Department of Water Affairs and Forestry

A PROTOCOL TO MANAGE THE POTENTIAL OF GROUNDWATER CONTAMINATION FROM ON SITE SANITATION

Edition 2
March 2003

Prepared for the National Sanitation Programme

CONTENTS

ACRONYMS

CMA	Catchment Management Association
COD	chemical oxygen demand – a measure of the level of organic contaminants in the water that will deplete the dissolved oxygen
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
GW	ground water
LOFLOS	Low-flush on-site sanitation system
N	concentration of nitrates in the water measured as nitrogen N (nitrates are also nutrients that may cause excessive growth of algae in water, but may also interfere with the oxygen carrying capacity of the blood in babies)
P	concentration of phosphates in the water measured as phosphorous P (phosphates are nutrients that may cause excessive growth of algae in water)
VIP	Ventilated Improved Pit Latrine
WSA	Water Services Authority
WSP	Water Services Provider

PREFACE

A key finding of the review that accompanied the revision of this GW Protocol was that the procedures of the version 1 GW Protocol were being applied by a number of different agencies with varying levels of skills and understanding of the issues involved. The results, although providing a significant improvement in the environmental attention on sanitation projects, still raised a number of questions as to whether it was being adequately effective in protecting either the groundwater resources or the health of the communities. On the other hand version 1 was used to discount perfectly adequate appropriate technology options for on-site sanitation against costly waterborne infrastructure that ultimately may pose significantly higher threats of pollution and a greater financial burden on the municipality. In response, a revised version has been prepared which attempts to address the concerns raised by the users of the protocol and sanitation practitioners by using a two-part approach, consisting of a *more sophisticated* areal survey combined with a *simplified* project-based procedure.

While it is suggested that the dual approach of the revised version is likely to be more effective than the existing version in protecting both the groundwater resources and the health of communities, the authors of the revised version need to make it clear that it has not been possible within the constraints of this particular contract to investigate adequately the rules contained in the revision of the GW Protocol to a sufficient extent as to provide an assurance of adequate safety in its use in all circumstances. It is therefore recommended that in cases where questions exist, further detailed investigations be carried out to improve the assessment of risk for the particular situation.

A key aim of the revised version has been to balance the three particular needs: (a) to avoid being over-conservative in any recommendations of sanitation infrastructure; (b) to provide a tool that requires relatively low resources in terms of expertise and finances for investigation and use of the tool; and (c) to provide an assurance of safety for protection of both human health and the groundwater resources.

Notwithstanding these challenges, it is suggested that the revised GW Protocol does in fact provide an improved method of assessment by comparison with the version 1 in both *form* and *overall philosophy*. However, in the exact details of the revised version (as contained in the tables of the revised version) further investigation is still required to provide an adequate assurance of safety.

These guidelines are in several instances simplistic, in that they oversimplify highly complex processes, and may in certain instances underestimate the contamination potential of certain configurations of sanitation system and subsurface conditions. Consequently, the revised GW Protocol may recommend solutions which carry a risk of failure - although this risk is suspected to be small. The use of these guidelines is considered to provide a better solution than no sanitation - or even unimproved sanitation. By providing guidelines that are too complicated to use or suggesting solutions that are too expensive and/or sophisticated to implement may result in poorer conditions than something simpler and cheaper that is within the capabilities of a particular community.

Where sufficient resources - either for investigations or interventions - are available, it is recommended that more detailed investigations be carried out commensurate with the value of the project and the risk associated with it. In other words, this GW Protocol is intended primarily for low-density rural settlements where skills levels and financial resources are low and where there is generally no existing sanitation - or the existing sanitation is inadequate. It is not intended for use in large, high-density peri-urban settlements, where skills levels and financial resources are generally higher.

A more accurate modelling exercise with pilot evaluations are recommended to be able to provide more accuracy to the tables and guidelines provided in this version of the GW Protocol.

This GW Protocol aims to meet the requirements of the constitution and the Water Services Act as effectively as possible within the constraints of both skills levels and financial resources.

Part 1 INTRODUCTION

1.1 Preamble

The important role that groundwater plays in the health of many communities cannot be overstated. In the future it is expected that groundwater sources will increasingly be the only source of additional water for the development of communities, particularly in the more remote areas. However the quality and quantity of these resources are constantly under threat from the activities of human existence and development. It is therefore of vital importance that adequate measures are taken to preserve our valuable groundwater resources. However concern regarding the contamination of groundwater should not be used as an motivation for not using on-site sanitation systems without a proper investigation of the implications of adopting alternative systems.

"Unsewered sanitation offers the only affordable technical solution for improved waste disposal in many parts of the developing world and it is not the intention of this protocol to discourage the use of on-site sanitation systems. Indeed, in some hydrogeological environments the capacity of the soil to attenuate microbiological pollution suggests that much more use might be made of such systems" (adapted from Ward 1989)

The Groundwater Protocol aims to provide simple tools for groundwater and sanitation planners and practitioners to ensure that the development programmes for communities continue to place a high value on the groundwater resources, and hence protect them from contamination from sanitation practices and other potential contaminants.

1.2 Assessment of experience with edition 1

A study was carried out at the end of 2002 to assess the experience of practitioners on the use of the 1st Edition of the Groundwater Protocol. The overall findings were as follows:

1. The version 1 GW Protocol appears to be beyond the capacity of many of the rural areas; at the same time it is too simplistic for urban areas, and confusing in the detail for those in all areas who have a good understanding of the issues. The source of this confusion is that the GW Protocol has attempted to provide a simple tool for a very complex problem; and has on the one hand sacrificed accuracy in both the form and magnitude of relationships, while on the other hand not making the tool simple enough.
2. The version 1 GW Protocol has included the useful format of a differentiated approach whereby there are escape clauses which require the user in clearly specified conditions to obtain specialist opinion.
3. A fundamental principle of the version 1 GW Protocol was that it was to be used by 'technical personnel who are not necessarily hydrogeological specialists'. In areas of the country where capacity is low, it seems that there is not even capacity of these 'technical personnel'.
4. A concern has been that the GW Protocol has been used to discount on-site sanitation in urban areas without an assessment of the full implications of installing a water-borne sanitation system in low-cost residential areas.

A detailed list of comments can be found in appendix A.

1.3 Main recommendations for changes to edition 1

The comments and concerns were discussed with the steering committee and the following modifications approved:

- The GW Protocol should be split into two studies or assessments:
  - area based assessment, generally carried out by hydrogeologists
  - project based assessment using outputs of area based assessment, generally carried out by sanitation practitioner (technical)
- The roles and responsibilities of the various role players should be specified
- The terminology of a portion of the report should be such that it provides appropriate information to the community itself
- The project level assessment and implementation of the recommendations should be incorporated into the H&H programme
- The concept of risk assessment, in comparison to other sanitation options, should be followed in the GW Protocol (rather than absolutes)
- The options or remedial measures should be revisited to include other practical options (especially dry sanitation systems) and to ensure practicality of the remedial measures
- The issue of ongoing monitoring of boreholes must be addressed
- The processes affecting the reduction of movement of contaminants, particularly bacterial pollution, should be described
- The response to possible higher pollution risks should follow a “recipe” type decision tree.

With respect to the more detailed aspects of the GW Protocol:

- More details on reduction of contaminants
- More tables for simplifying the assessments
- Table 1 needs revision to deal with fine-grained sands
- Area assessment should include a number of key tasks not presently listed
- Need options for different groundwater situations
- The situation of pollution from existing toilets should be considered
- Other contamination sources should be estimated in more detail
- Need stronger emphasis on steps to protect existing boreholes
- There should be a link to the H&H education programme
- Options for ranking aquifers should be considered

This presented a somewhat formidable list of new issues to try to rationalise and incorporate into a revised edition of the groundwater protocol. The following overall approach has been adopted:

- An attempt to be more simple, but at the same time adding in a 2-stage approach (aerial ‘first pass’ by specialists + simpler project-based protocol) to introduce some form of more specialist oversight or preliminary screening of GW assessments.
- Aiming for a simple, but more realistic approach, by using parameters that more realistically describe the real situation. This has required using a more detailed approach, but giving more assistance in classification.
- Another key principle has been to take a conservative approach i.e. to use formulae and assumptions that are conservative, but to allow the user to use more complicated methods if he/she is able to in order to get a more accurate but less conservative answer.

It is trusted that feedback will continue to be provided to improve the usefulness of later editions.

1.4 Guiding principles

The following guiding principles have been established to provide the background approach and hence to assist those using the protocol to be able to take the correct decisions at all stages of the assessment.

