Water quality protection strategy in Botswana

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Botswana is a large country with a relatively small population and the useful aquifers and reservoirs are so far relatively unpolluted although, in places, particularly within the villages, faecal and nitrate pollution is evident. Severe chemical pollution incidents have not yet occurred but with the development of industry and agriculture and the enlargement of urban infrastructures, which has occurred mainly where water is available, the risks are inevitably increasing.

In 1992, the Department of Water Affairs, Republic of Botswana, commissioned a study entitled 'Protection Zones and Guidelines for Major Wellfields, Aquifers and Dams in Botswana' with the objective of defending water resources from increasing pollution risk. The study included all of the 12 major wellfields in Botswana and in addition four potentially high-yielding aquifers yet to be developed, as well as five major dams.

The specific objectives were:

- formulation of a protection policy through protection zoning
- formulation of legislation for water resource protection
- recommendation of guidelines for regulations
- pollution risk identification and assessment

In the course of the study, the most common risks were seen to be from sewage and sanitation systems and from hydrocarbon spillage and waste oil disposal. There is increasing use and transport of more sophisticated chemicals such as pesticides and solvents which could, in the event of accident or wrongful disposal, cause severe damage to water resources.

In order to formulate a workable protection policy, reference was made to practice in USA, UK and Europe and adapted to suit conditions in Botswana. The capacity of the controlling institutions to execute the policy, especially in remote areas, was taken into account.

Groundwater and surface-water sources are to be shielded from pollution by protection zones.

Reservoir protection strategy

Each major reservoir catchment as far downstream as the dam is protected. In Botswana, catchments are fed from dendritic tributary networks with sandy soils and sandy channels and with ephemeral flow, and flash floods wash out pollutants accumulated during long dry periods. Ultimate run-off and interflow comprise between 1% and 5% of total precipitation. Catchments in undulating terrain with low gradients are ill-defined and the margins contribute little in the overall inflow: moreover, pollutants in the outer areas have long residence times and biodegradation enables dispersal of most pollutants. The pollution risk therefore diminishes in proportion to the distance from the outer watercourses to the dam.

Protection zoning is threefold: outer, buffer and inner:

- the OUTER PROTECTION ZONE, covering most of the catchment, is subject to normal development rules of licensing and monitoring of effluents from sewage treatment, industries and businesses, transport and storage of hazardous materials and general rules regarding areas close to watercourses.
- in the BUFFER ZONE the storage of hazardous materials and construction of industries or businesses involving any toxic substance should be totally prohibited, apart from essential fuel stores.
- within the INNER PROTECTION ZONE (less than 200 m from the full supply-level water line), only a limited number of activities can be allowed and provisions are already in force for most circumstances.

Groundwater protection strategy

Wellfield Protection Zones

Each major wellfield is allocated a Wellhead Protection Area (WHPA), the purpose of which is to provide:

- *wellfield management zones* within which land-use controls and restrictions will be applied to prevent contamination of groundwater supplying the wellfield;
- an *attenuation zone* to reduce concentrations of contaminants by the time they reach the boreholes;
- a *remedial action zone* to protect supply from accidental pollution incidents;
- the opportunity for *public education* in the outer zones in order to create an awareness of the groundwater resource and its vulnerability to certain kinds of activity.



Figure 1. Location of proposed Wellhead Protection Areas in Botswana

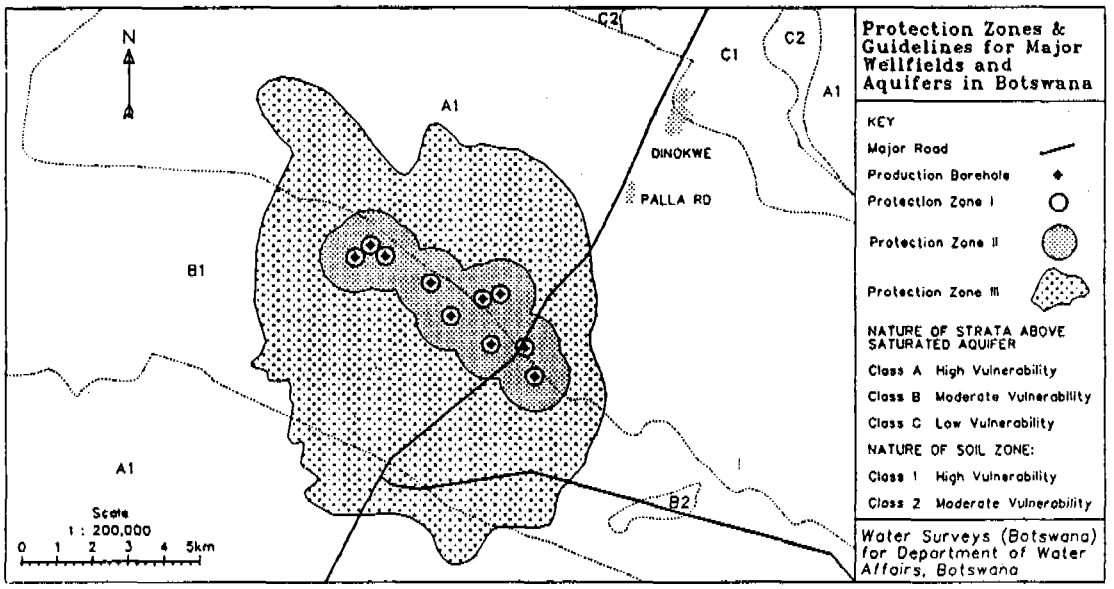


Figure 2. Combined wellfield protection, zonation and aquifer vulnerability map for an area in Northern Botswana

