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A Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa

Volume 2

Process and Related Activities

Final

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1 DESCRIPTION OF THE DOLOMITIC RESOURCE IN SOUTH AFRICA

Karst aquifers, specifically in dolomite rock, represent South Africa's single largest and most important aquifer type *(an explanation of "karst" is given in Section 1.4).* Dolomite aquifers store large volumes of water, support numerous springs and provide abundant resources for abstraction for urban and rural water use, agriculture and irrigation, industry and mining.

Karst aquifers in limestone occur near Oudtshoorn in the Western Cape Province. These aquifers are included in this Guideline, since processes forming karst aquifers in limestone and dolomite may be considered identical.

The National Water Act (Act 36 of 1998) defines an aquifer as "a geological formation which has structures or textures that hold water or permit appreciable water movement through them". Fetter (1980) describes an aquifer as "a geological unit that can store and transmit water to a borehole at rates fast enough to use reasonable quantities".

1.1 The origin of dolomite and stratigraphy

1.1.1 Background

The dolomite or limestone host rock is described and discussed in terms of its origin, extent and intrinsic properties. This is important background information in support of the description of the karst aquifer water resource and its capabilities.

The term dolomite, as a rock type, is usually confined to carbonate rocks with more than 15 % magnesium carbonate and usually originates from calcite limestone ($CaCO_3$). The calcite limestone is dolomitised, the term used to describe the process by which the original calcium carbonate is converted into double calcium magnesium carbonate ($CaMg(CO_3)_2$), wholly or in part (Whitten and Brooks, 1972).

Limestone formation is essentially a result of the accumulation of plant and animal skeletal material and/or the precipitation of $CaCO_3$ from sea water in shallow marine environments. Environments conducive to the formation of limestone existed along the margins of a vast inland sea, 2 300 Ma ago on the Kaapvaal Craton, which is now Southern Africa.

Table 1 summarises the dolomitic succession of sediments of the Cape and Transvaal Supergroups, from youngest to oldest, as a function of the thicknesses and distribution of chert within the dolomite.

Table 1: Description of the dolomite formations

The Kango Formation

Supergroup	Group	Member	Formation	Thickness (m)	Description
Cape	Kango		Groenefontein (Ng)	2400	Grit, arenite subordinate limestone lens,
		Kombuis	Matjies River (Nm)	1300	Limestone, dolomite, subordinate shale and sandstone
		Nooitgedacht		1000	Limestone, subordinate shale and sandstone

The Malmani dolomite

Supergroup	Group	Subgroup	Formation	Thickness (m)	Description
Transvaal	Chunniespoort	Malmani	Eccles (Vme)	~ 380	Chert-rich, dark coloured dolomite with stromatolites and oolitic bands. Chert content increases to top
			Lyttelton (Vml)	~150	Chert-free, dark-coloured dolomite with large stromatolitic mounds
			Upper Monte Christo (Vmm)	~258	Chert-rich dolomite
			Middle Monte Christo (Vmm)	~162	Chert-poor dolomite
			Lower Monte Christo (Vmm)	~275	Chert-rich dolomite
			Oaktree (Vmo)	~200	Chert-poor dolomite with interlayered carbon-rich shale towards the base
			Black Reef (Vbr)	~30	Basal conglomerate and quartzite with interlayered carbon rich shale

The Ghaap Plateau dolomite

Supergroup	Group	Subgroup	Formation	Thickness (m)	Description
Griqualand West	Campbell Rand	Ghaap plateau	(Vgd)		Coarse recrystallised dolomite with interbedded chert, prominent chert at base
			(Vgd)		Dolomite, limestone and chert with interbedded shale
		Schmidtsdrif	Monteville (Vsm)		Dolomite, stromalitic limestone interbedded with shale
			Clearwater (Vsc)		Shale and siltstone with interbedded dolomite
			Boomplaas (Vsb)		Oolitic stromatolitic dolomite with interbedded quartz, shale and flagstone

1.2 What constitutes a dolomite aquifer?

1.2.1 General

The importance of karst hydrology should not be understated, as it is estimated that approximately 20 percent of the earth's land surface qualifies as karst. A karst terrain is differentiated from other terrains by the presence of distinct solution features such as caves, conduits, dolines, sinkholes, intermittent and permanent springs and dry valleys. These terrains are composed of limestone, dolomite, gypsum, halite and other soluble rocks (Cawley, 1990).

Although dolomite has a relatively low primary permeability, the development of karstic features due to preferential dissolution of the carbonate rock along discontinuities, faults and fractures resulting from tectonic processes and chert-rich horizons, has served to develop a secondary permeability in the rock mass, particularly in chert-rich units such as the Monte Christo and Eccles Formations.

As dolomite and limestone are fairly soluble, solution activity plays an important role in eroding dolomite and limestone terrains. Rainwater dissolves atmospheric carbon dioxide to form a weak acid, carbonic acid. This weak acid percolates through the fractures and bedding planes and dissolves the dolomite or limestone on its way through. The general direction of seepage is downward towards the water table where it then follows the topography towards natural outlets such as river systems, continuing to dissolve the dolomite/limestone as it moves. In time, fractures are widened and subterranean channels may be developed (Hamblin, 1985).

Large horizontal caverns are formed in the rock by solution activity, particularly near deeply weathered vertical fractures, which provide relatively easy passage for carbonic acid charged rainwater. The formation of these caverns is more pronounced immediately below the phreatic surface, where the water is more acidic than at depth. The historic and present fluctuations of the water table are often responsible for the development of extensive networks of caverns within the dolomite, with a large storage capacity where these networks are present.

The weathered and fractured rock matrix, chert-rich horizons and network of cavities generated by both historic and present water table fluctuations all constitute the dolomitic karst aquifer. The dolomite rock itself is impermeable. The storage and movement of water through the dolomite aquifer is thus controlled by the presence of the weathered and fractured zones, the presence of chert beds and the presence of solution channels and cavities.

The presence of abundant intraformational chert, which is far more resistant to weathering than the dolomite, lends itself to the formation of an effective skeletal support structure for subterranean caverns within and below weathered dolomitic residuum.

Figure 1 illustrates a schematic cross-section through a dolomite aquifer in a pristine state with very low level of use.

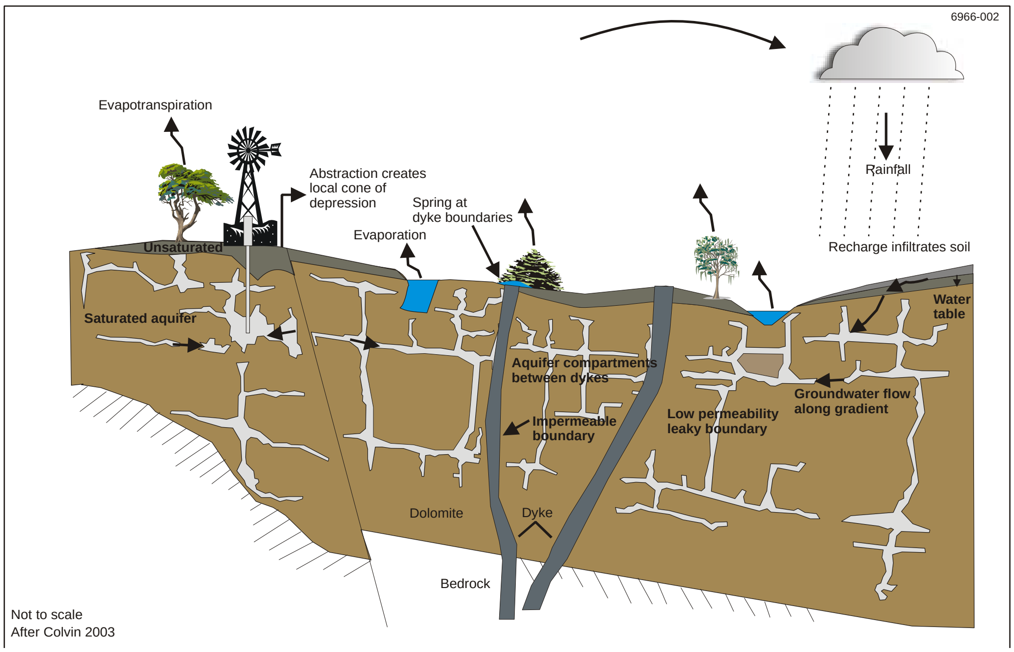

Figure 1: Schematic cross section through a typical dolomite aquifer

1.2.2 Geomorphology

The distribution and geological setting of dolomite on surface across South Africa is a result of pre, syn and post Transvaal tectonic, sedimentary and surface processes. Dolomite rock occurs at depth over a far wider area than can be appreciated from its surface distribution. It is covered by younger rock ranging in age from more than 2 billion years to several hundred million years. Ongoing geomorphological processes have stripped overlying sediments to varying degrees, exposing but sometimes re-covering the dolomite. Palæokarst surfaces of varying ages are widespread along the upper contacts of the Malmani underlying both Pretoria Group sediments and Karoo age deposits.

Dolomitic aquifer development is initiated by the creation of preferred pathways for rainwater to infiltrate and create solution cavities. Compartmentalisation of the dolomite is the result of magma injection into tensional fault zones associated or closely following such periodic tectonic events

Aquifer development on exposed dolomite is further strongly affected by factors such as rainfall, runoff, geological setting and topography. Generally the higher the rainfall the faster the rate of dissolution. Topography plays an important role in the development of an overlying weathering residuum and associated aquifers. Along the steep, high rainfall environment of the eastern escarpment, little to no dolomite weathering residuum is present. Although rainfall is lower, and steadily decreases towards the west, the dolomite surrounding the Johannesburg granite dome and stretching westwards forms generally flat relief and is exposed over far greater areas than along the eastern escarpment. These plateaux are ancient erosion surfaces and hence the dolomite bedrock has been exposed and subjected to weathering and dissolution processes over millions of years. Important aquifers are associated with these dolomites.

To the west and southwest between Johannnesburg, Klerksdorp and Lichtenburg, the dolomite forms a plateau with minor relief. The plateau decreases in elevation from about 1600 mamsl west of Johannesburg to approximately 1300 mamsl towards Mafikeng. A thick karstic weathering profile is present over most of the dolomite, typically consisting of dolomite pinnacles and solution channels filled with dolomitic residuum referred to as wad (Weathered and Altered Dolomite), and cavities. The dolomite landscape to the west of Johannesburg is further characterised by a low density of surface water channels as a result of the relatively high infiltration rates and low topographic relief. The dolomite forms a major east west watershed and springs tend to form around the outcrop boundary due to the change in topography.

The extensive outcrop of dolomite in the Northern Cape forms the Ghaap Plateau with an elevation varying from approximately 1250mamsl in the north-east to approximately 1100 mamsl in the north-western portion of the plateau near Kuruman and 1000 mamsl near Griekwastad in the south-west. Although the area is characterised by semi arid conditions and an absence of drainage over most of the outcrop a deep karstic weathering profile is frequently developed and important aquifers are present. Springs occur at changes in slope towards the edge of the plateau.

1.2.3 Compartmentalisation

Many dolomite areas are intruded by dolerite dykes, and this barrier or damming effect often divides the dolomite aquifer into separate compartments. Depending on the effectiveness of the barrier, these compartments can fill with groundwater and movement from one compartment to another will occur through near-surface flow in the upper few metres of weathered dolerite, or by spring flow at the lowest elevation. Water levels can vary by tens of metres across compartmentalised dykes.

A compartment within the dolomite is shown schematically in **Figure 1**.

Compartmentalisation can also occur by contact with other rock types, especially where the contact is faulted. Severe faulting within the dolomite can also cause a barrier effect where, for example, a chert-poor and chert-rich lithology are brought into contact with each other, or where a fault has become filled with cementing material and the permeability is reduced or lost completely.

1.3 Resource capability

Water shortages have become a reality in recent years and, with the increased demand for clean natural water resources, dolomite aquifers are now considered an important source of water. Karst terrains are renowned for their water resource potential. However, the vulnerability of karst water resources to contamination from point and non-point sources has led to a greater incidence of contamination of these resources. Karst aquifers are extremely vulnerable to contamination due to the ease with which contaminants can infiltrate relatively unfiltered into the aquifer system, and once there, are transmitted rapidly along the main conduits (Cawley,1990).

The resource capability of the dolomitic aquifers is a function of various interrelated aspects, including lithology, secondary porosity (both fractures and dissolution channels), degree of chert formation, structure, intrusions, the degree of karst formation, etc. The cross-section provided in **Figure 1** illustrates the occurrence of fissures and cavities in a typical dolomite aquifer. These features give rise to very high permeability, thus allowing swift flow of water. They also provide significant storage capacity within the dolomite aquifer. Some estimates suggest that total storage within the dolomite aquifer in South Africa amounts to 5 000 million m^3 (Colvin, 2003).

The highly transmissive properties of the dolomite aquifer, provided by the karst development, fissures and solution cavities, allow very high yields to be obtained from boreholes in many localities. Many users view this as being indicative of virtually unlimited groundwater resources within the dolomite aquifer, often accompanied by little regard for long-term sustainable use. The fissures and solution cavities giving rise to the favourable transmissivity may be relatively narrow features, and thus small declines in water levels caused by over-pumping and/or a decline in recharge can result in a sudden fall in water levels, aquifer dewatering and, ultimately, failure of the borehole as the storage of the aquifer becomes exhausted. This characteristic of dolomite dictates the need for proactive management to ensure not only long-term sustainability of the aquifer but also the prevention of sinkholes.

Dolomite aquifers are especially vulnerable to pollution, and management interventions are therefore essential. The often high permeability of the dolomite means that groundwater flow is rapid. The implication for pollution of the groundwater resources is that contamination can move rapidly through the aquifer and pollution plumes can develop over wide areas. Dolomite rock has little capacity to attenuate pollution. Contamination will, however, tend to be diluted by the large volumes of groundwater in storage.

Figure 2 illustrates the effect of over-pumping on the water levels of a typical dolomite aquifer compartment. It can be seen that excessive abstraction has caused water levels to fall so low that the water use has failed. **Figure 2** further illustrates the development of subsidence and the formation of a sinkhole caused by the decline in water levels and the absence of any management intervention.

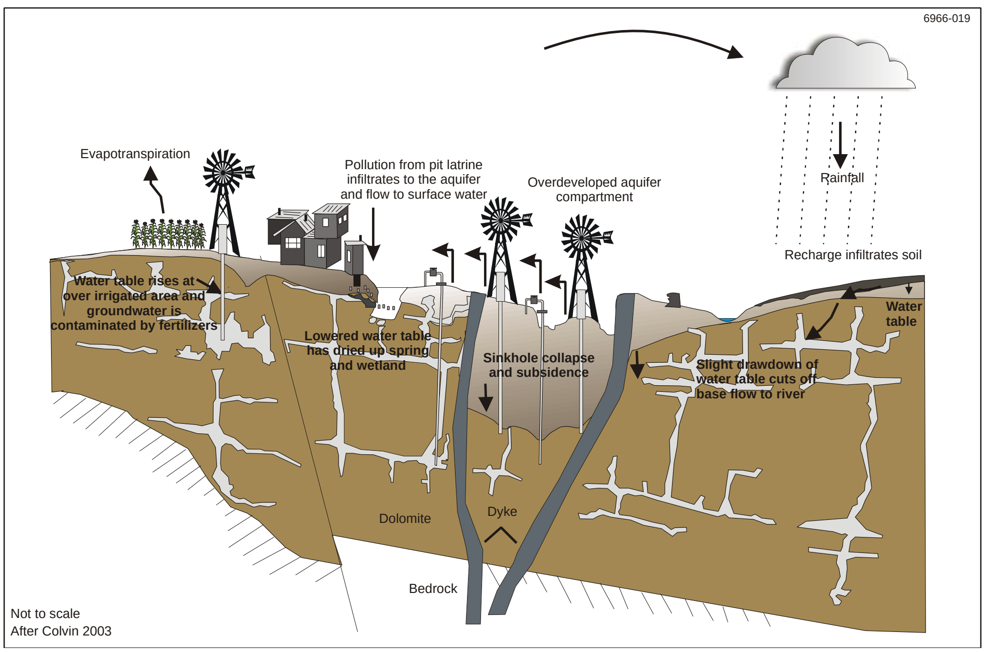

Figure 2: Schematic cross-section showing the effect of over-exploitation of a dolomite aquifer compartment

1.4 How dolomitic groundwater resources are replenished (recharge)

Recharge is the volume of water that reaches the saturated zone of the dolomite aquifer. It is that portion of rainfall that infiltrates through the soil horizon and contributes to the volume of water stored in the aquifer.