[1] The revised GW Protocol falls under the overall provisions of three government Acts: National Water Act (Act 36 of 1998), the National Environmental Management Act (Act 107 of 1998) and the Environment Conservation Act (Act 73 of 1989).
[2] The GW Protocol forms part of a set of procedures for the provision of sanitation and the protection of water resources, and should not in itself be used to justify a particular choice of action without the financial and socio-economic assessments required for holistic decision making.
[3] The GW Protocol is intended to permit assessments of environmental impact of sanitation systems to be carried out using the lowest skills levels feasible. Where resources are limited, effort in assessment needs to be in proportion to impact.
[4] GW Protocol procedures are to be integrated into regional institutional structures to ensure that the responsible authorities are informed of all studies and outcomes. Responsibilities for the various tasks of the GW Protocol need to be allocated in conjunction with institutional structuring.
[5] Impacts cannot generally be resolved in absolute terms, but are resolved in a water resources strategy. While certain practices are better than others, and there are certain interventions that can be made to further protect groundwater from contamination, *absolute* protection from *any* contamination by sanitation systems is unrealistic - certainly in the context of developing areas.
[6] Communities should be involved in the site assessments to be carried out, including the hydro census, and made aware of the health impacts related to contamination of the groundwater resources. They should also be involved in the longer term monitoring of the groundwater and the potential sources of contamination.
[7] Factors affecting the performance of sanitation systems (and the extent of contamination) are not only related to their theoretical performance, but also how carefully the systems are designed, managed and used.
[8] Groundwater resources are likely to become more valuable in the future, even in urban areas where piped water is supplied from surface sources. For this reason appropriate steps to ensure reasonable protection should always be taken.

1.5 Risks

The assessments associated with the GW Protocol are based on the principle of risk. Hence the assessment of the impact of a sanitation system should be based on the level of risk of the sanitation system to contaminate the groundwater in comparison to other sanitation alternatives, and in relation to the risk of contamination from other sources. Risk levels are based on three factors:

- the vulnerability of the underground water resources (aquifers), and
- the contamination load from the particular sanitation system,

The overall risk then provides the risk of contaminating the groundwater at the zone of the sanitation systems. This risk is then tempered by the strategic value of the aquifer related to the current and/or future use of water from the aquifer.

Part 2: THE GROUNDWATER CYCLE AND CONTAMINATION PROCESS

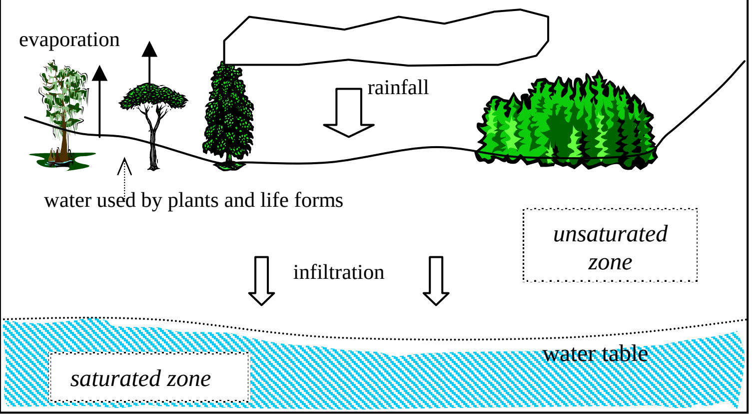
2.1 The nature of groundwater occurrences

Groundwater constitutes a major proportion of all the freshwater that is available for human use. Even in South Africa with many areas being semi-arid, groundwater is extensively used for domestic, industrial and agricultural use. In many areas the surface water resources have been almost fully utilised, and the only resource available for future developments are the groundwater resources.

When rain falls, a part of it infiltrates the soil. A proportion of this part is used by plants and other life forms in the upper soil layers, while another proportion will infiltrate more deeply, eventually accumulating as an underground water body or reservoir. Where significant quantities of water can be pumped out of this reservoir, it is known as an aquifer.

The underground zone which occurs immediately below the land surface but above the aquifer contains both water and air and is known as the unsaturated zone. The aquifer which underlies the unsaturated zone is a zone in which all interconnected openings are full of water. The upper level of this zone is referred to as the groundwater table. Groundwater can also occur as freely flowing within fractures (fractured aquifers). The water table or the level of the saturated zone can vary considerably from just a few centimetres to hundreds of meters below the land surface. This level is determined by a number of geological and geohydrological factors.

Figure 2.1 The groundwater system



2.2 Sources of contamination

In considering the potential for contamination of the groundwater by a proposed sanitation project or technology, it is essential that the contamination risk from all sources be considered. These could include the following:

- Existing toilets, including unimproved pit latrines, all types of improved on-site latrines, and any off-site sanitation systems including waterborne sanitation.
- Solid waste dumpsites, including household waste pits.
- Grey water disposal practices (often disposed of in the garden or in a pit in the yard).
- Cattle kraals or feedlots where cattle and other livestock are kept within confined spaces.
- Cattle dip tanks.
- Graveyards.
- Waste disposal from certain small industries, especially motor vehicle repairs, food stalls and shops, and small manufacturing enterprises.

The type and level of potential contamination from these sources is dependent on a number of factors, including the size and age of the facility, the level of use, and the precautions taken to prevent contamination. The level of contamination that flows to the groundwater could, in some cases, be quite considerable and pose a far greater threat than the planned new sanitation system.

2.3 Contaminants associated with on-site sanitation

Of the broad list of possible sources of contamination listed in section 2.2, the contaminants of concern may be divided into two groups:

(a) *microbiological* contaminants, typically viruses and bacteria, but also including larger organisms like protozoa and helminths (worms), and
(b) *chemical* contaminants, consisting of both organic (e.g. human wastes) and inorganic (e.g. salts) components. The organic components of primary concern are poisons and those that decay rapidly and form odorous by-products. The inorganic components of primary concern are nitrogen, phosphorus and chlorides.

Other groups of chemical contaminants that may be found in domestic wastewater include detergents, pesticides, cleaning solvents, paints and oils.

Microbiological contaminants are of concern because they may be direct causes of disease (e.g. typhoid, cholera, diarrhoea, dysentery), while chemical contaminants may cause disease (e.g. high levels of nitrates interfere with the ability of the blood to transport oxygen in babies) or make the water less useful for agriculture (high levels of phosphorous cause excessive algae growth in dams and irrigation canals while high levels of chloride hinder leaf growth in some crops).

A key difference between the microbiological and chemical contaminants is that while the microbiological contaminants will all die off over a period of time, chemical contaminants, particularly the inorganic components, are more persistent and will enter the groundwater usually some reduction due to adsorption, but without any change in form.

For the purposes of this protocol, the only contaminants considered are viruses and bacteria (microbiological) and nitrogen, phosphorus and chlorides (chemical). Other contaminants may need to be assessed where particular problems arise (e.g. outbreak of a disease), or if small industries are potentially disposing of poisons or oil-based products. In these cases separate studies should be commissioned.

2.4 Rates of contamination from sanitation systems

Contaminant pathways from different sanitation systems are illustrated in Figure 1.

The aim of any sanitation practice is to ensure that contaminants do not come into contact with humans or animals either directly or through contact with the water or soil. Contaminants from humans and animals that are disposed of on or in the ground may be transported away from where they are disposed of, usually being carried by water. The water that comes into contact with the contaminants may take one of three possible routes:

- overland to rivers, dams and lakes
- into the ground to the groundwater table
- into the ground and then seeping back out onto the surface

Fortunately many of the contaminants do not flow far with the water. Microbiological contaminants are quickly filtered out as the water flows through the soil, and many chemical contaminants are absorbed onto the soil particles. So in general the further away from the source of contamination, the lower the concentration of contaminants is likely to be.