Zoning disposition is based on that used in UK and USA. There is a choice of two criteria in determining the area of the WHPAs: to compute from models the rate of groundwater and contaminant travel and locate the zone boundaries accordingly, or to apply a fixed distance from the wellhead(s).

In Botswana most aquifers are dominated by structurally induced fractures and many have strongly anisotropic permeability, in contrast with the major aquifers of Europe and USA which are extensive, relatively isotropic and frequently porous; and the state of knowledge of aquifer properties is still incomplete. Groundwater modelling is constrained by these uncertainties. The Proterozoic aquifers are necessarily located in favourable structures and metasedimentary strata, and are therefore irregular and elongated. The extreme example is at Molepolole, where the wellfield follows a single fracture with minor offshoots for about 20 km. In addition to conditions in the zone of saturation, the nature and distribution of downward percolation via the soil and subsoil of groundwater and contaminant transport can be uncertain, especially in Proterozoic aquifers. The soil may be patchy or non-existent; in areas of high run-off, recharge may be through alluvium in storm channels. In such conditions modelling involves a high degree of creativity and consequently a fixed distance is applied.

The Karoo sandstone aquifers are extensively jointed and less inhomogeneous, and although high-yielding boreholes are located on fault swarms where conditions are anisotropic, the wellfield is considered to be influenced by the mass of relatively undisturbed aquifer and a time-of-passage criterion is applied. Groundwater flow and contaminant transport were determined using computer code Flowpath.

The WHPAs to be used are:

- a fenced OPERATIONAL COURTYARD, 20–30 m radius around the borehole: in Botswana, as in Europe, fuel spillage at the wellhead, where the ground is disturbed, is a common cause of groundwater contamination and strict hydrocarbon handling procedures in the operational courtyards are needed, together with total exclusion of animals;
- an INNER SOURCE PROTECTION ZONE to provide protection against pathogenic bacteria and viruses. These have a finite lifespan in groundwater, influenced by several factors – principally temperature and environment. In Botswana, the first line of defence against microbiological pollutants – the soil horizon in which attenuating processes occur – is usually thin or absent. Therefore the 50-day zone, which may be adequate in temperate climates with thick biologically active soils, is regarded to be inadequate and a 100-day zone or a minimum of 100 m radius from the borehole is recommended;
- an intermediate FRACTURE FLOW PROTECTION ZONE applied to fracture-porous aquifers and fractured aquifers which dominate in Botswana. Here, rather than time, the control is a distance of 1 km radius;
- an OUTER SOURCE PROTECTION ZONE, the 100-year catchment or capture zone of the borehole or wellfield. This travel time has been used as a compromise to defining the entire wellfield catchment which could extend for tens of kilometres. The threshold value of 100 years is somewhat arbitrary but it is considered that the zone will provide adequate protection from persistent chemical pollutants and to provide a remedial action zone.

The zones are therefore state-of-the-art and can be modified when further data become available.

Aquifer vulnerability mapping

In addition to the protection of wellfields, attention was directed to the protection of entire aquifers and a vulnerability classification was introduced as a basis for mapping, derived from assessment of both soil and geological conditions.

Vulnerable aquifers, assigned Class A, are highly permeable, often fractured, with no barriers to the rapid percolation of water downwards, and high water tables. Major examples in Botswana include the Ntane (Cave) sandstone, the Kanye dolomite and Ghanzi Group quartzites. Aquifers of moderate to low vulnerability, such as the Stormberg Basalt, are assigned Class B and those of low vulnerability, overlain by extensive aquicludes, Class C.

Soils were classified from 1 to 3, in terms of their ability to allow passage of pollutants, and their capacity for attenuation. Groundwater resource vulnerability zoning was simply mapped by overlay of the geological vulnerability map by the soils vulnerability map and overall classification determined from A1 to C3.

The inadequacies in the computer modelling of WHPAs and lack of understanding of how the groundwater system behaves on a local scale can be partly overcome by using a conjunctive vulnerability map–source protection zone approach, to provide a framework with which to protect both the current wellfield and the regional aquifer. A series of maps were produced of the WHPAs, each overlaid by the regional aquifer vulnerability map and the areas identified most susceptible to pollution of groundwater. Thus potentially polluting developments can be preferentially located within those areas of lower vulnerability where the groundwater quality is less at risk. See *Figure 2*. Following workshops throughout Botswana, these maps are in use for land-use planning purposes.