Recharge is usually expressed as a percentage of rainfall and varies considerably from year to year, depending upon the amount of rainfall. The volume of recharge depends upon numerous factors, including geomorphology, karstic features, rainfall distribution and rainfall intensity. In dolomite areas, recharge can vary from zero percent of rainfall during periods of below-average rainfall to more than 50 percent during periods of exceptional rainfall (Bredenkamp *et al*, 1995). This wide range in recharge is unusual and is due to the high permeability of dolomite as compared with other rock types, resulting from karst features, extensive dolomite pavements and thin soil cover.

Sustainable abstraction of the groundwater resources of a dolomite aquifer depends upon the balance between recharge and discharge, including natural outflow from springs and abstraction from boreholes. Water levels in the aquifer will start to fall when abstraction exceeds recharge, resulting in undesirable consequences such as springs drying up and borehole yields declining. Recharge is thus a key factor in understanding and quantifying groundwater resources. Unfortunately, recharge is difficult to quantify as it varies both in time and space and can change in response to groundwater abstraction (Parsons, 2004).

1.5 Water Levels

Water levels in dolomite aquifers are controlled by the topography, permeability and transmissivity of the aquifer, compartmentalisation, positions of springs and drainage lines, abstraction / impacts and volume of recharge.

Due to the high permeability of the karst features, water level gradients tend to be flatter in dolomite aquifers than in aquifers in other rock types.

1.6 Groundwater Quality

Knowledge of the quality of dolomite groundwater is important to:

- Confirm the background or natural status of the groundwater in the aquifer
- Confirm its suitability for intended use, potability, irrigation, stock watering and specialised industrial applications
- Identify areas where groundwater quality has been impacted by human activities, such as urban or rural development, irrigation, feed lots, mining and industrial activities, and
- Setting of resource quality objectives for the aquifer, spring flow and wetlands.

Groundwater in dolomite aquifers is generally characterised by the major dissolved elements, Ca^{2+}, Mg^{2+} and HCO_3^-, where half the HCO_3^- is balanced by Ca^{2+} and half by Mg^{2+}, and ultimately coming into equilibrium with calcite and dolomite. In practice, the establishment of equilibrium with dolomite is slow because such waters usually contain more calcium than magnesium. Over periods of thousands of years, however, the magnesium:calcium ratio of the water rises to the "equilibrium" value (Drever, 1988). Dolomite groundwater is characterised by a consistent composition, due to the consistent composition of the dolomite forming the aquifer across the country and the small amounts of soluble salt, which can be leached out of the rock in addition to $CaCO_3$ and $MgCO_3$.

Bond (1946) undertook a geochemical survey of underground water supplies in South Africa. This reference provides a good basis to establish a baseline of uncontaminated water qualities for many areas of the country. These have, of course, been exposed to contamination of one form or another since the survey. Bond took 22 samples of dolomite water across a wide area of the former Transvaal Province and Northern Cape Province. Except in the more arid regions of the Northern Cape, he found that the concentration of dissolved solids was very consistent, being approximately 200 and 300 ppm and rising to 750 ppm in the more arid regions.

Bond (1946) also found that dolomite water had a consistent pH value close to 7.8. He further found that an average of 87 percent of dissolved salts consisted of calcium and magnesium bicarbonates. Sulphate (SO_4), mainly in the form of $CaSO_4$, was found to be generally present but in very low quantities, averaging 1.6 percent SO_4 in terms of total solids. Fluoride was virtually absent, with only occasional traces being observed. Chloride was consistently low, averaging only 4.9 % of the total solids.

Dolomite is characterised by the development of wad, mostly in chert rich horizons, a manganese residuum formed by weathering and dissolution of the dolomite. This can give rise to elevated manganese in the dolomitic groundwater.

NOTE:

Water quality standards can be found in: Quality of Domestic Water Supplies, Volume 1. WRC Report No. TT 101/98

NOTE:

South African Bureau of Standards Specification for Drinking Water, SABS 241, and in Volume 1: Assessment Guide of the Quality of Domestic Water Supplies, prepared by DWAF, 1999.

1.7 Surface water – groundwater Interaction

Understanding the interaction between surface and groundwater in dolomite terrain is required to facilitate appropriate decision-making and resource management. Parsons (2004) states that tools to identify and quantify the contribution of groundwater to river flow and wetlands are lacking, and that, historically, surface and groundwater were isolated in policy and regulation. This resulted in surface and groundwater practitioners working in isolation and seldom appreciating the interconnectivity between the two. Similarly, surface and groundwater resources were managed separately. However, current legislation requires water resources to be managed in a holistic and integrated fashion (Parsons, 2004). This remains hampered by the low level of understanding the interaction between the dolomite and surface water resources.

Surface water – groundwater interactions in dolomitic terrain are expressed by springs, wetlands, base flow and recharge from surface flow. Their functionality and role must therefore form part of assessing dolomitic groundwater resources.

1.7.1 Springs

Springs are common in dolomite, especially around the periphery of the outcrop and along dykes. Springs represent the surface expression of the water table and thus form the discharge point for the dolomitic groundwater.

Spring flow forms the source for surface drainage in dolomitic terrain, which being typically highly permeable, has relatively few surface water channels. Wetlands often form around areas where the water surface. Spring flow also represents a valuable resource that can be captured and used for small-scale to bulk water supplies (e.g. Grootfontein and Molopo springs are captured and supply Mafikeng with some 10Mm^3/a) or irrigation use (Schoonspruit Eye).

Dolomitic spring flows vary from seepage to very substantial. For example, the Kuruman spring flows at approximately 235l/s with little seasonal variation, while Dinokana spring, west of Zeerust, flows at approximately 150l/s, varies considerably throughout the year and is impacted by abstraction. The Gerhard Minnebron spring west of Carletonville has a flow of approximately 600l/s and represents one of the largest spring flow in South Africa.

Springs arising in dolomitic terrain can be considered as an optional source of water to be developed. Depending upon their yield and reliability, they can be used either in conjunction with abstraction boreholes or as stand-alone sources. Springs are, however, vulnerable to significant variations in flow, with the low-flowing springs often drying up completely in periods of drought.

1.7.2 Wetlands

The NWA describes wetlands as transitory between terrestrial and aquatic ecosystems where the water table is usually at or near the surface, or the land is periodically covered with shallow water. In normal circumstances, such land supports vegetation typically adapted to life in the underlying saturated soil.

The ecological value of wetlands is widely recognised. Wetlands assist in attenuating floods, improve water quality, reduce river sediment loads and provide a habitat for fish and wildlife. Wetlands in dolomitic terrain are sustained by seepage of groundwater or spring flow or where the water table and a drainage channel coincide. The functionality and dependence of wetlands on dolomitic groundwater need to be understood in order to manage and conserve these components of the hydrogeological cycle (Parsons, 2004).

Dolomitic wetlands often form extensive and high-grade peat marshes, due to the low sediment inflow. They are generally classified as palustrine, groundwater-fed wetlands associated with springs.

1.7.3 Groundwater Base flow

Groundwater base flow represents the groundwater contribution to river flow and is mostly evident during periods of low flow in the river, periods of below average rainfall, during the winter months in summer rainfall areas and during periods of drought.

The dolomite aquifer contributes substantially to groundwater base flow, where there is direct hydraulic connection with the river and where dolomite springs comprise the source of numerous streams.

1.7.4 The ecological importance of surface water - groundwater interaction

In addition to providing contributions to river flow, springs play a critical role in providing fauna and flora with a source of water. Unique ecosystems develop around springs in response to the permanency of water (Parsons, 2004).

To understand what restrictions should be placed on allocable dolomitic groundwater, the nature, extent and degree of dependence of vegetation communities on dolomitic aquifers must be understood (Colvin et al, 2003).

The generic approach to establishing Resource Directed Measures (RDM) is valid for all elements of the water cycle. Some aspects, however, are more difficult to apply to dolomite groundwater and need careful consideration. The Reserve required by aquatic ecosystems in terms of quality and quantity is currently only considered in terms of surface water resources. The role of groundwater, including dolomitic groundwater, in supporting important terrestrial ecosystems in the extensive semi-arid parts of South Africa is not accommodated in the Reserve (Colvin *et al*, 2003).

1.8 Dolomite Resource Quality

As discussed in the preceding sections, the dolomite aquifer represents an important water resource which is particularly vulnerable, when compared with other rock types, to adverse impacts from development and poor management. The integrity of the dolomite aquifer must be maintained and protective measures applied to ensure sustainability, both in terms of quantity and quality. It is important therefore to establish a set of Resource Quality Objectives (RQOs) for the dolomite aquifer against which impacts can be judged and interventions and mitigation applied if necessary.

The protective measures to be considered are described in the following sections.

1.8.1 Risk Assessment

A risk assessment of likely impacts of any proposed development will form part of the planning process. The risk assessment will cover such items as:

- Ground stability: the likelihood of the formation of sinkholes and dolines. An example of a risk assessment in relation to sinkhole formation is given in **Table 3**
- Effect on the sustainability of the available dolomite aquifer groundwater resource
- Impact on groundwater quality, and
- Impact on spring flow, wetlands and dependent ecology.

A discussion of the Minimum Requirements and Mandatory Precautionary Measures in areas underlain by dolomites is included in **Appendix A** of this volume. This appendix has been prepared from the Journal of the South African Institution of Civil Engineering, (43) 2 2001.

With regard to Resource Management Decisions in groundwater the SAGDT (South African Groundwater Decision Tool) has recently been developed and uses the principles of Fuzzy Logic risk to define sustainability, impact on groundwater quality and surface water - groundwater interaction. This tool is supported by the Dir: WRPS at DWAF and can be obtained free of charge from the User Support System. Web address: www.usersupport.co.za

NOTE:

Further information concerning risk assessment in dolomite can be found in Tolmachev, V, (2005), Buttrick, D B et al, (2001) and Buttrick D B and van Schalkwyk, A, (1995)

The Department of Public Works (DPW) supports the use of the guideline document PW 344 for risk assessments in land use developments.

1.8.2 Hazard and vulnerability mapping

The preparation of hazard and vulnerability maps forms an important part of the assessment process described in **Section 5** of this Volume. Hazard and vulnerability mapping covers two aspects, namely ground stability and pollution risk.

Ground stability mapping forms part of the risk assessment process of **Section 1.8.1** above. Areas identified as being particularly at risk from the formation of sinkholes should be excluded from any land use such as buildings and waste disposal. It may also be necessary to exclude such areas from groundwater abstraction, or stringent controls imposed to minimise water level drawdown, even though these areas often constitute the most promising in terms of aquifer development.

Pollution vulnerability mapping will take into account such aspects as topography and slope, thickness of soil cover, depth to water table, permeability and/or transmissivity of the dolomite aquifer and existing groundwater quality. The degree of vulnerability of the dolomite aquifer will depend to a large extent on the intended land use.

These maps contribute essential input to the assessment and planning processes. GIS data bases can be helpful in preparing these maps.

Table 2: Inherent risk of doline and a specified-size sinkhole forming (Hazard)

Inherent Risk Class	Small sinkhole	Medium sinkhole	Large sinkhole	Very large sinkhole	Risk of doline formation	Recommended type of development in order to maintain acceptable development
Sinkhole diameter	<2m	2-5 m	5-15	>15 m		
Class 1	Low	Low	Low	Low	Low #NDS or DS	Residential, light industrial and commercial development, provided that appropriate water precautionary measures are applied. Other factors affecting economic viability such as excavatability, problem soils etc, must be evaluated.
Class 2	Medium	Low	Low	Low	Medium #NDS or DS	Residential development with remedial water precautionary measures. No site and service schemes. May consider for commercial or light industrial development.
Class 3	Medium	Medium	Low	Low	Medium #NDS	Selected residential development with exceptionally stringent precautionary measures and design criteria. No site and service schemes. May consider for commercial or light (dry) industrial development with appropriate precautionary measures.
Class 4	Medium	Medium	Medium	Low	Medium #NDS	Selected residential development with exceptionally stringent precautionary measures and design criteria. No site and services schemes. May utilise for commercial or light (dry) industrial development with appropriate stringent precautionary measures.
Class 5	High	Low	Low	Low	High #NDS	These areas are usually not recommended for residential development but under certain circumstances, selected residential development (including lower–density residential development, multi-storied complexes, etc) may be considered. May utilise for commercial and light industrial development. The risk of sinkhole and doline formation is considered to be such that precautionary measures, in addition to those pertaining to the prevention of concentrated ingress of water into the ground, are required in order to permit the construction of housing units.
Class 6	High	High	Low	Low	High #NDS	These areas are usually not recommended for residential development but under certain circumstances, high-rise structures or gentleman's estates (stands 4 000m² with 500m² proven suitable for placing a house) may be considered. May utilise for commercial or light industrial development. Expensive foundation designs may be necessary. Sealing of surfaces, earth mattress, water in sleeves or in ducts, etc.
Class 7	High	High	High	Low	High #NDS	No residential development. Special types of commercial or light industrial (dry) development only (e.g. bus or trucking depots, coal yards, parking areas). All surfaces sealed. Suitable for parkland.
Class 8	High	High	High	High	Low-High *NDS or DS	No development, nature reserves or parkland.

1.8.3 Protection Zones

On the basis of the vulnerability and hazard mapping undertaken, and in order to manage effectively any identified recharge areas and potential source of significant pollution that may be present or may occur in time (e.g. from waste disposal site, tailings dam, cattle feed lots), it may be necessary to establish protection zones in aquifer systems and potential impacts.

Protection zones are likely to be required around public water supply boreholes, recharge areas and within a spring capture zone. The spatial extent of the zone will depend upon the status of the resource and intended use of the borehole or spring. For example, under similar topographic and permeability circumstances, the protection zone around a bulk abstraction well-field or spring will be larger than that around a single borehole supplying a limited yield.

GIS databases can be helpful in delineating these zones.

> **NOTE*:***
>
> Further information concerning the delineation of protection zones is available in *Guideline for Groundwater Protection for the Community Water Supply and Sanitation*, *1st Edition 1995*, ISBN: 0621167878, Yongxin and Braune, 2001

1.8.4 Monitoring

Long-term quantity and quality monitoring is essential to ensure sustainability and to provide management interventions as necessary. Management and monitoring is discussed in detail in **Section 8** of this volume.

1.9 Distribution of Dolomite Aquifers in South Africa

Figure 3 illustrates the distribution of the dolomite outcrop across South Africa. Also indicated on this map are the limestone of the Southern Cape and the nineteen Water Management Areas (WMA) of the country. **Table 3** provides a summary of the WMAs in which dolomite aquifers occur. In some instances, dolomite aquifers stretch across provincial and WMA boundaries. The dolomite resources in each of these WMAs are described in the following sections.