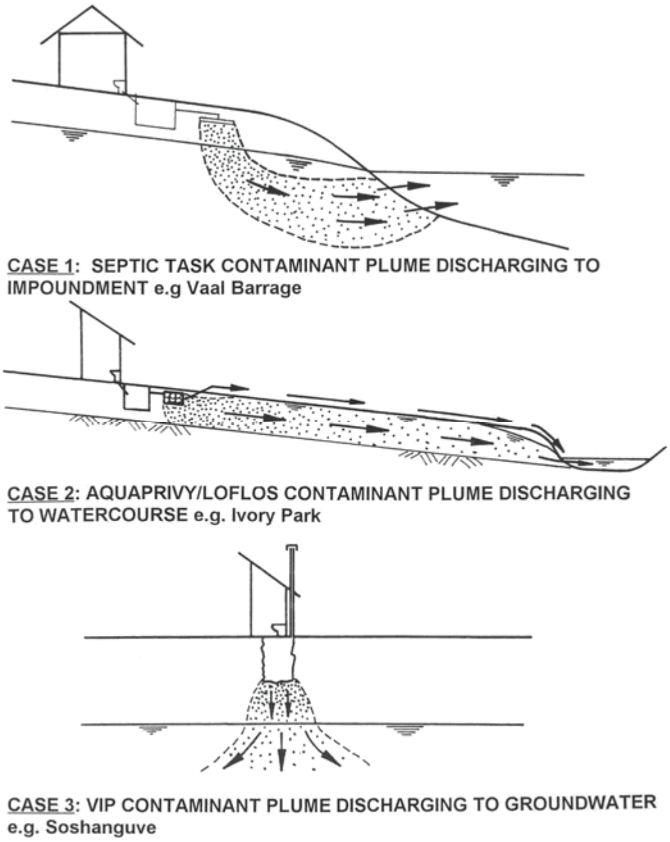


Figure 1: General layout and contaminant flow paths of different levels of service of water supply and sanitation (Van Ryneveld et al., 2001: p.48)

Based on the literature, Van Ryneveld et al. (2001) produced a table of water usage, contaminant loading and removal efficiencies for different levels of service of sanitation (with particular application to Gauteng):

<u>TABLE 2.1</u>: Summary of flows and contaminant loads for different levels of sanitation service

Parameter	*units*	*Water Borne convenience use*	*Water Borne essential use*	*LOFLOS (Low flush on-site sanitation)*	*VIP*	*Bucket*	*Chemical*	*no disposal systems*
to surface water:								
Flow	l/cap.d	200	100			2	2	
Total P	gP/cap.d	0.16	0.08			0.0016	0.0016	
Total N	gN/cap.d	2.5	1.25			0.025	0.025	
COD	gO_2/cap.d	8	4			0.08	0.08	
to ground surface:								
Flow	l/cap.d			26.5	28			20
Total P	gP/cap.d			0.9	0.9			2.5
Total N	gN/cap.d			3	0.6			10
COD	gO_2/cap.d			30	6			100
to groundwater:								
Flow	l/cap.d			3.5	2			
Total P	gP/cap.d			0.53 say 0.6	0.55 say 0.6			
Total N	gN/cap.d			3	4.5			
COD	gO_2/cap.d			7	12			

Note that flows include grey water disposal.

2.5 Reduction of contamination in the unsaturated zone

The unsaturated zone is the first line of natural defence against the pollution of the groundwater. Its role in the attenuation of the movement of contaminants is therefore of particular importance. However the processes that take place within this zone are complex and hence difficult to predict. Attenuation is generally the most effective in the unsaturated zone, and particularly in the upper soil layers where biological activity is greatest.

The reduction of contaminants in the unsaturated zone is a function of the rate of flow through the unsaturated zone, the type of contaminant, and the capacity of the media to adsorb contaminants or create an effective barrier to the movement of contaminants, e.g. through filtration. Thus clayey soils both reduce the rate of flow and absorb contaminants, whereas a gravely media as found within a fractured zone may both allow rapid movement and minimal absorption of contaminants. However a sandy soil, although highly permeable with a low absorption capacity, is often able to create conditions that form an effective barrier for the movement of contaminants through the sand layer.

To assess the potential of the unsaturated zone to reduce the movement of contaminants to the groundwater requires the determination of the geology, soil types and the thickness of the unsaturated zone. Table 1 is a useful tool for estimating the potential for the reduction of the movements of contaminants in the unsaturated zone.

2.6 Reduction of contamination in the saturated zone

Contaminant removal processes will continue below the water table in the saturated zone, but generally at slower rates because there is minimal biological activity at this level and because groundwater moves more rapidly than in the unsaturated zone. However dispersion and dilution will play an important role in reducing concentrations of contaminants. In very deep aquifers there may be some conversion of nitrates to nitrites and nitrogen due to a lack of oxygen in the groundwater. However this is not considered as a factor in standard assessments.

To determine the effectiveness of removal within the saturated zone, Table 1 may be used together with an assessment of the dilution factor and the estimated length of the flow path to the abstraction point.

Part 3 TECHNICAL CONSIDERATIONS

3.1 Special adaptations of sanitation systems to reduce contamination

Where socio-economic or geographic conditions result in the choice of a sanitation system that could cause significant contamination of the groundwater, other options will need to be considered to reduce or prevent the contamination of the groundwater.

3.1.1 Pit toilets

Pit latrines may be adapted in three main ways. These are:

- increasing the depth of the unsaturated zone by reducing the depth of the pit;
- sealing the pit but with a water close to the surface;
- converting the sanitation system so that the pit only contains dry solids

The depth of the pit may be reduced by either building a part of the pit above ground, or alternatively by digging a wider, shallower pit. In each of these cases the volume of the pit should not be reduced.

Sealing the pit has a similar impact as reducing the depth of the pit. In this case the pit fills up with a mixture of liquids and solids, but the liquid is drained off near the top of the pit. The drain pipe may be lead to a garden or grass patch, but should not be used on edible plants.

Options for converting the sanitation system so that the pit only receives dry solids include the urine diversion toilet, high rate aeration or desiccation toilets, and composting toilets. Details can be found in existing publications – see reference list at the end of this manual.

3.1.2 Septic tank systems and aquaprivies

Septic tank and digester type systems are potentially the greatest threat of on-site sanitation system to maintaining a good quality of groundwater. This is because they dispose of a lot more water than other systems into the ground, which acts as a carrier of the contaminants to the groundwater.

Options for reducing the impact of septic tank and digester systems on the groundwater include reducing the water used for flushing, or leading the effluent of the septic tank or digester to a place where it can be disposed of more safely. These include:

- small reed-bed (wetland) treatment systems (2-5 days retention time)
- wastewater stabilization ponds – facultative (15-40 days retention)
- combination of wetland with maturation pond (5 – 15 days retention)
- overland flow treatment and disposal system
- mound treatment and disposal system
- sand filter treatment and disposal system
- evapotranspiration disposal system, or
- disposing it sufficiently far from the groundwater abstraction point.

Details can be found in existing publications – see reference list at the end of this manual.

3.1.3 Waterborne sanitation systems and conservancy tanks

Although waterborne systems are usually considered the most environmentally safe sanitation systems, there are many cases where waterborne systems have had a major impact on both the groundwater and the surface watercourses due to broken pipes and overflowing manholes and conservancy tanks.

Reducing the risk of contamination from waterborne reticulation networks and conservancy tanks requires a higher level of ongoing maintenance. In addition constructing shallow sewer systems that can be more readily maintained at the local level could support improved maintenance. With regard to conservancy tanks, the installation of proper overflow drainage, and piping this drainage to a safe disposal site will reduce problems arising from inadequate maintenance.

3.2 Aquifer vulnerability and risks to groundwater supplies

Aquifer vulnerability is the likelihood of an aquifer being affected by a contaminant load imposed by human activities at the ground surface. The assessment of the vulnerability is based on the estimated travel time for water to move from the ground surface to the water table. As the water moves through the ground, natural processes reduce the concentration of many contaminants.

The vulnerability of aquifers to contamination from sanitation systems and other pollution sources is high in areas of high rainfall and shallow water tables. The vulnerability is also high for fractured aquifers and other permeable environments such as sandy or gravel soils. This is mainly because of high flow rates and less time and distances available for filtration, die-off and adsorption processes to take place. Proper management of groundwater and control of hazardous activities on vulnerable aquifers is essential for the protection and the sustainability of the groundwater resource. A proactive approach to protect the groundwater resources from pollution is encouraged, as it may be very difficult and costly to treat the groundwater once it has been contaminated, particularly in terms of inorganic contaminants.

For the purposes of this manual, five broad classes of aquifer vulnerability are defined (adapted from AR Lawrence et al 2001):

Table A: Vulnerability of Groundwater Aquifer due to Hydrogeological Conditions

Vulnerability Class	Measurements	Definition
Extreme (usually highly fractured rock and/or high ground water table)	High risk (table 1) and short distance (< 2m) to water table	Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface
High (usually gravely or fractured rock, and/or high water table)	High risk (table 1) and medium distance (2-5m) to water table	Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed
Medium (usually fine sand, deep loam soils with semi-solid rock and average water table (>10m)	Low risk (table 1) and medium to long distances to water table	Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants
Low (usually clay or loam soils with semi-solid rock and deep water table (>20m)	Minimal and low risk (table 1), and long to very long distance to water table	Only vulnerable to the most persistent pollutants in the very long term
Negligible (usually dense clay and/or solid impervious rock with deep water table)	Minimal risk (table 1) with confining layers	Confining beds present with no significant infiltration from surface areas above aquifer

3.3 Precautionary measures to protect groundwater abstraction points

The following measures should be taken to protect groundwater abstraction facilities to minimise the risk of pollution:

- Groundwater abstraction points should be sited away from all activities that pose a pollution threat.
- Groundwater abstraction points should preferably be sited upslope of and outside the villages and should be properly fenced.