More detailed vulnerability mapping (at a scale of 1:50,000) of the major groundwater resource areas is currently being produced by the Department of Geological Survey, Republic of Botswana.

Legislation

Existing water legislation has been reviewed and a new Water Act is being enacted which will allow for prohibition or restriction of pollution and the designation of protection areas, to enable enforcement of regulations or controls.

These powers, together with management of both surface water and groundwater resources within Botswana, will be conferred upon the Water Resources Council, to be created from the present Water Apportionment Board, but with an amended constitution and additional executive powers.

A new Act is also proposed which will confer modern, appropriate powers on both water supply and sewerage authorities, such as the power to prohibit the discharge of particular wastes into sewers and to enter into trade waste agreements with dischargers.

Guidelines for regulations

Guidelines for Regulations were drawn up which will enable the new Water Act to be effective. These outline activities which should be controlled within the different zones of the WHPAs, and are of increasing restriction nearer to the wellhead. Flexibility has been built into the proposed legislation in that the regulations may be applied as is seen fit. This means that priorities can be assessed and account taken of the practicalities and limitations of administration.

It is recognised that point-source risks may be easier to identify and control than diffuse pollution risks. Reduction in risk from diffuse discharges can only be combated through regional protection policy, together with an increase in public awareness of the effects of certain activities and the use of certain chemicals on groundwater quality. Local government and central government have particular responsibility, both in their own activities and in the education and supervision of others in reducing the risks of diffuse pollution.

Legally enforced regulations have not been drawn up for the vulnerability zones, but guidelines have been made available. It should also be the responsibility of local government authorities to be aware of aquifer vulnerability and accordingly promote sensible land-use planning and, where a potential risk is identified, to take precautions to minimise the risk. This is done firstly by examining the possibilities of relocation to an area of lower vulnerability and if necessary by conducting a site investigation to establish constructional and operational constraints. The guidelines are similar to those for wellfield protection areas but with relaxed restrictions.

Implementation

Liaison, both formal and informal, is seen to be crucial at ministerial, district and local levels between all governmental departments and district officials in matters affecting pollution and land-use.

For land-use planning and licensing purposes, a list is available to all in the Land Boards, Planning Departments and Environmental Health, of the activities which should trigger consideration of pollution potential and control criteria before allowing new developments within the area of the aquifer and wellfield. The list is arranged in two priorities and the seeking of advice is recommended where necessary from the Pollution Control Section of the Department of Water Affairs, particularly for those activities in Priority 1, with greater or more serious risk of pollution.

Should a decision be made by the Water Resources Council to allocate the responsibility of implementation of these and other regulations, including those under the proposed Water and Sewerage Act, to the Pollution Control Section of the DWA, it will be necessary to expand the Section very considerably for it to be able to provide a full service of advice, consultation and pollution prevention and control throughout the country. The Section could play a central part in achieving the necessary liaison between all officials and parties concerned and can itself call on specialist knowledge within Hydrogeology and Hydrology sections of the DWA and from the Geological Survey. The Pollution Section has constructed a database of industries within towns and major villages, using firstly the information given to the Department of Commerce and Consumer Affairs when an application for a licence to trade is made, and followed up with a site visit and inspection. The database and other similar information systems can be used as a proactive tool in integrated pollution control.

Education and public awareness

The Planning Authorities and Land Boards are seen as the front-line in the reduction of potential pollution in future developments by means of judicious land-use decisions. Because of the highly technical nature of the study, presentation and workshop material was prepared to introduce the concepts of water-quality protection and explain the use of wellhead protection zoning and aquifer vulnerability maps. The first presentation was to senior central government and district officers in May 1994 and was biased towards discussion of institutional aspects, legislation and implementation. The objective was to have a group of senior officers technically aware of the importance and means of water-quality protection and with the determination to achieve it through liaison with others. Further workshops have been held throughout Botswana by the Pollution Control Section, for District and Local Government officers. These are biased towards the local situation, and allow these officers to recognise the significance to water quality of industrial and residential developments and day-to-day activities such as pesticide spraying. The use of the local wellhead protection zoning and aquifer vulnerability maps is taught and liaison with other officers encouraged.

There is further opportunity to raise the general public awareness of the need not only for water-quality protection, but also for that of water conservation. Recognition of the importance of environmental matters is increasing in Botswana, with the National Conservation Strategy Board playing a significant part in planning for a sustainable use of the country's natural resources, and it is hoped that an educational programme on water-resource management may be made available to the general public, particularly to the schools.

Conclusion

Botswana is very much at the forefront of aquifer protection and is to be highly commended for instigating such a programme before severe problems arise, rather than after. During the course of the study, it has been encouraging to see how the policy is welcomed and, given the legislative framework and additional technical and administrative support, the generally excellent quality of water supply will be preserved.

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