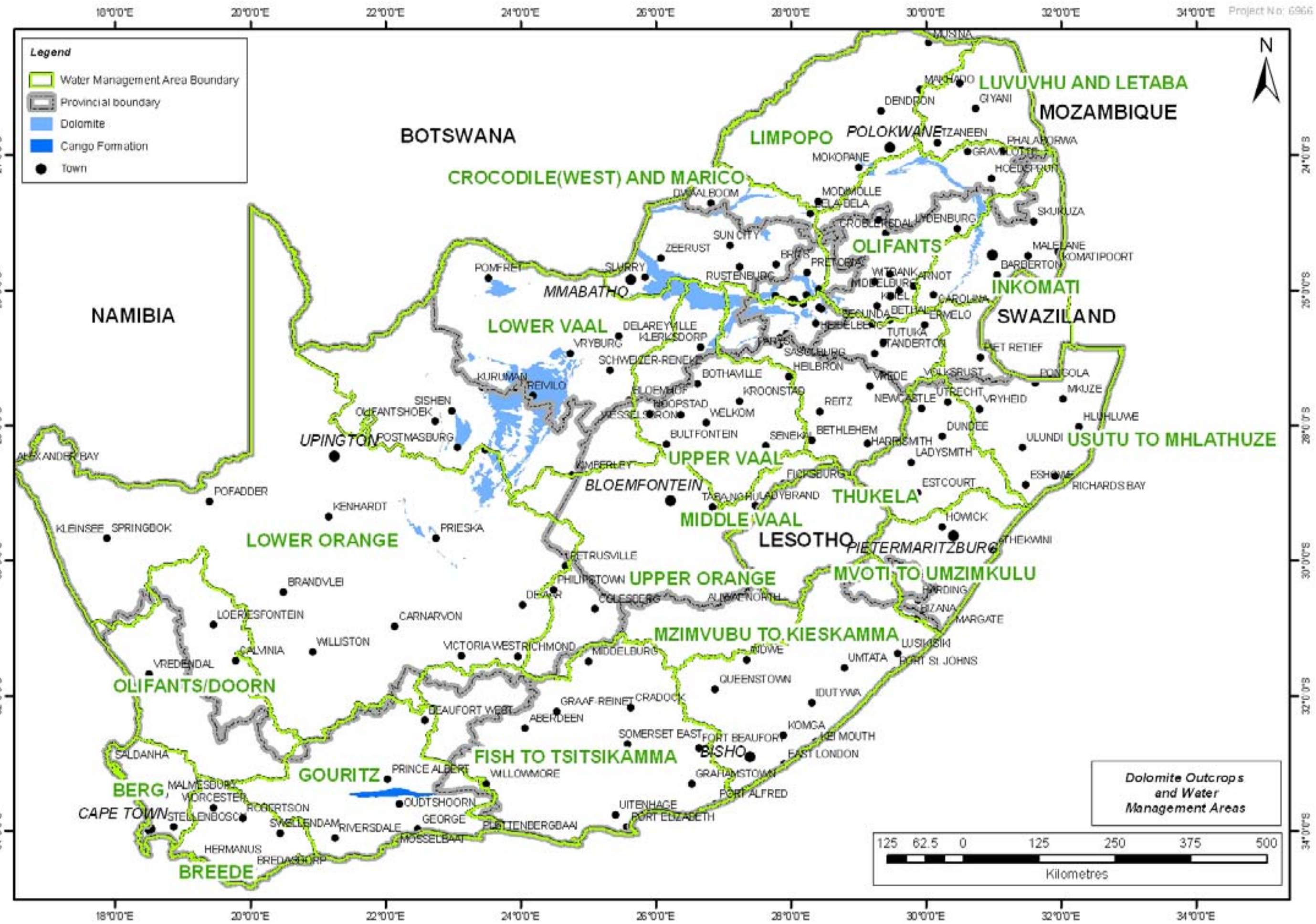

Figure 3: Extent of the dolomite outcrop across South Africa

Table 3: Summary of the WMAs in which dolomite aquifers occur

WMA No.	WMA	Province	Responsible Regional Office(s)
3	Crocodile (West) and Marico	North West and Limpopo	Hartbeespoort Dam Mmabatho
4	Olifants	Limpopo and Mpumalanga	Polokwane
5	Inkomati	Mpumalanga	Nelspruit
8	Upper Vaal	Gauteng, Free State, Mpumalanga and North West	Pretoria
9	Middle Vaal	Free State and North West	Bloemfontein
10	Lower Vaal	Northern Cape and North West	Kimberley & Mmabatho (delegated the NW dolomites in the NW Province to NW RO)
14	Lower Orange	Northern Cape	Kimberley
16	Gouritz	Western Cape	Durbanville

NOTE:

Most of the information given in the following sections describing the various WMAs has been sourced from the relevant ISP documents listed in **Section 8** from which additional information such as rivers, sub-areas, place names, etc. can be obtained.

1.9.1 Crocodile (West) and Marico: WMA No. 3

Associated Provinces: North West, Limpopo and Gauteng

This WMA consists of the Crocodile West, the Marico, the Ngotwane and the Upper Molopo catchments and covers an area of 47 490 km^2 (**Figure 4**).

The Crocodile (West) and Marico catchments drain the northern metropolitan areas of Johannesburg and the entire metropolitan area of Pretoria plus several other towns, including Brits, Rustenburg, Zeerust, Thabazimbi and Bella Bella. Large parts of this catchment also comprise the communal areas of Moretele 1, Odi 1, Odi 2, Bafokeng and Mankwe Districts. The catchment drains to the north-west and joins the Marico River on the South Africa/ Botswana border. The Limpopo River commences at the confluence of the Marico and Crocodile Rivers.

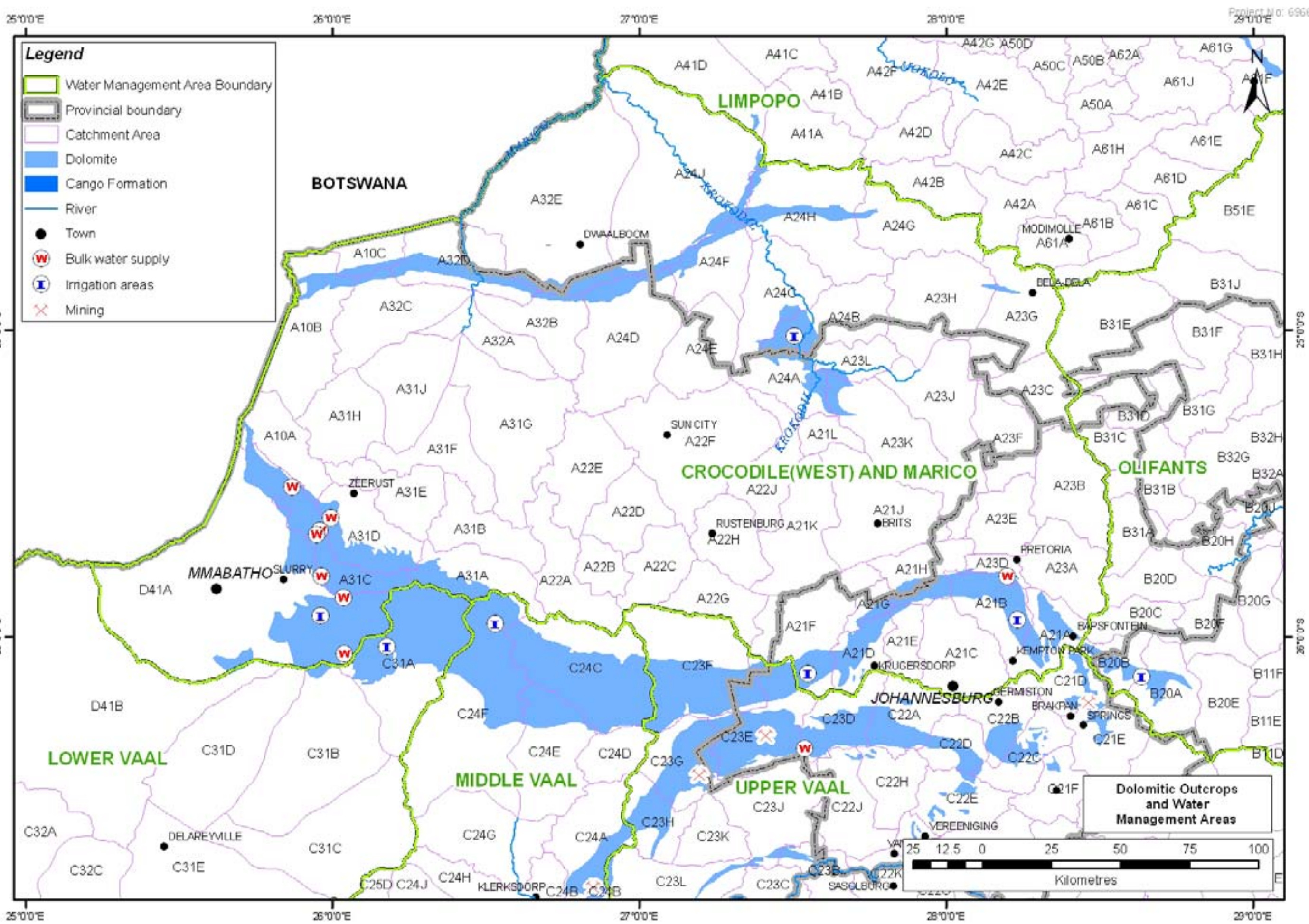

Figure 4: Occurrence of dolomite in the Crocodile West and Marico WMA

The Marico River forms a section of the South Africa/Botswana border upstream of the confluence with the Crocodile River. The Ngotswane River flows north-west into Botswana near Ramotswe, and the Upper Molopo River flows west, forming the border with Botswana west of Mafikeng. **Figure 4** illustrates the quaternary catchments with the occurrence of dolomite on the surface within the Crocodile (West) and Marico WMAs. An important consideration is that the Marico, Ngotswane and Upper Molopo drainages are all sourced from springs within the dolomite aquifer in the southern portion of this region, as shown in **Figure 4**.

<u>Quaternary catchments A21A, A21B, A21D, A21F, A21G and A21H</u>

This area comprises the hemispherical outcrop of dolomite to the east, north and west of the granite underlying Johannesburg. It encompasses the Rietvlei dam in A21A, and the World Heritage Site centred on Sterkfontein Caves in A21D.

The dolomite forms mostly flat ground to the east and NE of Johannesburg with extensive dry land agriculture and some irrigation, especially around Bapsfontein where a total of approximately 12km^2 is irrigated to the north and NW of Johannesburg the topography is more varied with rolling countryside becoming hilly. West of Johannesburg south of Krugersdorp the area is flat with extensive irrigation (approximately 69km^2) in the Tarlton area.

Borehole yields can be >40l/s from boreholes up to 250m deep. Average borehole yields vary from 2 – 10 l/s. Water tables vary from <10m in vlei areas to 50m.Groundwater use (1995 figures) is estimated to amount to 21.9 million m^3, this is mostly abstraction for urban supply from the dolomite aquifer in the Centurion area and irrigation abstraction in the Bapsfontein and Tarlton areas.

As seen by the widespread abstraction, the dolomite represents an important aquifer with significant groundwater resources. The potential for additional exploitation of the groundwater resources within this catchment may be considerable, this aspect requires detailed investigation to quantify the volume of water held in storage within the dolomite aquifer. The aquifer also contributes to base flow of the surface drainage flowing into the Hartbeespoort dam. Development will need to be properly managed to minimise the impact of current and future exploitation on spring flow, base flow and reserve requirements.

Groundwater quality is generally good. However, the dolomites are vulnerable to pollution, especially where karst conditions are present, and groundwater protection forms an important part of the catchment management in the dolomite areas.

The eastern part of Catchment A41C, catchment A31C and SW portions of A31A, and D and A10A.

This area is mostly agricultural. There is extensive irrigation in the southern part of the dolomite outcrop centred along the Lichtenburg - Mafikeng road. The northern part of the dolomite in catchment D41A and the southern area around Itsoseng is communal land. The bulk water supply for Mafikeng is mostly obtained from Grootfontein spring.

The Malmani dolomite forms generally flat to gently rolling landscape. The dolomite is intruded by numerous dolerite dykes which have effectively sub-divided the dolomite into a series of compartments which may or may not be hydraulically linked. Groundwater is widespread, especially in chert rich horizons and karst zones where borehole yields >5l/s are feasible, and yields of 20l/s are feasible.

As noted above this is an important regional groundwater resource suitable for development for bulk water supply. There is significant abstraction to supply Mafikeng, and Zeerust, and additional bulk water supply schemes are being assessed.

The dolomite feeds many springs and contributes base flow to the Groot Marico, Ngotwane and Molopo catchments.

The northern portion of A10B, and Catchments A10C, A32D ,A32E and A24D, F, H & J.

These are rural catchments, with communal areas in the south west and south east parts. Madikwe Game Reserve covers much of the area north of the dolomite. Most of A32E is cattle ranching with limited water requirements although some irrigation may be practised along the Limpopo River using water released from Molatedi dam. Groundwater represents the only source for water supply away from the Groot Marico river and Molatedi dam.

A narrow east west trending outcrop of Malmani dolomite forms rugged terrain in the southern parts of A10B and A10C. The topography becomes more subdued to the east in the southern part of A32E. The groundwater resources of these dolomites are mostly limited and underdeveloped and the area could be ecologically sensitive. In the west in particular groundwater quality is pristine and some contribution to base flow can be anticipated. Karst development is either absent or localised and borehole yields usually <2l/s.

The dolomite crosses the international boundary into Botswana at Ramotswe.

Further east Malmani dolomite forms a narrow SW - NE trending outcrop to the west of Thabazimbi. The topography is gently rolling to hilly. The groundwater resources of these dolomites are mostly limited (borehole yields <2 l/s) although yields of >5l/s are locally reported, e.g. in the northern portion of Mankwe District at Mokgalwaneng where conditions are favourable. Karst development is mostly absent or localised and groundwater occurrence tends to be structurally controlled.

Groundwater quality is good. Parts of this area are remote, groundwater quality is pristine and the area ecologically sensitive.

<u>The Crocodile River Fragment (Parts of Catchments A23K, A24A & B).</u>

This is an area of dolomite lying between ridges of quartzite across which the Crocodile River flows. The confluence between the Moretele River and Crocodile River is in this area. Assen is the main settlement. The dolomite forms relatively flat ground with widespread agriculture and irrigation. Irrigation water is drawn from alluvial deposits alongside the course of the Crocodile River as well as from the dolomite.

Borehole yields are can be >10l/s, especially from the shallow primary alluvial aquifer. Aquifers in the dolomite are areally limited and restricted to structural features and zones of deeper weathering and karst development. Groundwater levels in the alluvial aquifer are between 5 – 10mbgl, increasing to 20m in the dolomite aquifer.

The groundwater quality is good. The potential for elevated NO_3 due to agricultural activities is high and the aquifers are vulnerable to pollution

1.9.2 Olifants: WMA No. 4

Associated Provinces: Gauteng, Limpopo and Mpumalanga

The Olifants WMA area is the most northern WMA containing dolomite and comprises two main rivers, the Olifants and Steelpoort Rivers, together with numerous smaller rivers. The WMA covers a total area of 54 550 km^2 and has been subdivided into four sub-areas, namely, Upper Olifants, Middle Olifants, Steelpoort and Lower Olifants. **Figure 5** depicts the quaternary catchments that contain dolomites within the WMA.