- Groundwater abstraction points should be built with adequate protection ensuring that surface water does not reach the groundwater. Failed or abandoned boreholes or wells must be properly backfilled and sealed.
- Pump houses should be kept in a neat and dry state. For diesel pumps, oil and diesel spillages should be mopped up and all oil and diesel leakages should be sealed as soon as possible. The pump house floor should be properly constructed without cracks or open joints.
- Springs should be adequately protected and developed to prevent water contamination.

3.4 Geological conditions

The geological conditions will have a significant impact on the groundwater flow and the amount of water that can be abstracted from a borehole or well. The geology also governs the change in water quality as the water moves through the unsaturated and saturated zones. Coarse-grained rocks and soils tend to have higher permeability and porosity, which in turn allows for easy and rapid flow of water. These types of rocks make good aquifers provided the quality of water is also of a good standard. Fractured rocks may also allow rapid movements of water through them. This is in contrast to the fine-grained rocks with a very low porosity. In these rocks water flows very slowly. Some rock layers are almost completely impervious (i.e. no water flows through at all).

The rock types and the thickness of the geological layers will determine the rate and the amount of reduction of contaminants that can take place, as well as the level of impact that surface drainage will have on the underlying aquifers. Generally, in fractured and shallow coarse-grained rocks there is limited reduction or removal of contaminants, while in deep fine-grained rocks significant reduction of contaminants can be expected. However in many cases fractures and faults have a far greater influence on the flow rates and reduction of contaminants than the flow through the geological layers themselves.

Some of the processes that change the quality of the water are influenced by the chemical nature of the rock, and the existing physical conditions. As a result groundwater derives its chemical character from the rocks or the soil through which it is flowing, however this is also determined by the rate of the reactions and the amount of time available.

3.5 Hydrogeological conditions

It has been noted that the vulnerability of groundwater to pollution is dependent on the nature of the subsurface and the depth to the water table. As a basic principle, the longer it takes the contaminants to reach the groundwater, the less the impact on water quality of the aquifers. Data has shown that most pathogenic organisms die off within 10 days, with shorter periods where the microbiological activity in the unsaturated zone is enhanced. In table 1 the different types of geological conditions are related to the permeability or speed of travel of water through the geological environment.

It should be further noted that the movement of water within the saturated zone (i.e. below the water table) will usually not exceed a few meters per day and can be as low as 1 meter per year. Hence the passage of water through aquifers may take years or decades rather than days. This is particularly the case of deep aquifers.

Where groundwater is being extracted for use, an understanding of the area of recharge, rates of flow and flow direction is important in minimizing and/or controlling groundwater pollution. Flow rates below the water table will be increased by pumping because a cone of depression is formed around the pump extraction point. In cases where contamination of the groundwater has occurred, it may be possible to avoid extracting polluted water by pumping from deeper levels and minimising the cone of depression by pump management.

3.6 Borehole siting, development and protection

Geohydrologists responsible for the siting of boreholes should take due consideration of factors which can have a negative impacts on the quality of the groundwater to be pumped. Groundwater abstraction points should be sited as far away as possible to all activities and environments which can impact negatively on the water quality. Boreholes should preferably be sited outside and preferably upslope of the villages. However as other factors such as depth to water table, fractures and faults, and the existence of permeable layers are the main factors governing the siting of boreholes, it may be necessary for special precautions and remedial actions to be implemented to protect the quality of what may be the only available water source.

Borehole construction should be done with consideration of preventing contamination and collapse thereof. Depending on the existing geology it is important that a borehole should be properly supported with casing to prevent it from collapsing. A sanitary seal on the upper part of the borehole is important to prevent surface water form seeping directly into the borehole and thus polluting the groundwater within the borehole. At the surface a concrete collar should protect the borehole. The collar should be constructed in such a way that it allows drainage away from the area around the borehole.

Boreholes should also be equipped for easy monitoring of water quantity and quality. To monitor the groundwater level and rates of abstraction, boreholes should be fitted with piezometer tubes and a flow meter. To monitor for quality boreholes should be fitted with sampling taps.

The standard construction and equipping of boreholes as described above should be a contractual obligation for drilling contractors.

3.7 Surface water conditions

Surface water systems have a significant impact on groundwater systems, and in many situations vice versa. Surface water infiltrates to the groundwater, and in many cases groundwater provides the water to springs and the base-flow to streams and rivers. As already stated for groundwater, it is equally important to protect surface waters from being contaminated from sanitation systems and other contamination sources.

3.7.1 Vulnerability to contamination from sanitation systems

Surface waters can become contaminated from sanitation systems in the following situations:

- blocked or broken sewer pipes;
- poor drainage properties of soils into which wastes are disposed, e.g. from septic tanks and digesters, resulting in seepage onto the surface or directly into streams;
- rainwater intrusion into pit latrines which fill and overflow;
- springs contaminated from nearby latrines;
- disposal of human wastes directly onto the surface which are washed into streams when it rains.

In many of these situations the resulting contamination, particularly in terms of bacteria and viruses, can be dramatic and result in significant health risks to downstream users of the surface waters.

3.7.2 Vulnerability to contamination from other sources

Surface waters are commonly contaminated from a wide variety of sources as a result of human activities. These are similar to the sources of groundwater pollution and in many communities include the following:

- Solid waste dumpsites, including household waste pits.
- Grey water disposal practices (often disposed of in the garden or in a pit in the yard).

- Cattle kraals or feedlots where cattle and other livestock are kept within confined spaces.
- Cattle dip tanks.
- Certain small industries, especially motor vehicle repairs, food stalls and shops, and small manufacturing enterprises.

The level of contamination will depend on the amount of water disposed of in each of these practices, and the vulnerability to rainwater wash-off from these areas. As with sanitation systems, the impact on surface water quality could be dramatic and pose significant health risks to downstream users.

Although this protocol deals specifically with contamination of the groundwater resources, the interaction between groundwater and surface water means that surface water contamination must be considered as a potential contributor to contamination of the groundwater resources. In addition steps should not be taken to protect groundwater resources at the expense of contamination of surface waters.

Part 4 APPROACH TO ASSESSMENT OF CONTAMINATION RISK

4.1 General approach

Two options are proposed for the assessment of the risk of contamination of the groundwater resources as a result of sanitation improvement programmes. The first option involves a two-stage approach and is recommended. However if it is not possible or feasible to undertake a two-stage assessment, the requirements for a single stage assessment are described in the second option. These two options relate to the level of involvement of different role players in undertaking the assessment.

4.1.1 Two stage assessment – area based hydrogeological assessment followed by project based sanitary surveillance.

In this situation (which is the recommended approach) stage one involves an area-based hydrogeological assessment, carried out preferably by a hydrogeologist. The size of the area can vary from a sub-catchment with 2 to 3 communities to a local municipality or whole district. The investigation would comprise an assessment of the geological formations, the major and minor groundwater aquifers, water bearing faults and fractures, and the major surface water resources. The investigation will highlight sensitive areas where special precautions must be taken, as well as make recommendations for future groundwater resource management. The procedures are outlined in 4.3 below.

The second stage involves the project or community based assessment, usually undertaken by the sanitation engineer or technician. The information of the area-based assessment is used to identify sensitive areas within the boundaries of the sanitation project. The main activities are to assess local community level issues that may affect the choice of sanitation system and the potential to contaminate the local groundwater resources. This part of the assessment will include participation by the community in carrying out many of the tasks that are required for the assessment. The procedures are outlined in 4.4 and 4.6 below.

4.1.2 Single stage assessment at project level

Where no area-based assessment has been carried out, a more detailed project level assessment will need to be carried out. This will include a higher level of hydrogeological investigation than for the stage 2 (community based) assessment of the two stage assessment. This assessment should still include participation by the community in carrying out many of the tasks that are required for the assessment. The procedures are outlined in 4.5 and 4.6 below.

4.2 Characteristics of urban areas, small towns and rural areas

The first edition of the GW Protocol was primarily aimed at rural areas. In urban areas, high settlement densities together with greater financial resources have in the past permitted fairly widespread use of full water-borne sanitation. However, financial constraints together with increasing low-income populations in urban areas are encouraging the consideration of alternatives, and particularly of on-site sanitation. This in turn has necessitated the extension of the use of a GW Protocol to these areas as well.

