100	µg/L	Guideline value. Chronic lead poisoning may occur at levels of 0.5 to 1.0 mg/L.
Magnesium (Mg)	6,000	mg/L	Reduced growth and bone mineralization in immature chickens. An upper limit of 300-400 has been suggested for dairy cows. Magnesium form part of the hardness in water.
Manganese (Mn)	>0.05	mg/L	No toxicity guideline established. Manganese together with iron will discolour fixtures. Manganese and iron can present problems in restricted flow devices in drinking water lines where manganese precipitation may plug the line. Manganese will also present problems when the water is to be disinfected.
Mercury (Hg)	3	µg/L	Guideline value. Mercury is a health hazard to animals and to human consumers.
pH	6.5-8.5	pH units	Guideline values. If pH is lower than 5.5, acidosis and reduced feed intake may occur in cattle, but is unlikely to have an effect on pigs. Chlorination efficiency is reduced at high pH. A low pH may cause precipitation of some antibacterial agents delivered through the water system (for example sulphonamides).
Zinc (Zn)	50	mg/L	Guideline value. This is an essential element for livestock, but at high levels it can exert toxicity. The lowest recorded effect was at 20 mg/L where the rumen microbes in cattle were affected (decreased digestion of cellulose).

Extracted from Petersen H.G. 1999. Livestock and Water Quality Agriculture and Agri-Food Canada-Prairie Farm Rehabilitation Administration

CONCLUSION

This study reveals that quarrying carried out in pans threatens the livelihoods of the communities in the semi arid to arid regions due to its adverse effects on the pan systems upon which communal livestock rearing and wild life depend. The pools of water that collect in quarry pits during the raining season sustain the livestock during the early dry season periods. But, they probably encourage the concentration of livestock in such quarried pans and lure livestock owners not to venture farther afield to make provision for watering their livestock in the latter part of the dry season periods. The study indicates that when the dry season is severe and or prolonged, the quarry pools become death traps to the livestock that are stranded in them. The water deteriorates rapidly both in quantity and quality as the dry season goes on. The combination of insufficient water intake and poisoning by highly polluted water probably accounts for the mass deaths of livestock experienced at these quarry pits in the late dry season. The situation is becoming more critical both for the humans and animals because the wells along the fringes of the pans are drying out because of falling water tables and the groundwater aquifers also are being polluted from infiltrating surface water.

There is need for a close and regular monitoring system of companies and individuals that are given mining rights in the pans. Environmental Impacts Assessment (EIA) studies should be conducted before permission for quarrying and mining rights are issued. Although EIA is a requirement in Botswana, the implementation of recommendations emanating from the EIA exercises and the Environmental Management Plans (EMP) still remains the weakest link that greatly diminishes the effectiveness of the EIA requirement. Amongst other issues, the EIA should consider ways in which quarrying can take into account the dynamics of surface and underground water movements in order to minimize water table subsidence and drying out of wells, particularly during the dry season. There is clearly a need to control quarrying to avoid the complete collapse of the pan system, its water, flora and fauna and all the economic activities they sustain. There is need to consider the depth of quarrying as this probably contributes to falling water table and the contamination of aquifers by water infiltrating from the surface. It is also obvious that the movement of livestock to the quarry sites by local livestock owners needs to be monitored and controlled. It might be necessary to fence off the quarries and control the inflow and outflow of livestock into the pools. Presently, the livestock are moved into the pits and abandoned there for the duration of the dry season. The owners merely look on when the water dries out and the animals begin to die. The carcasses of dead animals are not removed to prevent spread of diseases. As indicated above, decomposing carcasses contribute to the heavy pollution of the stagnant pools in quarry pits.

REFERENCES

Campbell, A.C. (1991). Socio-Economic Survey, Remote Area Development: Western Sandveld Remote Area Dwellers. Ministry of Local Government and Lands and Norwegian Development Agency for International Development Cooperation.

Chanda, R., Totolo, O., Moleele, N., Setshogo, M., and Mosweu, S. (2003). Prospects for subsistence livelihood and environmental sustainability along the

Kalahari Transect: The case of Matsheng in Botswana's Kalahari rangelands. *Journal of Arid Environments* 5: 425-445.

Cooke, H.B.S. (1964). The Pleistocene environment in Southern Africa. In: Late Cainozoic Paleoclimates of the Southern Hemisphere. pp 391-404. Vogel, J.C. (Ed) Balkema, Rotterdam.

Department of Surveys and Mapping. (2001). Botswana National Atlas. PC Atlas 1.0C. Gaborone, Botswana.

Devitt, P. 1971. Man and his environment in Western Kalahari or "A little technology is dangerous thing". *Botswana Notes and Records* 3: 50-56.

Fresenius, W., Quentin, K.E., and Schneider, W. (1988). Water Analysis A Practical Guide to Physico-Chemical, Chemical and Microbiological Water Examination and Quality Assurance. Springer-Verlag, Berlin, Germany.

Goudie, A.S. and Thomas, D.S.G. (1985). Pans in Southern Africa with particular reference to South Africa and Zimbabwe. *Zeitschrift für Geomorphologie. N.F* 29: 1-19

Hart, B.T. (1974). A Compilation of Australian Water Quality Criteria. Australian Water Resources Council, Department of Environment and Conservation, Australian Government Publ. Serv., Canberra, Tech. Pap. 7.

Hart, B.T. (1984). Australian Water Quality Criteria for Heavy Metals. Department of National Development and Energy. Australian Water Resources Council. Australian Government Publishing Serv., Canberra. Tech. Pap. No. 77.

Hem, J.D. (1959). Study and interpretation of the chemical characteristics of natural water. US Geological survey. Water Supply Paper No. 1473.

International Development Research Centre. Ottawa, Canada. (1997). Small Scale Desalination for Remote Areas of Botswana. IDRC Library Documents reference@idrc.ca.

Kassas M. (1999). Rescuing drylands: a project for the world. *Futures* 31: 9-10.

Lancaster, I. N. (1978a). The pans of Southern Kalahari, Botswana. *Geographical Journal* 144: 81-98.

Lancaster, I. N. (1978b). Composition and formation of Southern Kalahari pan margin dunes. *Zeitschrift für Gemorphologie, NF*, 22: 148-169.

Mabbutt, J.A. (1977). Desert Landforms. MIT Press, Cambridge, Massachussetts.

Canadian Council of Ministers of the Environment. (1987). Canadian Water Quality Guidelines. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Manitoba Agriculture. (1992). Evaluating water quality for livestock. Fact sheet Agdex No. 716-13-00.

National Research Council. (1974). Nutrients and Toxic Substances in Water for Livestock and Poultry. National Academy of Sciences, Washington, D.C.

National Research Council. (1998). Nutrient requirements of swine. Tenth revised edition, National Academy Press, Washington D.C.

Petersen H.G. (1999). Livestock and Water Quality Agriculture and Agri-Food Canada-Prairie Farm Rehabilitation Administration.

Thomas, D.S.G., and Shaw, P.A. (1991). The Kalahari Environment. Cambridge University Press, Cambridge.

Van Der Mass, H.A., Riezebos, H. T, Immerzeel, A, van der Jagt, C.J, Teekens, P. & Wijnhound, J.P. (1994). Matsheng Baseline Survey: Socio-economic and Biophysical Baseline Survey of the Matsheng Villages in the Northern Kgalagadi Sub-District. Part 1. Ministry of Local Government Lands and Housing, Gaborone.