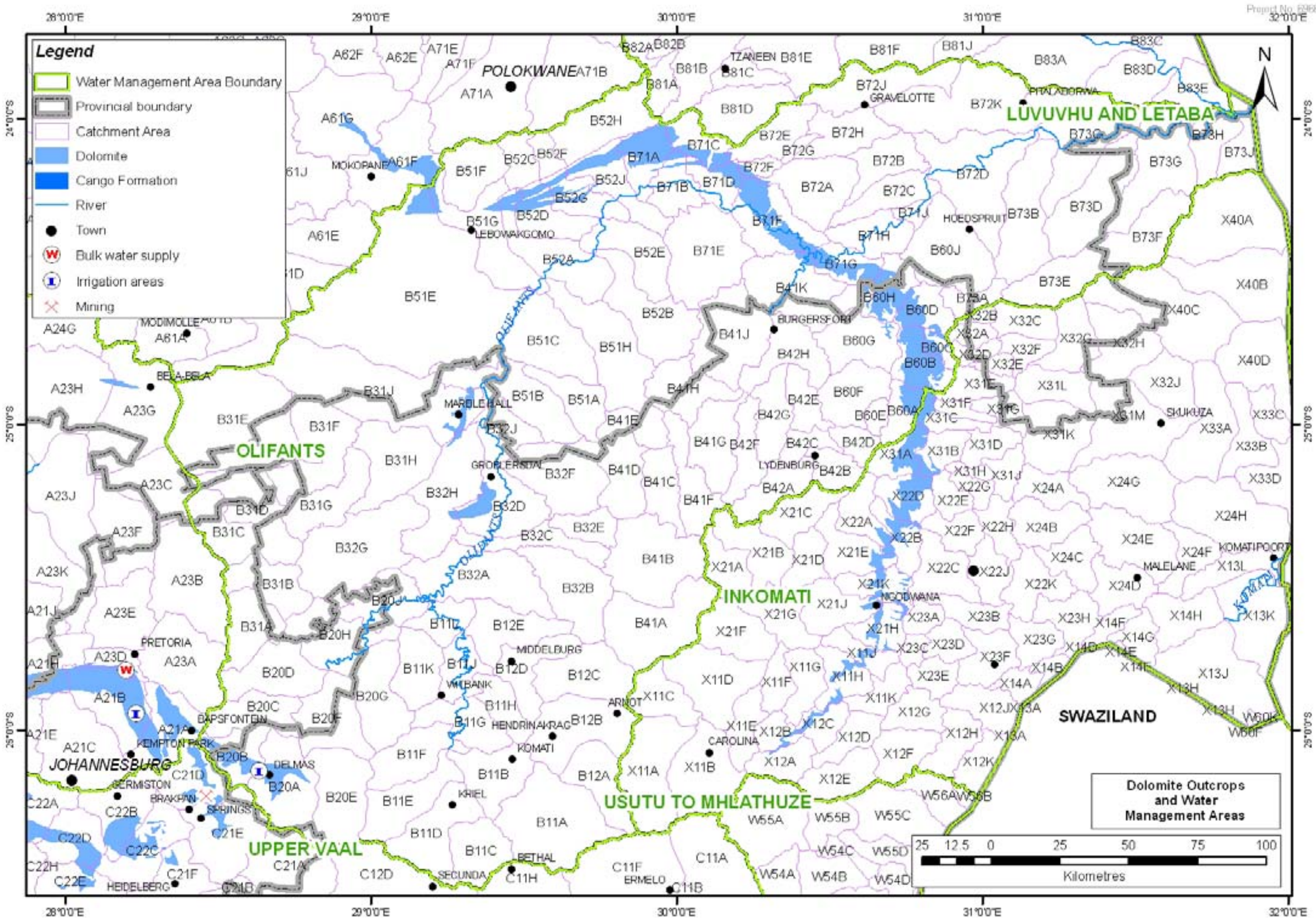

Figure 5: Occurrence of dolomite in the Olifants WMA

The mean annual rainfall over the catchment varies from 700mm in the Highveld region (Delmas/Witbank area) to 1 000mm along the south-eastern escarpment, declining to some 500mm in the Lowveld region of the WMA. The rainfall is seasonal, with most occurring during the summer months. The estimated annual recharge varies significantly over the WMA, with the highest recharge (>10% of MAP) occurring along the escarpment, and the Lowveld and the central area north of Marble Hall experiencing the lowest recharge (4-8% of MAP).

Quaternary catchments B20A and B20B

An east-west trending outcrop of dolomite, covering some 210km^2, occurs across quaternary catchments B20A and B20B. This dolomite outcrop stretches westwards into the Upper Vaal WMA, forming an extensive hemispherical dolomite outcrop between Johannesburg and Pretoria (**Figure 5**).

The dolomite strikes in a NW-SE direction and dips NE at 15º. It is dark grey to grey, massive and characterised by the occurrence of chert-rich and chert-poor horizons. The dolomite is variously weathered and is fractured with extensive development of karst, particularly in the chert-rich horizons. To the south, the dolomite is overlain by a thin cover of Karoo strata.

The dolomite is intruded by several dolerite dykes whose main strike direction is SW-NE, with subordinate NW-SE and N-S dolerite dyke trends. A major NW-SE trending dyke transects the central part of the outcrop, sub-parallel to the Delmas-Bapsfontein road. The dykes are assumed to compartmentalise the dolomite at depth but the compartmentalising effect is not evident where the water table is less than 30 metres below ground level.

Quaternary catchments B31J and B32H

A narrow NE-SW trending strip of dolomite outcrop occurs in and near Marble Hall in the Middle Olifants sub-area (Quaternary Catchment B31J). Very little is known about this dolomitic terrain. A second such unreported outcrop occurs to the south-west of Groblersdal in quaternary catchment B32H.

Quaternary catchments B51E, B52D, B52G, B52J, B71A, B71C, B71D, B71F, B71G, B60A, B60B, B60D and B60H

The Malmani Dolomite outcrops to the east of the Pretoria Series strata, along the escarpment in the Steelpoort Valley sub-area, forming a wide arc to the east of Lebowakgomo (**Figure 5**).

The dolomites form extensive areas of rugged terrain and are mostly undeveloped (Olifants ISP). North of Lebowakgomo, the dolomite outcrop extends west and forms a small outcrop in the quaternary catchment B51E.

Groundwater occurrence in the dolomite is enhanced in karst zones and zones of fracturing and solution weathering. Depending on the topographic position, water levels vary from 0.0m at springs and seepages to more than 50m in mountainous terrain.

1.9.3 Inkomati: WMA No. 5

Associated Province: Mpumalanga Province

The Inkomati WMA area is located to the south of the Olifants WMA and lies entirely within Mpumalanga Province and borders Mozambique and Swaziland. Its main rivers are the Sabie, Komati and Crocodile (East) Rivers which all join in Mozambique to form the Inkomati River and flow to the Indian Ocean.

Topographically, the WMA is divided by the Drakensberg Mountains into the western highveld plateau and the subtropical lowveld to the east. Elevations range from 2 000 mamsl in the west to 140 mamsl in the east. Rainfall across the WMA is also variable, with the highest rainfall occurring along the eastern escarpment (1 200mm/a), declining towards the eastern lowveld to 400mm/a.

The WMA has been divided into five sub-areas, namely the Sabie, the Sand, the Crocodile, the Komati (West) and the Komati (North) Sub-Areas.

By far the greater portion of the WMA is underlain by crystalline igneous and metamorphic rocks, comprising granites and gneisses. Along the western margin of the WMA, and uncharacteristically overlying the older crystalline rocks and forming the escarpment, are the westerly dipping, mainly sedimentary rocks of the Transvaal Supergroup, including the Malmani dolomite near the base of the escarpment (Inkomati ISP).

This dolomite outcrop along the eastern escarpment is continuous with that of the Olifants WMA to the north (**Figure 6**). The main river is the Crocodile River but there are numerous smaller rivers. The WMA covers a total area of 28 942 km^2.

Dolomite occurs along the escarpment characterised by high rainfall (>1 000mm/a). The contribution that dolomite groundwater can make to this WMA has not yet been fully recognised.

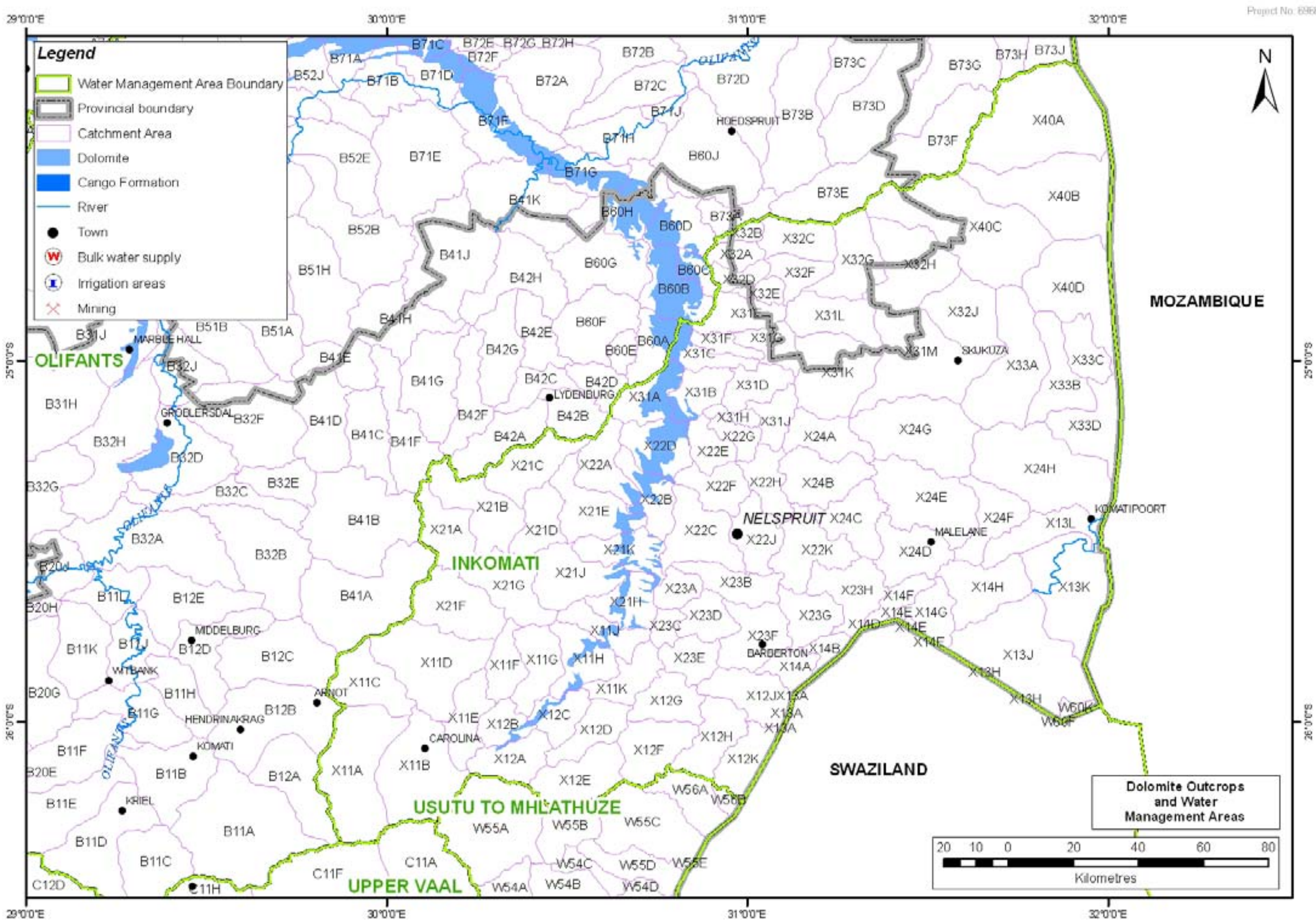

Figure 6: Occurrence of dolomite in the Inkomati WMA

The ISP document states that, because of the prevailing geomorphological conditions in this region, the dolomite is not generally the extensive high-yielding groundwater aquifer as found in other parts of the country.

Very little is currently known about the aquifer characteristics of the dolomite in this area. However, the high rainfall in the area suggests that the contribution of the dolomitic groundwater to base flow in a number of the streams arising in the escarpment in these quaternary catchments will be significant.

Quaternary catchments X31A, X31B, X31C, X31E, X31F, X22A, X22B and X22D

The dolomite outcrop crosses the boundary from Olifants WMA into the Inkomati WMA near Graskop, forming the edge of the escarpment. South of Sabie, the dolomite outcrop area becomes narrower and dips below overlying shales and quartzites of the Timeball Hill Formation of the Pretoria Group.

Quaternary catchment X22B

The Sudwala Caves, an extensive cave system and well-known tourist attraction, is located in this area.

Quaternary catchments X21H, X21J, X11H, X11J, X12 A, X12B and X12C

The dolomite in these quaternaries continues to thin and dip to the south-west, disappearing below the Pretoria Group sediments near the headwaters of the Seekoeispruit, east of Silobela (Carolina).

Quaternary catchment X21E

The Elands River drains through the southern portion of this catchment. The Sappi Ngodwana Mill and effluent irrigation fields are located in this quaternary on top of dolomite.

The dolomite constitutes a major aquifer underlying the valley, capable of delivering large volumes of water. The widespread weathering and karst within the dolomite and chert, together with a major fault, have produced highly permeable conditions. The aquifer is vulnerable to contamination from the irrigation of effluent. A number of boreholes intersect aquifers within the dolomite and chert, with blowing yields in excess of 20 l/s and as high as approximately 50 l/s (Janse van Rensburg H, 2004).

1.9.4 Upper Vaal: WMA No. 8

Associated Provinces: Gauteng, Free State and North West

The Upper Vaal WMA includes the upper reaches of the Vaal, Klip, Wilge, Liebensbergvlei and Mooi Rivers and extends downstream to the confluence of the Mooi and Vaal Rivers, covering an area of 55 565 km^2. The Vaal, Grootdraai and Sterkfontein dams are located within this WMA (Upper Vaal ISP).

The Upper Vaal Catchment WMA covers not only a large area but also provides an important contribution to South Africa's economy, representing some 20 percent of the country's GDP (Upper Vaal ISP).

The Upper Vaal WMA is subdivided into three sub-areas, namely, Upstream of the Vaal Dam sub-area, Wilge sub-area and Downstream of the Vaal Dam. **Figure 7** shows the main river systems and towns, the quaternary catchments and the occurrence of dolomites within the quaternary catchments.

Rainfall in the Upper Vaal WMA is strongly seasonal, with most rain occurring during the summer period (October to April). Peak rainfall months are December and January. Rainfall generally occurs as convective thunderstorms, sometimes accompanied by hail. Frost occurs in winter and occasional light snow may be experienced in the high-lying areas in the south-eastern portions of the WMA. The mean annual rainfall distribution decreases relatively uniformly from east to west and ranges from 1 000mm in the east to as low as 500mm in the west, with an average of approximately 700mm.

The geographical distribution of the Malmani Dolomite is given in **Figure 7**. It is described on the published 1:250 000 Geological Maps (2626 West Rand and 2628 East Rand) as undifferentiated, because chert-rich and chert-poor formations within the dolomite have not been distinguished in this WMA. Sediments of the younger Karoo Supergroup commonly fill ancient sinkhole features in the dolomite (Barnard, 2000).

Important features of the groundwater resources of the Upper Vaal WMA are the large dolomitic aquifers which extend across the north-western part of the WMA. The northern outcrop extends from north of Krugersdorp westwards towards Ventersdorp. This area is largely agricultural and extensive irrigation is practised. The southern outcrop forms a wide arc south of Johannesburg from the Springs area westwards past Carletonville towards Potchefstroom.