The differences between urban areas, small towns and rural areas are graded rather than distinct, and are characterised by two main factors: (a) settlement density; and (b) financial resources. Densities of rural settlements tend to be considerably lower than those of urban areas (in rural areas, densities are generally less than 10 houses/ha while densities of (low-income) urban areas tend to be around 30-50 houses/ha and can be even higher). In terms of financial resources, rural areas tend to have fewer financial resources than urban areas. A further factor is that many rural areas are dependent on local groundwater resources, whereas in urban - and certainly metropolitan - areas, water is often obtained from further a-field, and is therefore not subject to contamination by on-site sanitation systems in the same way.

Urban areas tend not to have the same institutional structure as rural areas. Sanitation projects are generally pursued as part of housing provision, and not as part of a stand-alone sanitation project as in the DWAF Sanitation Programme.

Hence the approach to the assessment in the different settlement types should take into account the settlement densities, the use of the local water resources, and the ability for the institutional structures to operate and maintain the installed system. These aspects are dealt with in the risk assessment in section 5.

4.3 Area-based geological assessment of aquifers (Stage 1)

The area-based assessment of the geology and aquifers is the recommended approach to carrying out the first stage of the assessments for determining the potential risk of contamination of the groundwater resources. The assessment will identify the hydrogeology of a selected area, which may be a catchment or a defined geographical region that is useful for planning.

The main aim of this assessment is to identify the aquifers and to determine sensitive areas where the risk of pollution will be high. The activities listed in the following table would form the main assessment, with the report format (appendix B) being forwarded to all role-players involved in sanitation projects within that area. It should be noted that a report should also be made available to the communities that will be participating in the sanitation programmes, and hence a version of the report using the format required for the community report should be compiled in addition to the report for other role-players.

<table>
<tr><th>Two Stage Assessment of Groundwater Potential and Contamination Risk
Stage 1: Area-based assessment</th></tr>
<tr><td><u>Activities: Groundwater Potential</u>
1. Collect background information:
▪ Geological maps
▪ Rock types
▪ Geological formations
▪ Aerial Photos
▪ Geochemistry
▪ Geological profiles
▪ Topographical Maps
▪ Classification of aquifers
▪ Groundwater exploitation
▪ Water Resource Reports
▪ Major settlements and intense agricultural activities
▪ other including WSDPs, Water Resources and Water Quality Management reports

2. Compile landscape map indicating:
▪ Rock types
▪ Geological contacts
▪ Confined and unconfined aquifers
▪ Main faults and fractures (fractured aquifers)
▪ Major and Minor aquifers
▪ Recharge areas
▪ Vulnerable aquifers
▪ Regions of deep weathering
▪ Groundwater flow directions</td></tr>
</table>

4.4 Project-based assessment of contamination risk (Stage 2)

The project-based assessment of the contamination risk will include the following components:

! *Water resource audit*
In some cases the water resource audit would have been carried out as part of general water resources assessments. The provincial office of the Department of Water Affairs and Forestry should be consulted for these records. If the water resources audit has not been done for the area, it will be necessary to undertake an audit for the GW Protocol as a separate study, but only with regard to the local water resources. In any event the community should be requested to indicate all the water sources that they are aware of and some information regarding the flow and reliability of these sources.

The local based water resources audit should include the following information:

Activity 1: Local (project based) audit of water resources
1. Collect information on groundwater resources: ▪ Existing active boreholes (position, pump rate-ℓ/day, recharge area) ▪ Abandoned boreholes (position, why abandoned, yield when functioning) ▪ Springs (position, high and low flow rates, recharge area, use by community) ▪ Identification of dykes, seepage areas (wetlands) and other features indicating the presence of groundwater resources. 2. Collect information on groundwater resources: ▪ Streams and rivers (position, low and high flow rates, use by community) ▪ Pans, dams and lakes (position, approximate area, recharge area, use by community) ▪ Find average rainfall figures and normal runoff paths during high rainfall incidents, and identify major storm water runoff channels (position) 3. Collect information on water use by the community and neighbouring communities: ▪ Main source of water (e.g. pipeline, spring, borehole, etc.) ▪ Supplementary sources ▪ Reliability of all sources ▪ Quality of sources (e.g. good, suspect, poor)

! *Assessment of existing contamination sources.*
Existing contamination sources need to be given appropriate attention. While provision needs to be made for assessment of existing systems, which may not have been assessed adequately before they were first installed, the emphasis on assessment of existing systems needs to be on monitoring of performance rather than theoretical initial assessment.

Activity 2: Assessment of existing potential sources of groundwater contamination
1. Collect information on existing threats to groundwater quality: ▪ Existing toilets, including unimproved pit latrines, all types of improved on-site latrines, and any off-site sanitation systems including waterborne sanitation. (type of systems, density of households, existing status and level of maintenance) ▪ Solid waste dumpsites, including household waste pits (type of systems, existing status and level of maintenance). ▪ Grey water disposal practices (type of systems, existing status and level of maintenance). ▪ Cattle kraals or feedlots where cattle and other livestock are kept within

Activity 2: Assessment of existing potential sources of groundwater contamination
confined spaces (type of systems, density of kraals, existing status). ▪ Cattle dip tanks (position, existing status and level of use). ▪ Graveyards (position, existing status and whether still in use). ▪ Small industries, especially motor vehicle repairs, food stalls and shops, and small manufacturing enterprises (type of enterprises, number and density of establishments, existing status and methods for disposal of wastes). ▪ Poorly constructed boreholes where surface water is able to flow into hole (position and status).

! *Assessment of sanitation alternatives.*

The alternatives for upgrading the sanitation of a community is based on a number of factors, including political influence, technical considerations, institutional requirements, and aspirations of the community. It is important that the selection is ultimately based on a rational assessment of all viable alternatives, and that the impact and ongoing operation and maintenance requirements of the chosen alternative are well understood and accepted by all role players, but particularly the community themselves.

Activity 3: Assessment of sanitation alternatives
1. Assess preferences and implications of all alternatives ▪ Identify current technologies and aspirations of residents ▪ Assess economic status and affordability levels within community ▪ Identify district municipal sanitation strategy and longer term maintenance support ▪ List most appropriate sanitation options ▪ Note likely impact of options on groundwater resources ▪ Present options to all decision makers (including community representatives)

! *Assessment of risk of contamination.*

Having gathered all the background information on the groundwater resources and the existing situation within the communities, the first analytical step is to assess the risk of contamination of the groundwater resources as a result of the proposed sanitation project. This risk should be compared with the risk of other alternatives, as well as the level of contamination that is likely to be coming from the existing facilities and practices within the communities.

Activity 4: Assessment of risk of groundwater contamination
1. Assess risk from proposed sanitation project ▪ Estimate the hydraulic loading from the selected sanitation option (see table 2) ▪ Estimate the average depth of the unsaturated zone (note that a reduction should be made if the measurements have been taken during the dry period) ▪ Estimate the time of the hydraulic flow from the sanitation system to the water table under normal conditions (see table 1: time of flow = depth of unsaturated layer ÷ rate of flow) ▪ Reduce time of flow if hydraulic loading (table 2) is > flow rate from table 1 (see table 2). ▪ Assess the potential for reduction of the contaminants (see table 1). ▪ Calculate the risk of contamination of the groundwater. ▪ If risk is significant, estimate the reduction of the contaminants within the water table (i.e. within the saturated zone). 2. Assess risk from existing sources of contamination ▪ Estimate the hydraulic loading from each source of contamination (see table 3) ▪ Estimate the average depth of the unsaturated zone (note that a reduction should be made if the measurements have been made during the dry period) ▪ Estimate the time of the hydraulic flow from the sanitation system to the water table under normal conditions (see table 1: time of flow = depth of unsaturated

Activity 4: Assessment of risk of groundwater contamination
layer ÷ rate of flow) ▪ Reduce time of flow if hydraulic loading (table 3) is > flow rate from table 1, in which case use hydraulic loading rate in the calculation. ▪ Assess the potential for reduction of the contaminants (see table 1). ▪ Calculate the risk of contamination of the groundwater. ▪ If risk is significant, estimate the reduction of the contaminants within the water table (i.e. within the saturated zone).

4.5 Joint assessment of groundwater potential and contamination risk

Where no area-based assessment has been carried out, a more detailed project level assessment will need to be carried out, incorporating both a detailed assessment of the groundwater potential and the vulnerability of the aquifers to contamination. The following activities should be carried out:

Single Step Assessment of Groundwater Potential and Contamination Risk Community or Village Level
Activities: Groundwater Potential 1. Collect background information: ▪ hydrogeological environment ▪ soil types ▪ groundwater exploitation ▪ aerial photos ▪ classification of aquifers ▪ water resource assessments 2. Compile landscape map indicating: ▪ village or community boundary ▪ existing boreholes and springs ▪ depth to water table ▪ soil types and depth to rock ▪ geological profile ▪ major and minor aquifers ▪ regions of deep weathering ▪ fractures and faults ▪ high drainage areas, and ▪ GW flow direction
Activities: Contamination Risk 3. Collect information on existing threats to groundwater quality (activity 2 in 4.4) 4. Carry out a water audit (community based) (activity 1 in 4.4) 5. Assess most appropriate sanitation options (activity 3 in 4.4) 6. Assess the risk posed by the selected sanitation options (flowchart A) (activity 4 in 4.4) 7. Assess the risk of contamination from other sources (activity 4 in 4.4)

Example: Calculation of contaminant risk from VIP latrines in a rural community

Background Information:
- geological structure: shales and mudstones from the Karoo supergroup with a dolerite dyke passing through a portion of the village
- loam soils to a depth of 1 m
- borehole with diesel pump on dolerite dyke
- depth of water table approximately 12m
- village has 350 households
- borehole is downstream of houses with a distance of 50m to the closest house

Existing threat to groundwater quality:
- approximately 30% of houses have an unimproved pit toilet
- there are street taps and households dispose of grey water in their gardens
- solid waste is minimal and buried on site
- approximately 10% of households bring cattle and goats into a kraal at night

Water resources
- groundwater is the main developed water supply for the community, and the borehole supplies approximately 75kℓ/day
- some households collect water from springs within 1 km from the village, and more so when there is a breakdown of the pump
- rainfall averages 650mm/a

Sanitation Options
- VIPs are considered the most appropriate sanitation option

Contamination risk from proposed VIP programme
- hydraulic load from VIP’s = 20 mm/d (table 2)
- permeability = 0.5 m/d (table 1 + measured)
- hydraulic flow time to water table = depth to water table ÷ permeability = 10m ÷ 0.5m/d = 24 days
- potential for attenuation of contaminants – high for bacteria and viruses, minimal for nitrogen and chloride except through dilution

Contamination risk from other sources
- hydraulic load from solid waste and grey water disposal = 5 mm/d (table 3) - insignificant
- hydraulic load from cattle kraals = 20-50mm/d in wet season (table 3) – significant within 20m of kraals
- contamination risk from cattle kraals is significant during the wet season

Response to conditions
- Recommend that VIP latrines constructed on or with 10m of dolerite dyke have a partly sealed pit with piped liquid drain to a point at least 30m away from dyke.
- Recommend that no cattle kraals be permitted directly on or within 10m of dolerite dyke.
- Institute pumping programme that minimises draw-down of water table.
- Institute a borehole water monitoring programme and a community based sanitary surveillance programme.

4.6 Participation of communities in the assessments

The participation of communities in the assessment of the contamination risk is strongly encouraged. This participation should be incorporated into the health and hygiene education component of a water supply and/or sanitation project in close consultation with the Department of Health (Environmental Health Offices). The particular areas where the community would be best placed to contribute are:

- undertaking of a hydro census within and around the settlement;
- compilation of landscape map;
- assessment of existing threats to groundwater quality;
- evaluation of sanitation options;
- ongoing monitoring of the performance (with Department of Health).

This list is not limiting the areas of participation, but lists where communities are well qualified to make valuable contributions.

This level of participation is considered essential for creating an awareness of the importance of protecting the groundwater resources in the longer term, and to establish a programme of ongoing sanitary surveillance of all potential health risks within the settlements. It is clearly essential that the community participate in the selection of the most appropriate sanitation solution for their community that will ensure the protection of the environment and safeguard the health of the community.

The involvement of local government should also be encouraged. However in many situations local government will be responsible for the managing the implementation of the sanitation project, and hence also for the groundwater protocol. Where the project is being implemented by other agents on behalf of local government, such agents should ensure that local government participates in the decision making associated with the groundwater protocol.

4.7 Roles and responsibilities of main stake-holders

While roles and responsibilities for undertaking the groundwater protocol may vary in different regions, it is imperative that these are allocated within each region and made known to all role-players. At this time environmental protection is constitutionally a key provincial responsibility and hence all reports must also be forwarded to the relevant provincial authorities. In addition the Provincial Department of Health is responsible for environmental health within communities, and hence must take a role in terms of incorporating the groundwater protocol into the health and hygiene programmes within the communities.

Whilst the provincial department of Environmental Affairs has the constitutional responsibility for the protection of the environment, a Water Services Authority (WSA) would carry primary responsibility for any contamination from any sanitation systems which is installed under its authority, although it would normally transfer the responsibility to the Water Services Provider (WSP) - or possibly the implementing agent, depending on the agreement. The WSA would be answerable to DWAF (as custodian of the nation's water resources) for any contamination. In time, this responsibility for the water resources is to be transferred from DWAF to the Catchment Management Agencies (CMAs).

Any responsibilities carried by the Implementing Agent or Sanitation Contractor would depend on the terms of the contractual agreement between the WSA/WSP and these parties. In general, responsibility for the more conceptual decisions (e.g. choice of level of service, and specification of generalised remedial interventions) would be carried by the WSA (or possibly the WSP), with the responsibilities for more detailed implementation (e.g. materials and workmanship conforming to specification) being carried by the Sanitation Contractor.

The following are proposed as key responsibilities that must be adopted by relevant institutional structures within each region:

Roles and Responsibilities of Key Stakeholders:

Activity related to the GW Protocol	Responsible Institution(s)
Overall responsibility for protection of the environment	Dept. of Environment Affairs, DWAF
Planning and contracting area-based geohydrological assessments	Dept. of Environment Affairs, DWAF, WSA, District Municipality
Carrying out of area-based geohydrological assessment	Contracted hydrogeologist
Planning and contracting project-based GW Protocol assessments	WSA, IA, DWAF
Carrying out of project-based assessments	Contracted Sanitation Practitioner
Approval of GW Protocol assessment	IA, WSA, DWAF (Sanitation + Geohydrology),
Implementing recommendations of the GW Protocol	WSA, IA, Local Authority
Incorporation of GW Protocol process into H&H awareness programme	IA, Dept. of Health
Ongoing monitoring of groundwater quality and impacts	WSA, community, local authority

Part 5 THE GUIDELINES

The assessment of the risk of contamination is based on the three risk levels described above, carried out within the institutional and regulatory framework of the region or province. A two-stage assessment process is recommended, although a single stage can be undertaken where constraints exist. Stage 1 is the assessment of the vulnerability of the groundwater aquifers within a wider area (usually incorporating 10 or more individual communities). Stage 2 is a site specific assessment of the contamination sources and the use of the groundwater within a single community.

Flowchart for assessing the groundwater contamination risk from sanitation projects

1. Clarify roles and responsibilities:
programme management, project management, reporting, monitoring, implementation of recommendations, health and hygiene programme, maintenance of records.

2. Has an area-based hydrogeological assessment been carried out for the project area?
(check with hydrogeology office in the DWAF Regional Office).

YES

NO
<u>either:</u> undertake area-based geological assessment of aquifers (see Stage 1 Task List)
<u>or:</u> carry out parts 1 and 2 of the single stage assessment (see 4.5 in main document)

3. Carry out project based assessment of contamination risk (Stage 2 Task List)
   - Collect information on existing threats to groundwater quality
   - Carry out a water audit (community based)
   - Identify ground and soil conditions, and depth to water table
   - Assess contamination from all sources including sanitation options

4. Compile situation report and map of project area
   - Map sensitive areas in the project area, and note main soil and rock structures.
   - Quantify and plot main water resources on project map. (see Task List 2)
   - Quantify all existing potential sources of contamination of the groundwater (see Task List 2)

5. Assess level of risk
   - vulnerability of aquifer (section A)
   - contamination load (section B)
   - overall risk (section C)
   - strategic value of groundwater (section D)

% for very high risk, select alternative system or secure alternative water source
% for high risk, plan remedial action (Options List 1) or map zone where no water abstraction is permitted
% for medium risk, ensure minimum distances are maintained and that remedial measures are taken within close proximity of abstraction points.

6. Are the conditions for ongoing operation and maintenance of the existing and/or proposed sanitation systems acceptable to ensure no additional future contamination risks?