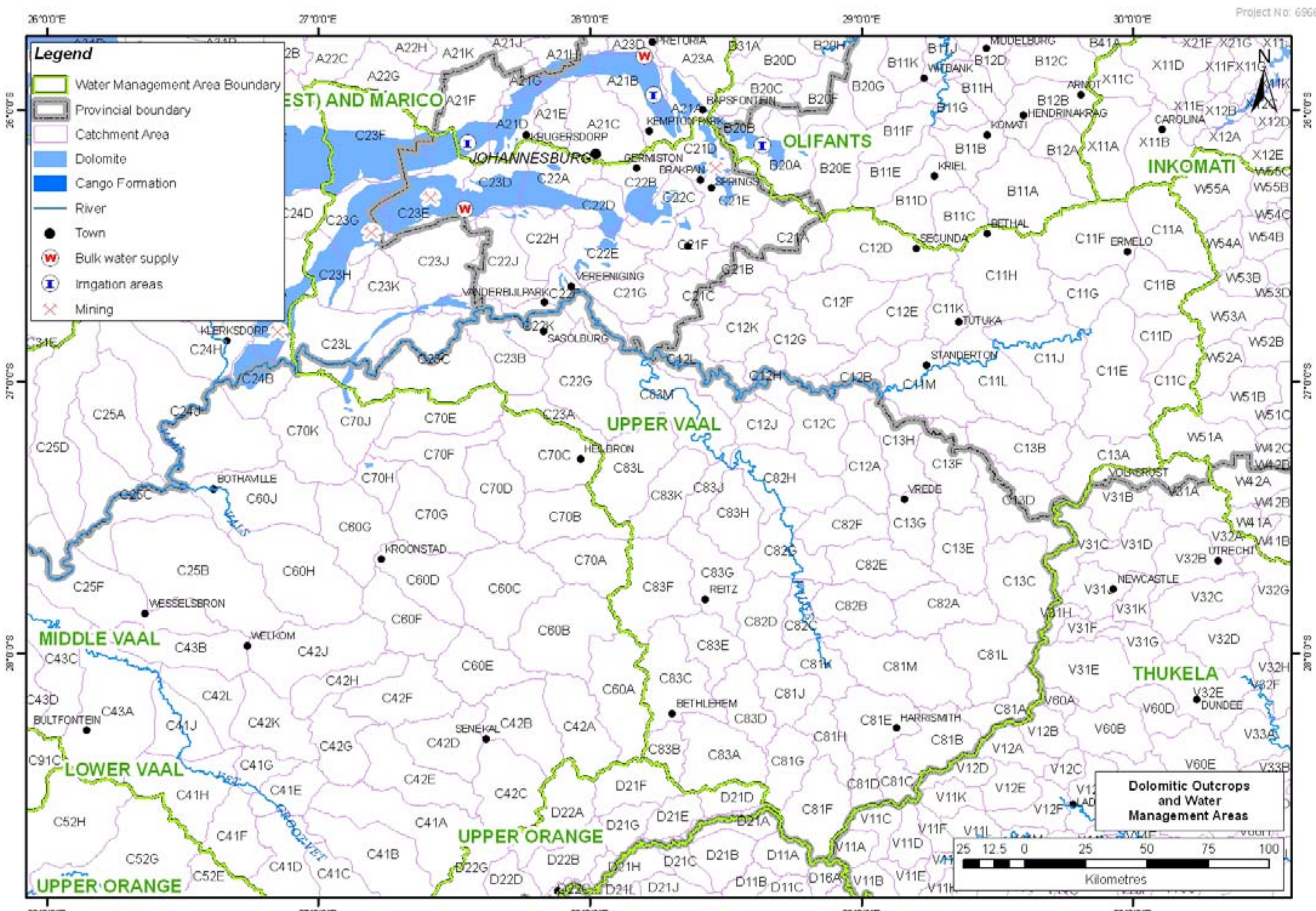

Figure 7: Occurrence of dolomite in the Upper Vaal WMA

Quaternary catchments C23F, C23D, C23E and C23G

Much of the water in the Mooi River, which is known for its strong base flow, originates as springflow from the aquifers present in the northern belt of dolomite (C23F).

The Gemsbokfontein West, Venterspost, Bank and Oberholzer compartments in the southern belt of dolomite have been dewatered by the gold mining activities of the Far West Rand gold mining area between Randfontein and Carletonville. Here the Wonderfonteinspruit, which rises in the north of C23D and flows to the south-west, has been diverted into the One Metre Pipeline across the dewatered compartments. Further south-west and upstream of Boskop Dam, the Turffontein and Gerhard Minnebron springs, have a combined flow of more than 800 l/s.

Quaternary catchments C22A, C22D and C22E

South of Johannesburg, the dolomite forms a relatively narrow strip stretching eastwards beyond Lenasia towards Walkerville. The Klip River flows eastwards across this dolomite outcrop, which is known as the Klip River compartment and is characterised by extensive wetlands, several springs and high borehole yields (>20 l/s).

Quaternary catchments C22B and C22C

The dolomite outcrop to the east of Alberton and north-west of Heidelburg is known as the Natalspruit compartment.

Quaternary catchments C21D and C21E

An outcrop of dolomite, known as the Varkfontein/East Rand Basin Compartment, occurs to the east in the Brakpan area and is drained by the Blesbokspruit. This dolomite is surrounded by a relatively thin cover of Karoo Sediments and is heavily impacted by the gold mining activities in this area (now mostly abandoned). Recovery of water levels in the closed gold mines may lead to decant and potential pollution of the dolomite groundwater.

1.9.5 Middle Vaal: WMA No. 9

Associated Provinces: Free State and North West

The Middle Vaal Catchment WMA is located downstream of the confluence of the Vaal and Rietspruit Rivers and upstream of the Bloemhof dam. The WMA extends to the headwaters of the Schoonspruit River in the north and the Vet River in the south. The WMA covers a total area of 52 563 km^2 and includes the western half of Free State Province and the eastern half of North West Province. Major rivers in the Middle Vaal WMA include the Schoonspruit, Rhenoster, Vals, Vet and Vaal Rivers. The area is subdivided into three sub-areas, namely, the Rhenoster/Vals sub-area, the Sand/Vet sub-area and the Middle Vaal sub-area.

Figure 8 illustrates the occurrence of dolomite within this WMA and shows the quaternary catchments which contain dolomites.

Rainfall is strongly seasonal with most rain falling in the summer period from October to April. Peak rainfall months are December and January. Rainfall occurs generally as convective thunderstorms, sometimes accompanied by hail. The mean annual rainfall distribution decreases relatively uniformly from east to west and ranges from 700mm in the east to as low as 500mm in the west, with an average of approximately 550mm (Middle Vaal ISP).

<u>Quaternary catchments C24C, C24E and C24F</u>

Dolomite outcrops occur over virtually the entire WMA north of Ventersdorp and comprise the Schoonspruit and parts of the Grootpan and Lichtenburg/Itsoseng compartments. The area is mostly agricultural and extensive abstraction for irrigation occurs.

This dolomite outcrop is part of the NW dolomites, extends westwards into, and underlies large parts of, the Crocodile (West) and Marico WMAs.

<u>Quaternary Catchments C24A and C24B</u>

Dolomite outcrops occur in a narrow band from the Upper Vaal WMA, north of the Vaal River in a south-westerly direction, past Stilfontein, extending across the Vaal River to the south.

The dolomite underlies much of the Klerksdorp, Orkney, Stilfontein and Hartbeesfontein (KOSH) gold mining area. Impacts on the quality of the dolomite groundwater resources from the gold mining activities are known.

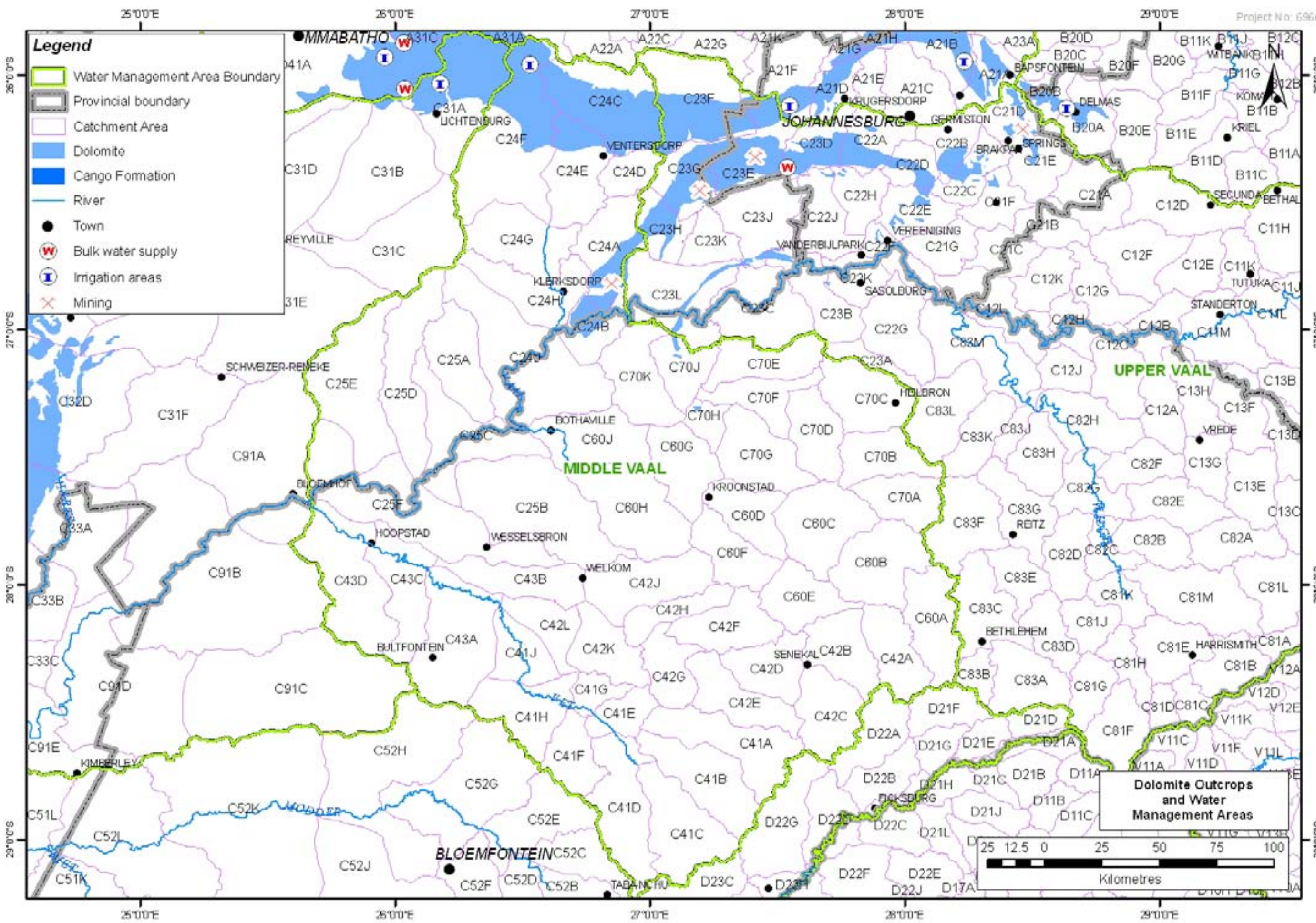

Figure 8: Occurrence of dolomite in the Middle Vaal WMA

1.9.6 Lower Vaal: WMA No. 10

Associated Provinces: Northern Cape and North West

Solution cavities in dolomitic rocks of the Ghaap and Chuniespoort Group, often developed in association with diabase dykes and faults, contain large quantities of exploitable groundwater. Some dykes isolate compartments which may be dewatered during overexploitation. The contact between the banded iron formation and the dolomite is transitional with alternating shale and dolomite bands. This zone is a well-developed aquifer in association with faults and dykes.

Where suitable dolomitic aquifers are available, large-scale irrigation is developed in this otherwise very arid WMA. Problems encountered on these irrigation sites are over-utilisation of the resource and associated lowering of water tables. Disputes regarding water allocation have become a major concern of DWAF regional management (Lower Vaal ISP).

Several local municipalities are dependant on groundwater as a source of bulk water use in this WMA. The water is supplied from boreholes sited within municipal properties. Dolomitic aquifers are often exploited for this purpose and it is estimated that some 140 000 residents in urban areas are reliant on groundwater.

The Sishen Mine, established in 1953, is one of the seven largest opencast mines in the world. It currently abstracts approximately 50Ml/day of dolomitic water, of which 30Ml/day are used in the operation and the remainder distributed for domestic purposes at Sishen, as well as other mines such as Hotazel and Olifantshoek mines through the Vaal-Gamagara pipeline. It is estimated that this groundwater will eventually be depleted and that water will have to be imported to Sishen Mine from other sources.

Other mines that abstract dolomitic groundwater for dewatering and other purposes include Pering and Finch mines.

The distribution of dolomite within this WMA is shown in **Figure 9**.

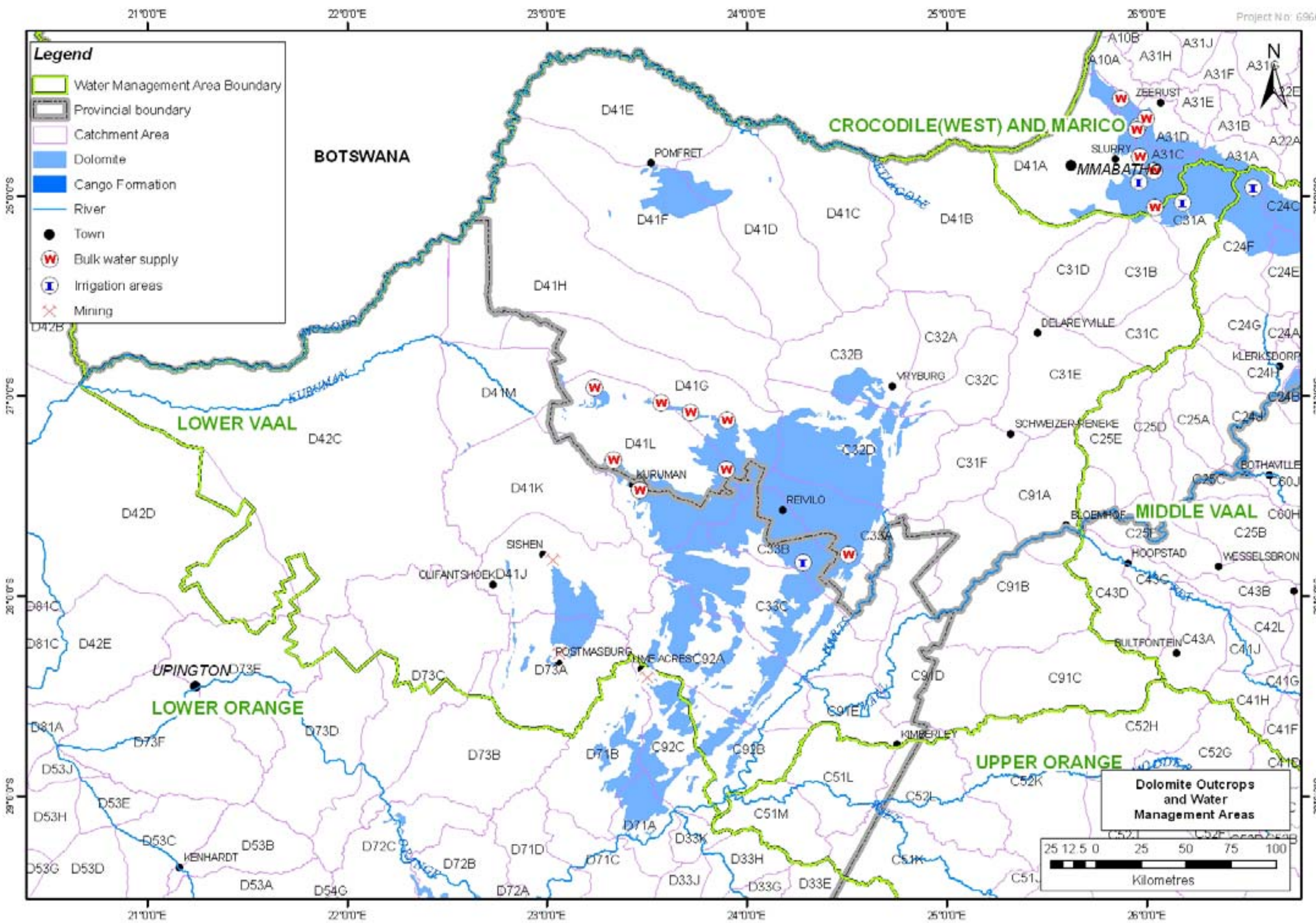

Figure 9: Occurrence of dolomite in the Lower Vaal WMA

Quaternary catchment C31A

The Itsoseng Lichtenburg compartment, forming the western portion of the North West Province dolomite outcrop, falls partially within the Lower Vaal WMA. Extensive abstraction for irrigation and bulk water supply occurs and the dolomite water resources are vulnerable to over-exploitation.

Quaternary catchments D41J and D73A

This half-moon shaped outcrop of dolomite is located to the west of the main body of the dolomitic outcrop in the Northern Cape Province.

Quaternary catchments D41D and D41F

This dolomite outcrop represents the most western and northern occurrence of dolomite on the surface in this WMA. It is surrounded by a cover of Kalahari Sands, but it is not known whether this outcrop is linked at depth with the main body of dolomite some 100 to 120 km to the south-east.

Quaternary catchments C32B, C32D, C33A, D41G and D41L

This portion of dolomite represents the north-eastern extent of the Ghaap Plateau and is located in the Northern Cape Province.

Quaternary catchments C33A, C33B, C33C, C92A, C92B

Located in the Northern Cape Province, this dolomite covers the central portion of the Ghaap Plateau. Significant areas of the dolomite are covered by windblown Kalahari Sands and banded iron stone and chert rubble.

Kuruman is located close to the western boundary of the Ghaap Plateau. The well-known Kuruman 'Eye' (spring), declared a national monument in 1992, emerges in Kuruman. As far as is known, this spring yields a more or less constant flow of about 235 l/s and has never dried up. The spring has supplied the community since the town was established in 1887 (Esterhuyse, 1994).

1.9.7 Lower Orange: WMA No. 14

Associated Province: Northern Cape

Dolomitic and related carbonate rocks of the Postmasburg Group, Campbell and Griquatown Sequence, all forming part of the Griqualand West Sequence, occupy the north-eastern lobe of this WMA.

This WMA is characterised by a semi-arid climate with scrub vegetation.

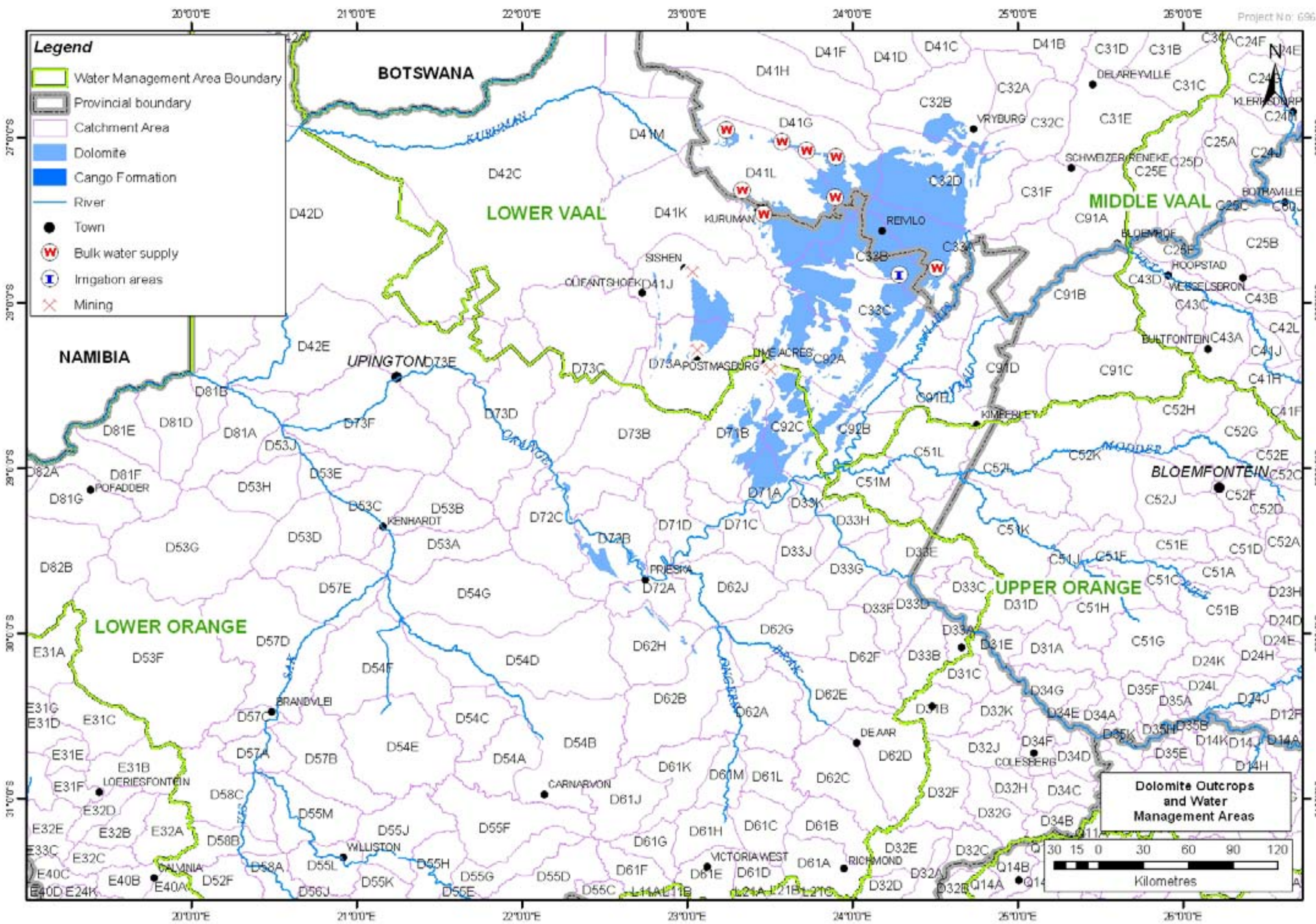

Figure 10: Occurrence of Dolomite in the Lower Orange WMA

Dolomite, limestone and related sedimentary rocks make up this broad lithostratigraphic unit (**Figure 10**).

<u>Quaternary catchments C92C, D71A and D72B</u>

The bulk of the dolomitic outcrop occurs over quaternary catchments D71A & B and C92C and stretches across the WMA boundary into the Lower Vaal WMA. This dolomite forms the southern portion of the Ghaap Plateau.

A further narrow strip of dolomite, approximately 50km long and less than 5km wide (on average), outcrops in a roughly north-west to south-east orientation along the Doringberg Fault, west of Peiring. The main body of the outcrop is located in quaternary catchment D72B.

1.9.8 Gouritz: WMA No. 16

Associated Province: Western Cape

The approximately 9 500m-thick sequence of metasedimentary rocks of the Kango Group consists, at its base, of approximately 2 300m of limestone, shale and subordinate sandstone. **Figure 11** shows the occurrence of dolomite in the Gouritz WMA.

The Klein-Karoo and Karoo regions have typically semi-desert climates, hot summers and mild winters with summer temperatures regularly exceeding 30º C (Meyer, 1999).

The basal Matjies River Formation is the only known karst aquifer in the Gouritz WMA. The lithological sequence of the Kango Group is complexly folded, strikes east-west and outcrops to the north of Oudtshoorn. The famous Cango Caves are within the limestone of this Formation.

Two members can be identified within the Matjies River Formation, namely, the basal Nooitgedacht Member, which is approximately 1 000m thick and consists of alternating lenses of shale and sandstone, and two prominent limestone horizons. The overlying Kombuis Member is approximately 1 300m thick and is composed mainly of limestone, dolomitic limestone with subordinate shale and siltstone (Meyer, 1999).

The groundwater potential of the Matjies River Formation is good, especially in the valleys where substantial coverage by alluvial deposits occurs. An analysis of the Matjies River Formation indicates that 65 percent of groundwater sources yield 5 l/s or more.

The groundwater from the Matjies Formation has a notable alkaline nature and varies in quality between 20 and 200 mS/m.

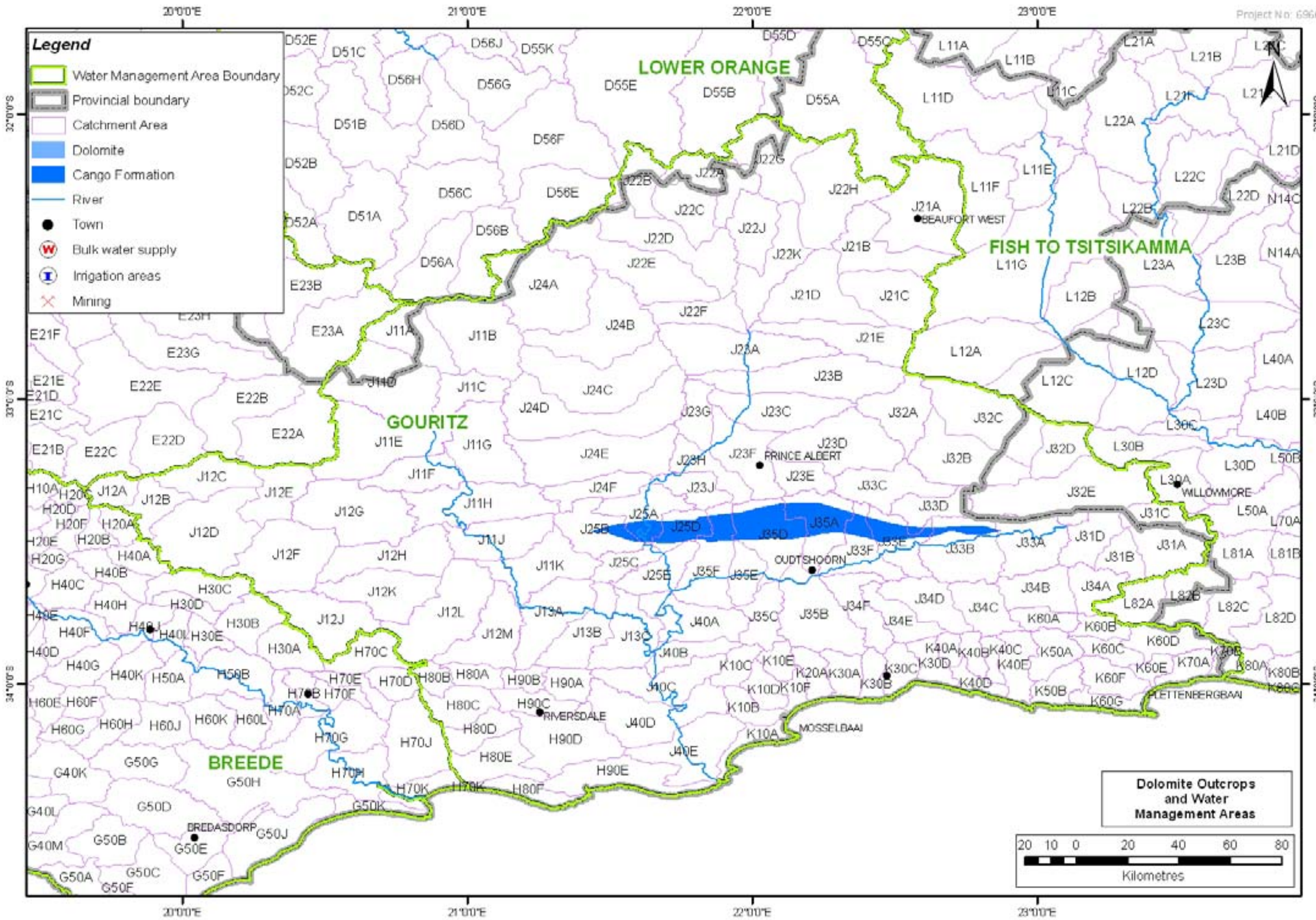

Figure 11: Occurrence of dolomite in the Gouritz WMA

2 THE FUNCTIONS OF VARIOUS ROLE-PLAYERS

A structured approach to the effective assessment, planning and management of the dolomitic resource is required. Efforts to coordinate the assessment, planning and management of dolomitic groundwater resources may be led at a local, catchment or national level.

2.1 The Water Manager/Planner

The typical role of a Water Manager/Planner at catchment or local level is to assess the water use requirements and to identify target areas within the dolomite area where these needs can be addressed. This may be based on advice from national level or arise directly from local requirements. The responsibilities of the Water Manager/Planner include the following tasks, among others:

- Reconcile water availability and demand
- Assess water requirements
- Identify target areas within the dolomite area for potential resource development and requirements for the protection of the resource
- Prepare the Scope of Work of the identified task(s)
- Determine what hydrogeological expertise is available and required
- Determine whether a specialised hydrogeological consultant is needed
- Be able to assess proposals and tenders
- Appoint a recognised specialised hydrogeologist, and
- Appoint an experienced contractor on the basis of a tender and technical specification.

2.2 The Water Boards

Water Boards are organs of state that are established to provide water services to other water services institutions. Water Boards may be responsible for implementing and maintaining water use schemes, based on abstraction from dolomitic aquifers that have been identified through the assessment and planning process. Where this is the case, the responsibilities of the Water Board will be similar to those detailed for the Water Manager.

2.3 The Water Services Authority

The Water Services Authority is responsible for the provision of water services to the end user. The Water Services Authority is responsible for preparing a Water Services Development Plan (WSDP) within its area of jurisdiction. This plan will include details on the use of water from and the expected development on the dolomitic aquifers. The Water Services Authority will appoint a Water Manager or Water Board.

2.4 The Dolomite Committee

The Dolomite Committee is responsible for day-to-day management of the water resources in the dolomite aquifer within a WMA or local catchment. The Committee will be responsible for management functions, such as water use control (including licensing), resource assessment, and management of the available resources.

2.5 The Water User Association

The Water User Association is responsible for the day-to-day management of the water resources being utilised, including those of the dolomite aquifer. The primary functions of the Water User Association will include monitoring and management of the water resource, enforcement, and groundwater protection.

This will be undertaken in consultation with the Dolomite Committee.

2.6 The Hydrogeologist

The specialist knowledge to undertake groundwater investigations may be available within the institutional framework of the Department’s National Office and/or Regional Offices, WSPs, CMAs or WUAs. Such expertise may also be obtained from an external Professional Service Provider.

The Hydrogeologist would typically undertake the following tasks:

- Report to, and liaise with, the Water Manager, Water Planner and Water Users, as applicable
- Draw up a suitable programme of work to fulfil the objectives of the Scope of Work as specified by the Water Manager/Planner
- Ensure the application of correct scientific assessment/development methods
- Prepare technical specifications for borehole drilling, testing and equipping
- Recommend the appointment of contractors, as applicable

- Ensure adherence to the technical specifications by the appointed contractor by being responsible for field supervision
- In the event that the drilling of new boreholes is required, select drilling locations according the application of sound scientific principles and techniques, as described in **Section 5.3.4** and **5.3.5** of this Guideline, and
- Make recommendations based on the technical specifications.

One of the most critical functions of the Hydrogeologist is to prepare technical reports and to make recommendations on development, target areas, sustainable resources of the dolomite aquifer, sustainable borehole yields, well-field configuration, monitoring protocols and potential environmental and other impacts that could arise as a result of using dolomitic groundwater. The exact nature of any assessment, however, will be based on the original Scope of Work.

2.7 The Hydrologist

Because of the large surface water – groundwater interaction component in dolomites the Hydrologist is described as a specific role player. The Hydrologist is responsible for reviewing and assessing the surface water requirements and potential impacts. The hydrologist will form part of the team assessing the integrated use and protection of the water resources. Interaction between the Water Manager responsible for the dolomite aquifers, the Hydrogeologist and the Hydrologist is essential in the assessment, planning and management of the dolomitic aquifers.

2.8 The Drilling/Testing Contractor/Operator

The Drilling/Testing Contractor/Operator is responsible for:

- Undertaking the drilling and construction of boreholes according to the applicable technical specification, and
- Test pumping boreholes according to the applicable technical specification.