YES

NO
assess level of future risk from tables 1, 2 and 3
   - for high risk, consider alternative options (Options List 1) and/or formulate workable maintenance plan
   - for medium risk, institute improved monitoring and awareness programme with remedial plans where required

7. Is there other environmental legislation or by-laws applicable to the project area that impact on the choice of sanitation system?

NO

YES
ensure requirements of this legislation are met

8. Formulate and commission ongoing monitoring programme
   - monitor borehole quality
   - sanitary surveillance programme within community

9. Submit copy of report to WSA, DWAF & Dept. of Environment Affairs

A. ASSESSMENT OF THE VULNERABILITY OF THE UNDERGROUND WATER RESOURCES

The vulnerability of the underground water source is related to the distance that the contaminant must flow to reach the water table, and the ease with which it can flow through the soil and rock layers above the water table. An assessment of the soil and rock types, and the distance to the water table may be obtained from an area hydrogeological report, from a site inspection, and using table 1.

Five broad classes of aquifer vulnerability are defined:

Table A: Vulnerability of Groundwater Aquifer due to Hydrogeological Conditions

Vulnerability Class	Measurements	Definition
Extreme (usually highly fractured rock and/or high ground water table)	High risk (table 1) and short distance (< 2m) to water table	Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface
High (usually gravely or fractured rock, and/or high water table)	High risk (table 1) and medium distance (2-5m) to water table	Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed
Medium (usually fine sand, deep loam soils with semi-solid rock and average water table (>10m)	Low risk (table 1) and medium to long distances to water table	Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants
Low (usually clay or loam soils with semi-solid rock and deep water table (>20m)	Minimal and low risk (table 1), and long to very long distance to water table	Only vulnerable to the most persistent pollutants in the very long term
Negligible (usually dense clay and/or solid impervious rock with deep water table)	Minimal risk (table 1) with confining layers	Confining beds present with no significant infiltration from surface areas above aquifer

B ASSESSMENT OF THE CONTAMINATION LOAD FROM THE PARTICULAR SANITATION SYSTEM AND OTHER SOURCES

The contamination load from a particular sanitation system is related to the design or type of sanitation system, the use of the system, and the ongoing maintenance of the system. This must also be measured in the context of the total contamination load from all sources within the community.

Tables 2 and 3 give a guide for estimating potential for a selected sanitation system or other source of contamination to pollute the groundwater. The result of this part of the assessment can either be simply the level of risk of contamination (minimal, low or high) and any conditions which may increase or decrease the risk, or alternatively a reasonable estimate of the time of flow from the sanitation system to the water table.

C OVERALL RISK

The overall risk of contamination is based on both risk components. Table C provides an overall assessment of the risk based on the aquifer vulnerability and the contamination load from the sanitation system and the other contamination sources. In estimating the overall risk, this should be determined firstly for the selected sanitation system, and then for each of the other significant sources that may be a threat.

Table C: Overall risk of contamination of the groundwater

		Contaminant load risk		
		high	**medium**	**minimal**
Aquifer vulnerability	**Extreme**	very high (obtain alternative water source or ensure treatment)	high (implement remedial measures)	high (implement remedial measures)
	High	high (implement remedial measures)	high (implement remedial measures)	medium (take precautionary measures)
	Medium	high (implement remedial measures)	medium (take precautionary measures)	low (no action required)
	Low	medium (take precautionary measures)	low (no action required)	minimal (no action required)
	Negligible	low (no action required)	minimal (no action required)	minimal (no action required)

D STRATEGIC CLASSIFICATION OF THE GROUNDWATER

The use of the groundwater and the point of abstraction are the final components of the assessment. Should the present and/or potential future strategic value of the groundwater imply that certain types of contamination are unlikely to be a problem, the sanitation system may be acceptable despite it posing a risk as assessed in components A and B above.

The strategic value of the groundwater is a function of the potential yield of the aquifer, the present or probable future use of the groundwater, and the existence of alternative water sources. The following table provides a simplified classification of the strategic value and the impacts of a sanitation system based on the strategic use of the groundwater.

Table D: Strategic Value of Groundwater and Risk of Impact of Contamination

Strategic value			Relevance of threat of contaminants		
Groundwater Use (present or future)	**Potential Yield**	**Comment**	**Bacteria and viruses**	**Nitrates**	**Chlorides**
Domestic use (drinking water)	> 1 Mℓ/d	very important aquifer, should be protected even in remote areas	Medium risk but can be treated	High risk – cannot be easily treated	Minimal risk
	0.1 – 1 Mℓ/d	important aquifer to local communities	High risk – often inadequate treatment	Medium risk – no treatment	Minimal risk
	< 0.1 Mℓ/d	could be important to single community	High risk – often no treatment	Medium risk – no treatment	Minimal risk
Agricultural use (animal drinking water)	> 1 Mℓ/d	very important aquifer, but sanitation contaminants unlikely to pose a threat	Low risk	Minimal risk	Minimal risk
	0.1 – 1 Mℓ/d	important aquifer to local communities	Low risk	Minimal risk	Minimal risk
	< 0.1 Mℓ/d	could be important to single community	Low risk	Minimal risk	Minimal risk
Agricultural (irrigation) or industrial use	> 1 Mℓ/d	very important aquifer, but sanitation contaminants unlikely to pose a threat	Low risk	Minimal risk	Low risk to some crops
	0.1 – 1 Mℓ/d	important aquifer to local communities	Low risk	Minimal risk	Low risk to some crops
	< 0.1 Mℓ/d	could be important to single community	Low risk	Minimal risk	Low risk to some crops

5.2 Assessment of measures to reduce the risks

The options for addressing situations that give rise to unacceptable risk are dependent on the specific situation on-site. These should be negotiated and decided on by the sanitation engineer in consultation with the geohydrologist and the community. Risks can be reduced by taking one or more of the following remedial or precautionary steps:

- move groundwater abstraction point sufficiently far from contamination sources;
- use less polluting sanitation system, e.g. VIP, eco-san, LOFLOS;
- increase the flow-path from the sanitation system to the water table, e.g. raise pit, seal lower part of pit, install fine sand filter;
- treat water abstracted from borehole, e.g. chlorination;
- remove liquid effluents from households close to abstraction points, e.g. pipe to wetland;
- protect water abstraction point, e.g. sanitary seal, casing to abstract from deep levels, pump management to minimise cone of depression.

The following broad options are listed for particular situations:

	Situation or Options	**Responsibility**
Situation:	**Very high overall risk (e.g. shallow water table in highly fractured rock with high loading of contaminants from septic tanks or leaking sewers)**	
Options:	Find alternative source of water Select alternative sanitation system e.g. eco-san (if primary cause of very high risk) Install water treatment (disinfection) system on borehole water	geohydrologist, sanitation engineer
Situation:	**High overall risk (e.g. faults and fractured rock result in rapid flow to groundwater table of all wet or semi-wet on-site sanitation systems)**	
Options:	Increase path length to groundwater table by shallower pits, raised pits or partially sealed pits Adopt eco-san sanitation systems Minimise infrastructure close to faults (pit latrines, cattle kraals, sewer pipes, etc.) Move or install water abstraction points sufficiently far from pollution sources	sanitation engineer
Situation:	**High to medium overall risk (e.g. gravel or coarse sand and wet or semi-wet on-site sanitation systems)**	
Options:	Increase path length to groundwater table by shallower pits, raised pits or partially sealed pits Adopt eco-san sanitation systems Move or install water abstraction points sufficiently far from pollution sources	sanitation engineer and geohydrologist
Situation:	**Medium to low risk (e.g. on-site latrines close to abstraction point but in fine sand, shale or clays)**	
Options:	Case borehole to draw water from deeper levels only Pipe grey-water away from households close to abstraction point Institute ongoing borehole monitoring and sanitary surveillance	sanitation engineer and geohydrologist
Situation:	**Sewers with significant pipe leaks or regular manhole overflows (high risk)**	
Options:	Detect and repair major leaks and employ a higher level of on-going maintenance Convert to small, manageable local treatment systems (e.g. artificial wetlands, mound drainage systems, ponds, or evapotranspiration beds.	sanitation engineer
Situation:	**Existing borehole is contaminated**	
Options:	Install proper sanitary seal and concrete collar Prevent abstraction from higher level aquifers (i.e. case to ensure only withdrawal from deep aquifers) Install water treatment system (e.g. chlorination) Formulate and implement a pump management system to minimise the cone of depression Move borehole so that distance from contamination source is extended Address nearby sources of contamination	geohydrologist and sanitation engineer

5.3 Groundwater monitoring and sanitary surveillance programme

5.3.1 Monitoring the groundwater

Monitoring of both the quality and quantity of groundwater at the point of abstraction forms a very essential basis of sustainable management of the resource. Effective and accurate monitoring requires that boreholes and pump operators should be equipped with the essential monitoring equipment:

Equipment Requirements for Groundwater Monitoring	
A.	**Measurement of quantity pumped and water table levels**
	▪ A water meter installed at the borehole to measure the amount and the rate of abstraction. ▪ Water level monitoring-Piezometer Tube of 25mm or 32mm diameter must be installed in boreholes for measuring water levels ▪ Dip meter for measuring borehole water depth
B.	**Measurement of water quality**
	▪ A sample tap must be supplied close to the borehole to allow direct sampling of water from the borehole ▪ Sterile sample bottles for microbiological analyses ▪ Clean sample bottles for chemical analyses ▪ Basic testing equipment for on-site measurement of temperature, pH, conductivity and active chlorine (if chlorination is practised)

Note that the water quality results should be compared with the minimum standards as set out in the DWAF Water Quality Guidelines to assess the potability of the water. The frequency of sampling or the sampling plan guidelines are outlined in the SABS 241:Edition 5 and Quality of Domestic Water Supplies: Volume 1 1999 and Volume 2, 2000; documents.