The technical specifications must detail what is required of the contractor. Model drilling and testing specifications applicable to dolomite aquifers are described in **Appendix B.1** and **Appendix B.2** respectively.

The contractor will typically report to the Water Manager or the appointed Hydrogeologist.

2.9 Other Role-players

The roles and responsibilities of other role-players (District and Local Municipalities, Water Forums, ward councillors and task teams) are summarised in **Section 6.2** of **Volume 1** of this Guideline. The task teams in particular will provide technical input for the management of the dolomitic water resources. Currently, the most active forums and task teams are concentrated in the Far West Rand area of the Upper Vaal WMA and the Ventersdorp/KOSH area of the Middle Vaal WMA.

3 PUBLIC PARTICIPATION

The Department has developed *Generic Guidelines for Public Participation* (September 2001) which provide a generic approach to understanding the value of public participation in decision-making processes and assisting the Department in implementing public participation in its activities. These Generic Guidelines highlight the objectives and benefits of public participation, the principles, methods and tools for public participation, generic processes and guidelines for implementation, contribution of public participation towards sustainable development, as well as recommendations to the Department on how to improve public participation. The Generic Guidelines therefore serve as the main reference for conducting public participation processes in dolomitic areas.

An introduction on how to conduct public participation in dolomitic areas is included in **Section 7** of **Volume 1**, and provides definitions of public participation and its benefits. This Chapter has been designed to assist the Water Manager, in all aspects of public participation. It describes how to engage the public (i.e. authorities, water users, directly affected parties and other interested and affected parties) to participate in the management of these water resources in order to achieve sustainability.

The following sections provide a brief summary (the details are contained in the Department's *Generic Guidelines for Public Participation)* on aspects such as: when to undertake public participation; at what level to pitch it; how to identify stakeholders; how to analyse the stakeholder profile; what methods to adopt to engage stakeholders; and how to deal with stakeholders' issues of concern. Also described are the principles of risk communication, ongoing awareness creation and building and maintaining good relations with water users and communities living in dolomitic areas.

3.1 Who is "the public"?

There is no single "public." The public is made up of many different and diverse groups. Some may participate throughout a process, while some may only participate during part of the process. Some may enter the process late or leave early.

The International Association for Public Participation (IAP2) defines "the public" *as: "Any individual or group of individuals, organisations or entities with an interest in the outcome of a decision. They are often referred to as stakeholders. They may be, or perceive that they may be, affected directly or indirectly by the outcome of a decision. Internal stakeholders (individuals who work for or with the decision-making organisation) are also part of the public.*

“Stakeholders” are those individuals, groups, communities, organisations, associations or authorities whose interests may be positively or negatively affected by a proposal or activity, and/or who are concerned with a proposal or activity and its consequences. The term therefore includes the proponent or developer, the authorities and all interested and affected parties (I&APs).

“Directly affected parties” are those people who will or may be directly impacted (e.g. farmers using water from dolomitic areas for irrigation).

3.2 Why do public participation?

Public participation involves stakeholders representing different sectors of society, technical specialists, authorities and project proponents who work together in a joint effort to produce better decisions than if they had acted independently. Public participation is mainly conducted to:

- Satisfy local regulatory requirements (e.g. South African Constitution, National Water Act, Environment Conservation Act, National Environmental Management Act)
- Satisfy Departmental specific guidelines (e.g. the Department of Water Affairs and Forestry’s Generic Guidelines for Public Participation)
- Satisfy international Best Practice principles for public participation
- Enrich decision-making processes, and
- Add value beyond the lifespan of a project, that is, to achieve and/or contribute to sustainable development.

The value of public participation to developers and the authorities is that stakeholders often help them to think through a proposed project, its implementation and management. Stakeholders can often give an up-front indication of environmental or social issues that may cause project difficulties at a later stage. Through the public participation process, stakeholders therefore provide their input and advice “free of charge” and assist developers and authorities to understand the environmental and social consequences of their decisions.

3.3 When is public participation required?

As mentioned in the Department's *Generic Guidelines for Public Participation*, *"the Constitution of South Africa sets out the Government's responsibility to provide the public with the opportunity to be involved in Government decisions that affect their lives."* Thus, the Constitution lays the foundation for the necessity of public participation in any future development project, and this responsibility is reflected in many, if not all, of the South African Government's regulations. In particular, public participation, or the requirement for public participation, is an integral part of the Department's acts, policies, strategies and regulations, and other non-regulatory processes (see **Box 1** for examples of legislative, regulatory and non-regulatory processes).

From an international perspective, the training guideline, Southern African Institute for Environmental Assessment (SAIEA) 2005 *Training Course: Public Participation in Environmental Assessment in Southern Africa,* contains an extensive list of Southern African Development Community's Protocols, Declarations, Charters and Memoranda of Understanding, Agreements, Treaties and International Conventions that underpin the importance of public participation, particularly in cases where water resources are shared by different countries (see **Box 2**).

Apart from all the above regulatory requirements for public participation, it is always beneficial to adopt it as a Best Practice principle as part of the process to assess, plan and manage dolomitic water resources. For example, public participation is vital in the following situations:

- When planning the development of a waste site close to a dolomitic resource
- When planning to abstract water from a dolomitic resource close to a sensitive ecological system
- When planning a housing development close to a dolomitic water resource
- When communicating potential or actual risks associated with sinkhole formation, and
- When there is a need to create awareness and build understanding about dolomitic water resources in order to plan and manage the resource.

These are just a few examples from an extensive list of when to conduct public participation. If there is uncertainty as to when to conduct public participation, it is best to consult the Department: Water Affairs and Forestry.

The following section provides some references that can be used to design a public participation process.

Box 1: Examples of legislative, regulatory and non-regulatory processes

Regulations:

- Constitution of the Republic of South Africa (Act 108 of 1996)
- National Water Act (Act 36 of 1998) and the White Paper on Water Policy (30 April 1997)
- Water Services Act (Act 108 of 1997) and the White Paper on Water Use and Sanitation (November 1994)
- National Forests Act (Act 84 of 1998)
- National Veld and Forest Fire Act (Act 101 of 1998)
- National Environmental Management Act (NEMA) (Act 107 of 1998)
- Environment Conservation Act (Act 73 of 1989)
- Promotion of Access to Information Act (Act 2 of 2000)
- Minerals and Petroleum Resources Development Act (Act 28 of 2002).

Policies and Strategies:

- White Paper on Water Policy (30 April 1997)
- White Paper on Water Use and Sanitation (November 1994)
- Batho Pele – White Paper on Transforming Service Delivery (September 1991)
- National Water Resource Strategy (2004)
- Draft Position Paper for Water Allocation Reform (2005).

Non-regulatory requirements:

In addition to the policies in Section 3.2.2, other non-regulatory processes within the Department require public participation, including:

- Waste Management and the Minimum Requirements (DWAF, First Edition, 1998)
- CMA/WUA Guide 4: Public Participation for Catchment Management Agencies/ Water User Associations (DWAF, 2000)
- Water Quality Management Series, Volumes 1-3 (Sub-series No MS 8.2, Edition 1, March 2003).

Box 2. SADC Protocols, Declarations, Charters, Memoranda of Understanding, Agreements and Treaties

The importance of public participation is underpinned by the existing SADC Protocols, Declarations, Charters, Memoranda of Understanding, Agreements and Treaties, as listed below.[1] Web addresses are also supplied.

- **SADC Protocols**
  - Protocol on Control of Firearms, Ammunition and other related materials
  - Protocol Against Corruption
  - Protocol on Culture, Information and Sport
  - Protocol on Illicit Drug Trafficking
  - Protocol on Education and Training
  - Protocol on Energy
  - Protocol on Extradition
  - Protocol on Fisheries
  - Protocol on Forestry
  - Protocol on Health
  - Protocol on Immunities and Privileges
  - Protocol[1] on Legal Affairs
  - Protocol on Mining
  - Protocol on Mutual Legal Assistance in Criminal Matters
  - Protocol on Politics, Defence and Security Cooperation
  - Protocol on Shared Watercourse Systems Revised
  - Protocol on Trade
  - Protocol on Transport, Communications and Meteorology
  - Protocol on Tribunal and Rules of Procedure Thereof
  - Protocol on Tourism
  - Protocol on Wildlife Conservation and Law Enforcement

  http://www.sadc.int/index.php?lang=english&path=legal/protocols&page=index

- **SADC Declarations**
  - Declaration and Treaty of SADC
  - Declaration on Gender and Development
  - Declaration on Information and Communications
  - Declaration on Productivity
  - Declaration on HIV/AIDs

  http://www.sadc.int/index.php?lang=english&path=legal/declarations&page=index

[1] Adapted from Southern African Institute for Environmental Assessment (SAIEA) 2005. Training course - Public Participation in Environmental Assessment in Southern Africa. Developed as part of the SAIEA Calabash Project. First Edition, 2005.

SADC Charters

- Charter of the Regional Tourism Organisation of Southern Africa (RETOSA)
- Charter of Fundamental Social Rights in SADC

http://www.sadc.int/index.php?lang=english&path=legal/charters&page=index

SADC Agreements

- Agreement Amending the Treaty of SADC

http://www.sadc.int/index.php?lang=english&path=legal/agreements&page=index

SADC Memoranda of Understanding

- Memorandum of Understanding on Macroeconomic Convergence
- Memorandum of Understanding on Cooperation in Taxation and Related Matters
- Memorandum of Understanding on SQAM

http://www.sadc.int/index.php?lang=english&path=legal/moa&page=index

SADC Treaties

- Declaration and Treaty of SADC
- Amended Declaration and Treaty of SADC

http://www.sadc.int/index.php?lang=english&path=legal/treaties&page=index

3.4 How to design a public participation process

Public participation processes are not carved in stone, nor is there a blue-print for such processes. A public participation process must be designed to satisfy local regulatory requirements, and international requirements if conducted across the borders of different countries. These may include one or more of the National Water Act, the EIA Regulations, the National Environmental Management Act, the Environment Conservation Act and international best practice principles as proclaimed by the International Association for Public Participation (IAP2) and other applicable legislation and/or protocols (see **Box 2**).

Very few of these regulations and best practice principles provide guidelines on how to conduct public participation. The Department's *Generic Guidelines for Public Participation* (September 2001), specifically **Section 4**, describe the sixteen principles of public participation that must be considered when designing a process to engage stakeholders. Another valuable resource on how to conduct public participation, albeit in Environmental Assessment, is the training guideline by the Southern African Institute for Environmental Assessment (SAIEA) 2005, *Training course - Public Participation in Environmental Assessment in Southern Africa.*

It is important to note that the context to public participation at national level is different to that at catchment and site-specific levels. Each has different requirements and these must be borne in mind when designing a public participation process and when implementing methods to achieve desired outcomes. However, certain of the guidelines must be considered and certain generic steps must be followed when conducting an effective public participation process, whether undertaken on a national, catchment or site-specific level. These generic steps are outlined in **Figure 12** and are briefly discussed in the following sections. More details are contained in **Section 5** of the Department's *Generic Guidelines for Public Participation.*

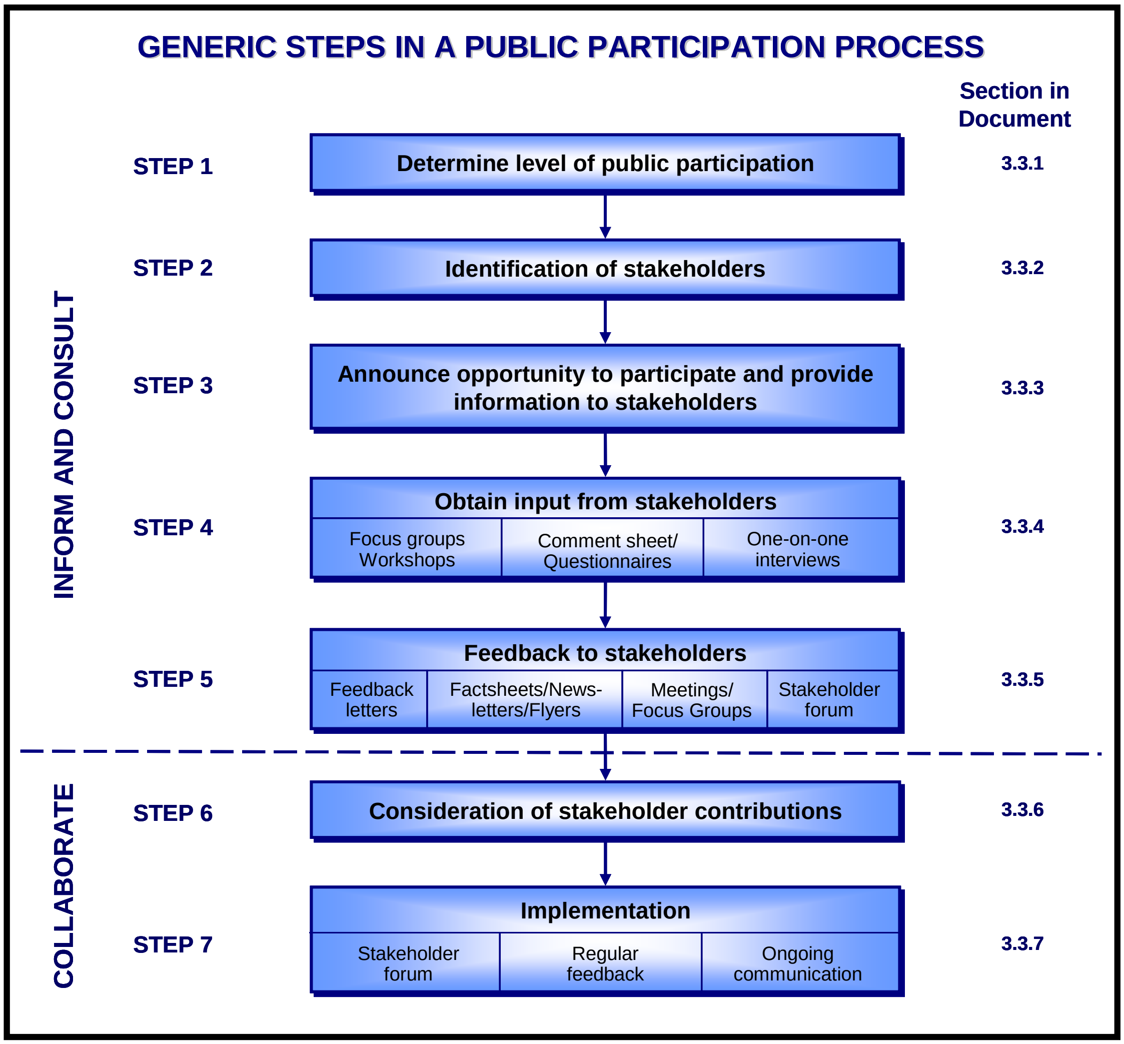

Figure 12: Generic steps in a public participation process

3.4.1 Step 1: Determine the level of public participation

A confusing aspect about public participation is that different parties have different definitions and use different terminology. What is important is that most organisations recognise public participation as a spectrum or a continuum rather than an absolute (Southern African Institute for Environmental Assessment (SAIEA) 2005, *Training course - Public Participation in Environmental Assessment in Southern Africa*).

The International Association of Public Participation (2005) differentiates between five levels of public participation in its Spectrum of Public Participation, each with different objectives and each with increasing public impact on decision-making:

- **Inform:** The objective is to provide the public with balanced and objective information to enable people to understand the problem, alternatives and/or solutions
- **Consult:** The objective is to obtain public feedback on analysis, alternatives and/or decisions, in particular those points that are relevant to the subject at hand. It involves acknowledging concerns and providing feedback on how public input has influenced the decision
- **Involve:** The objective is to work directly with the public throughout the process to ensure that public issues and concerns are understood and considered at every stage and are directly reflected in a particular proposal or activity
- **Collaborate:** The objective is to work with the public as a partner on each aspect of the decision, including the development of alternatives and the identification of the preferred solution; and
- **Empower:** The objective is to place final decision-making in the hands of the public.