Pump operators or whoever is responsible for groundwater monitoring should be issued with the relevant monitoring equipment including a dip meter and a record book (preferably with duplicate copy books so that more than one set of data is available). One set of the records should be kept at the borehole with the pump operator whereas the other set can be supplied to the responsible authority for the management of the water resource.

It is also important that people who are responsible for this exercise should be properly trained for this responsibility and be regularly evaluated to ensure a good quality data is collected.

5.3.2 Sanitary surveillance by community

A sanitary surveillance programme should be initiated in all communities, but particularly in those embarking on new sanitation projects or where there is a high risk of contamination of the ground and surface water resources. The main components of a community sanitary surveillance programme are proposed as in the table below.

Suggested Components of Community Sanitary Surveillance Programme	
C.	**Monitoring of community health**
	▪ Recording of sanitation related illnesses reported at the clinic ▪ Assessment of the level of flies, mosquitoes and other insect vectors
D.	**Monitoring of the state of latrines and other waste disposal**
	▪ Periodic survey of the state of latrines at households and institutions ▪ Periodic survey of the practices of solid waste and grey water disposal ▪ Periodic survey of areas at and around boreholes and springs
E.	**Monitoring of water collection and storage**
	▪ Periodic survey of water collection practices and related hygienic storage of water in the home ▪ Periodic assessment of the state of the water supply infrastructure

Suggested Components of Community Sanitary Surveillance Programme	
F.	**Monitoring of the disposal of sewage (where applicable)**
	▪ Periodic assessment of sewer pipes and sewage treatment facilities ▪ Periodic assessment of latrine pits and the existence of water in the pits ▪ Periodic assessment of on-site septic tanks, digesters, and soak-aways

5.4 Reporting of investigation and decision making process

No specific report format is provided at this stage as experience with version 1 is that each agency compiles a report according to their own preferred format. However the essential assessment process should be described, with the layout plan of the community with sensitive areas highlighted. The task lists in section 4 should each be reported on, and the risk assessment process must be fully described and the recommendations clearly listed.

Copies of the report must be forwarded to the Geohydrology Division of DWAF provincial office, as well as to the Provincial Department of Environment Affairs.

5.5 Conclusions

This revised version of the groundwater protocol has been commissioned by the Department of Water Affairs and Forestry to address issues from the use of the first edition as outlines in 1.2 and appendix A. The overall aim has been to maintain a simple procedure, but based on more understandable conceptual procedures so that local practitioners can address situations not clearly spelt out in the document. However a non-geohydrologist should be able to use the outlined steps and tables to make a reasonable assessment of the risk of contamination of the groundwater, and take appropriate decisions where the risk of contamination is unacceptable.

This protocol should not be used to discount on-site sanitation systems in favour of waterborne systems without a full assessment of all implications of the selection.

Comments and suggestions for the modification and improvement of the protocol would be most welcome and should be forwarded to the Chief Director, Geohydrology, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001.

APPENDICES

Appendix A: Comments from review of the use of the 1st version of the GW Protocol

Some of the requirements of a protocol that the users reported were not adequately considered adequately covered in the first edition are:

Overall comments:
- Need references to other documents where necessary
- There is a need for a more “scientific input” in the GW Protocol
- There is a need for management guidelines in the GW Protocol, particularly related to the long term monitoring
- The terminology of the report is too technical. A more layman’s language report should be produced that can also be given to the community.

Assessment of groundwater potential and evaluation of use:
- Table 1 needs revision to deal with fine-grained sands.
- The aquifer classification system may be misleading
- Options for ranking aquifers should include reference to number of people it can serve, capacity of the aquifer, and alternative sources of water
- Information on most existing boreholes is lacking
- There is no clear understanding or link between an EIA and the GW Protocol

Assessment of flag situations:
- The labelling of “flag situations” tends to slow down the process, especially where the project agent is competent
- The 3m flag distance to the water table is conservative
- The 50m radius around boreholes is conservative – 30m is acceptable

Evaluation of pollution risk
- Need to look in more detail at pollution from existing latrines and other sources.
- It is not always practical to estimate the depth of the unsaturated zone
- Surface contamination is often a significant cause of GW contamination
- Flow in the saturated/submerged layers should still be considered in terms of attenuation of contaminants

Other
- The strategic value of GW as a back-up must always be considered
- The categories in table 1 should lead to procedures of what to do
- Consideration should be given to commissioning “after implementation” studies to check what level of contamination is actually occurring
- Sealing the pit is not a practical option to prevent contamination from pit latrines

In addition it was recommended that the following issues should be included:

Overall recommendations
- Rather carry out regional/area assessments in detail using geohydrologists, then less detailed on-site assessments by sanitation technical personnel.
- Need to use risk assessment approach – lead to lowest pollution risk option.
- The GW protocol needs to be directly linked to the sanitation programme, rather than as a separate study (incorporated as part of a “guidelines for sanitation projects”)
- The protocol should indicate why it is needed and where it leads to

Recommendations on options for reducing risks

- There is a need for options for different groundwater situations
- Need stronger emphasis on steps to protect existing boreholes
- The GW Protocol could show typical construction details for the different options
- More pit-lining options should be described

Recommendations on options for community involvement

- A community member (e.g. Quality Controller) should be trained in the GW Protocol
- Community should be informed and helped to understand recommendations
- The assessment and implementation of the recommendations should form part of the H&H programme at community level
- Basic posters showing the importance of GW protection would be useful

Recommendations on options for ongoing monitoring

- Procedures for taking borehole samples should be described
- More information on the dynamics of bacterial migration in soil should be given

Recommendations on the tools and format

- A "quick check list" is needed for municipalities
- The protocol should be simple, not require too much time, and not be too costly
- A generic ToR to carry out the Protocol assessment would be useful
- Illustrative diagrams or photos on options would be useful
- Procedures for addressing existing settlements are required.

Appendix B: Groundwater flow and aquifer recharge

Groundwater like surface water is always in continuous flow, though the rates of flow are magnitudes less than the flow rates of surface water. In most cases gravity processes drive groundwater flow. Like surface water groundwater tends to flow from high lying areas to low lying areas. The rate of movement of groundwater from recharge areas to discharge areas depends on the hydraulic activities and of aquifers and confining beds. The time ranges form a few days in areas adjacent to discharge area to thousands of years for water that moves from the central part of some recharge area through the deeper parts of the groundwater system. Once water has percolated through the soil and entered the groundwater regime, it can flow in the subsurface regime for variable periods of time, depending on the existing conditions. Recharge occurs during and immediately after precipitation. Water generally enters groundwater systems in recharge areas and moves through them. Generally recharge areas are high lying, in mountainous terrain and consist of highly permeable rocks and soils to allow easy percolation of water into the soil.

Generally there is a very small percentage of the rainwater which enters the groundwater regime as a recharge. This percentage will vary from area to area and it is largely dependent on the existing geology. Highly permeable surface rocks allow for a higher recharge rate, where impermeable rocks or soils with low porosity allow for a very limited recharge. Recharge also varies form year to year depending on the annual rainfall fluctuations.

There is a continuous interaction of groundwater and surface water regimes. In times of drought groundwater can supply the surface water as basal flows and the reverse situation can also occur. Generally groundwater tends to flow at right angles to the surface waters. Natural discharge of groundwater also occurs at springs and wetlands

Appendix C: Literature

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