In the development of policies, strategies and guidelines, public participation mainly takes place at the “Inform” and “Consult” levels of the continuum, and sometimes at the “Collaborate” level. As an example, the national policy consultation process for the National Water Resource Strategy (NWRS) evolved from the consult level to a collaborative level due to the nature of the project. A project does not necessarily need to remain at a specific level but can grow from one level into another depending on the type of the project, its sensitivity and the interest generated by the project.

With regard to the assessment, planning and management of water resources in highly impacted and sensitive dolomitic areas (e.g. where water has been over-abstracted by farmers, or slimes dams built in dolomitic areas), public participation should be pitched at the "Inform", "Consult" and "Collaborate" levels. This will ensure the involvement of stakeholders in the management and protection of the resource. However, in areas where impacts to water resources are low, public participation needs to take place only at the "Inform" level. This approach applies equally to the national, catchment and site-specific levels.

The level of public participation is dependent on the anticipated scale of impacts and sensitivity of public perceptions, as illustrated in **Figure 13**.

NOTE:

For more information or a guideline to implementation, refer to section 6.2.2 of the Department's Generic Guidelines for Public Participation (September 2001). Section 7 of this volume also provides information on the methods of public participation.

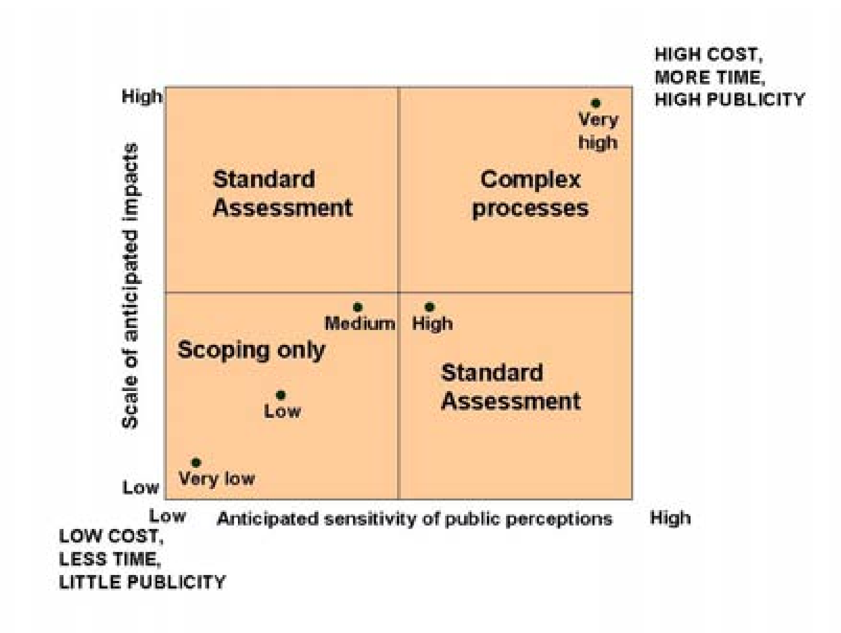

Figure 13: Level of public participation

3.4.2 Step 2: Identification of stakeholders

When identifying stakeholders with whom to consult, It is important to bear in mind the scale of the process (i.e. national, catchment and/or site-specific) and to be sensitive to the power relationships within the stakeholder groups (*SAIEA 2005, Training course - Public Participation in Environmental Assessment in Southern Africa*). This can play a vital role in the degree to which stakeholders will actively participate in the project. Up-front knowledge about the dynamics in stakeholder groups can also determine the success of the process. Before identifying stakeholders in the project area, it is important to consider the following questions (*SAIEA 2005, Training course - Public Participation in Environmental Assessment in Southern Africa*):

- Is there an existing stakeholder profile in the project area?
- Who needs to be informed of the process and brought on board?
- What are the traditional systems of power, government and authority?
- What languages are spoken?
- What specific cultures, traditions or rituals are important?
- What are the mechanisms of communication in the community?
- Who are the dominant individuals and groups among the stakeholders or community?
- What are the correct channels to use when engaging with stakeholders?
- Are there any special interest groups that need to be involved in the project and how can women, the youth, the disabled and people with HIV/AIDS be incorporated into the public participation process?
- Are there any specific marginalised people in the project area who may need special assistance to attend meetings (e.g. transport)?
- What capacity to participate does community and civil society groups have? For example, do they have access to time, finances, knowledge and skills to enable them to get involved? Do they lack access to these resources and/or have limited resources to get involved? What can be done to overcome this problem?
- What lessons can be learned from previous experience?
- Who needs to be informed of the process and brought on board?
- Who will benefit from the planning, assessment and management of water resources in dolomitic areas?
- Who might be negatively affected by the regulation of use of water resources in dolomitic areas?

- Who might stand in the way or obstruct the process of licensing water use from dolomitic areas?
- Who may have resources, such as skills and finances, to contribute to the planning, assessment and management of water resources in dolomitic areas?
- Who are the relevant decision-makers in the process?

To ensure that no group of stakeholders has been left out, categorise the list of stakeholders into different sectors of society. These sectors are listed in **Box 3**. They may not all be relevant but the list can be used for cross-checking purposes. Every area has a unique group of stakeholders (e.g. some areas may have more rural communities than others) and it is important to identify the right people to participate in the project. Take care not to exclude marginalised people merely because they may need extra care and attention.

Box 3: List of sectors of society

- National government
- Provincial government
- Local government
- Tribal authorities
- Mining
- Industry
- Business and commerce (e.g. farmers' cooperatives involved in the sale of centre pivot irrigation systems to farmers)
- Transport
- Agriculture (e.g. farmers associations)
- Environmental bodies, incl. NGOs and conservation groups
- Water users (e.g. individual farmers and landowners) and user associations
- Community-Based Organisations, residents' associations, women's groups, the youth, disabled, people with HIV/AIDS
- Labour unions
- Power
- Health
- Education
- Religious groups, churches

NOTE:

For more information on how a final stakeholder list might look, see Section 6.2.3 (Boxes 9 and 10) of the Department's Generic Guidelines for Public Participation (September 2001).

The stakeholder list should include marginalised groups such as women, the youth, the poor, disabled people, rural people, emerging farmers/ etc.

When developing the stakeholder database, and to ensure that all relevant stakeholders are included, it is important to network with the Department's Regional Offices. Comprehensive existing stakeholder databases developed for other processes are held by the Department and these can be used for public participation. These processes included developing the following PP databases which are available:

- The National Water Resource Strategy
- Water allocation
- NORAD
- KOSH study, and
- DANIDA-funded Integrated Water Resource Management process.

3.4.3 Step 3: Announcing the opportunity to participate and providing information to stakeholders

Several techniques are available to announce the opportunity for stakeholders to participate in the assessment, planning and management process of dolomitic water resources. These include:

- Announcement letters
- Paid advertisements in national, regional or local newspapers (preferably placed in the main body of the newspaper and not in the classifieds or legal sections)
- Mail-drops
- Newspaper inserts, and
- Press releases.

Techniques to share information include:

- Printed material (e.g. fact sheets, newsletters, brochures, posters, flyers)
- Information repositories at public places (e.g. libraries, distribution centres, community centres, schools)
- Technical reports (e.g. proposed Management Plan for dolomitic areas)
- Poster displays

- Briefing meetings/workshops (this technique worked well in developing this guideline document and works well when one needs to obtain stakeholder input), and
- Industrial theatre (this technique works especially well in rural areas where literacy levels are low and in dealing with young stakeholder groups).

As previously mentioned, there is no “blueprint public participation process” as each geographical area has its own unique group of stakeholders. The social profile of these stakeholders should be well-known to the public participation practitioner or the Water Manager. For example, when convening meetings with people living in remote rural areas, it would be considered impractical to invite them by letter to a meeting 100 kilometres from where they live. One should be aware that such cases may involve considerable additional effort. There may often be a need to first create awareness about the dolomitic water resource, and to provide people with sufficient information in a way that is applicable to their level of comprehension (e.g. visual posters with photographs, community theatre) in order to build trust and to capacitate them to contribute meaningfully.

The Water Manager, who has on-going contact with stakeholders in his area, generally tends to know stakeholders’ preferences in how they like to be consulted. Thus, certain groups may prefer informal discussions around a table with key representatives, while other groups may prefer formal workshops. It may sometimes be necessary to combine techniques to share information. For example, when this Guideline was being developed, stakeholders were informed by an announcement letter, received a draft copy of this document and were invited to workshops.

3.4.4 Step 4: Obtaining input from stakeholders

Obtaining input from stakeholders will not only enrich the public participation process but will build understanding, trust, ownership and a willingness to work together. The objective in this case is to find sustainable solutions for the management of water resources in dolomitic areas. However, one will need to be sensitive to the methods adopted when communicating with different stakeholder groups. For some groups, a document describing the project may be sufficient, while others may require small meetings with visual presentations and illustrations.

Many techniques are available to obtain input from stakeholders, including one or a combination of the following techniques:

- Information hotline
- Comment sheets and questionnaires
- Community facilitators visiting communities
- Site visits

- Focus group meetings
- Open houses
- Public meetings and workshops, and
- One-on-one interviews.

> **NOTE:**
>
> Section 6.2.3.2 and Boxes 13, 14, 15 and 16 of the Department's Generic Guidelines for Public Participation (September 2001) provide more information about how to convene meetings with stakeholders.

Note that the advantage of bringing people together in a meeting, workshop or open house exposes the different viewpoints of different groups to each other. This has the benefit of creating better understanding and appreciation of each other's situations and challenges, and developing new ideas and solutions.

3.4.5 Step 5: Feedback to stakeholders

Regular feedback (every three months) to stakeholders is an essential part of the public participation process. It ensures that stakeholders are constantly aware of new information, decisions and the consequences of the decisions and/or activities. It also encourages their continued involvement in the process. Feedback to stakeholders can be by means of:

- Feedback letters
- Issues and Response Reports
- Media releases
- Fact sheets, newsletters, brochures, flyers
- Meetings, workshops, open houses, focus groups, and
- Stakeholder forums.

> **NOTE:**
>
> See **Section 6.2.3.3** and Box 17 of the Department's Generic Public Participation Guidelines (September 2001) for information on how to solicit feedback from stakeholders.

3.4.6 Step 6: Consideration of stakeholders' contributions

The international Best Practice guidelines for public consultation specifically note that stakeholders should have the opportunity to verify that all comments they have raised have indeed been considered. Stakeholders' contributions should be reflected back to them after each milestone in the process. They need to feel heard, otherwise they either lose interest or mistrust the process. In particular, they must be able to see *where* their issues have been taken up in the process, and if not, must receive an explanation as to why not. Experience also shows that, once stakeholders have the opportunity to consider the diversity of views raised by the various sectors of society, it is easier to accept trade-offs as a result of conflicting views.

An Issues and Response Report is useful in this regard. This report should be expanded as the process progresses, and serves to provide feedback to stakeholders as well as acting as a useful record of all contributions.

Acknowledgement of stakeholders' contributions is important. Written contributions can be acknowledged in writing (letter) and contributions at meetings by distributing the proceedings within one month of the meeting, formally asking those who attended to ensure, within five working days of receiving the proceedings, that their contributions have been captured accurately.

3.4.7 Step 7: Implementation

To ensure sustainability of the process, stakeholder involvement should continue into the implementation phase, in this case the implementation of a management plan for dolomitic areas. This can be achieved through:

- Ongoing regular feedback
- Ongoing communication and awareness creation, and
- Formation of a Stakeholder Forum or a Stakeholder Monitoring Committee.

3.5 Risk communication principles

Conducting public participation in sensitive areas with sensitive stakeholders can pose a challenge to those involved in the process and may require conflict resolution skills or knowledge of the main principles of risk communication. For example, dolomites occurring in urban areas are considered to be a sensitive matter, therefore the application of risk communication principles may be valuable to Water Resource Managers.

More than three decades of research and hundreds of articles published in scientific journals underpin the science of risk communication. Sandman (1986) says that *“the most common sources of risk information are people who are professionally inclined to ignore feelings (technical specialists, engineers, scientists). And how do people respond when their feelings are ignored? They escalate — yell louder, cry harder, listen less — which in turn stiffens the experts, which further provokes the audience. The inevitable result is the classic drama of stereotypes in conflict: the cold scientist or bureaucrat versus the hysterical citizen.”*

Water Managers who have contact with stakeholders can reduce the Department’s social risk by becoming familiar with and applying the basic principles of risk communication. Trust, credibility, personal contact and control form the basic foundation for risk communication. Some pointers are listed:

- Meaningfully interfacing with third parties requires experts and technical specialists to switch from right brain (content, data, statistics, science, facts) to left brain (feelings, empathy, respect; collaborative problem-solving)
- Accept and involve the public as a legitimate partner; listen to their specific concerns
- Understand that the risks that kill people and the risks that upset people are often completely different
- Do not use the DAD model: Decide, Announce, Defend. Leave room for dialogue and resolving disputes before decisions are implemented, otherwise costly delays may result later on
- Express caring, empathy and commitment, and respond humanely. Do not trivialise people’s feelings. These attributes account for more than 50 percent of trust in high-concern situations. When people are worried and upset, they don’t care what you know until they know that you care. People often decide if a person is caring within as little as nine seconds
- Show respect. Do not negate people’s concerns just because you are not of the same political orientation as they are. Their concerns may be real and sufficiently substantial to support legal action; listen first, then formulate your response
- Adapt to the fact that many people use health, safety and environmental risks as a proxy or surrogate for other social, political or economic concerns. Sometimes it is the only way they know how. Assist them to express their unspoken but real concerns
- Do not use complex and difficult probabilistic or technical language to communicate information about risks. Keep it simple. Avoid technical jargon and any words that teenagers won’t understand

- When people speak emotionally, do not immediately respond with data, but with sympathy and caring; breaking a conflict is often *“a matter of explicitly acknowledging the feeling (and the legitimacy of the feeling) before trying to explain anything substantive — because any effort to explain substance first will be experienced by people as just another way of not noticing how they feel”*

- Be honest, frank and open. Openly acknowledge past misbehaviour and current problems. Explain plans and financial commitment in place to rectify current problems and ask for suggestions

- Coordinate and collaborate with other credible sources. If air quality is the problem, compare emissions to international standards and guidelines. Indicate that the company will be guided by the country’s Air Quality Authority. If environmental management is the problem, make it known that the plant environmental management certification/ accreditation is being obtained, and explain what it means (continuous environmental improvement)

- Do not use the “wrong” public relations techniques. While public relations textbooks may highlight the need for quality information and mutually beneficial relationships, public relations often employ techniques such as stonewalling, smoke-screening, whitewashing and blaming someone else (Susskind and Field, 1996)

- Let go of some control. Allow stakeholders to select the dates and times of meetings, to indicate the language of their choice, to indicate by what methods they would like to receive their information, to assist in listing criteria for making choices, and to assist in exploring alternatives. Lay people, *“undeterred by conventional expert wisdom, often have good ideas that experts can adapt to the situation at hand; as a minimum, lay people are the experts on what frightens them and what would reassure them”*

- Discuss achievements with humility, and

- Honour commitments, and if not possible, be open and transparent about the problems.

3.6 Monitoring and evaluation of the public participation process

The monitoring and evaluation of a public participation process is an important component of the process, as it not only determines the way forward but also allows valuable lessons to be learned for future reference. Moreover, it can indicate the value that it has added to the assessment, planning and management of the water resource, and can provide water managers with an idea of the main challenges and how to manage these proactively.

A Public Participation Evaluation Report should be compiled, and should include important considerations in the evaluation process, for example:

- Did the public participation process meet the statutory and other requirements?
- Was the public participation process regarded as sufficient, that is, was it conducted with fairness, in an efficient manner, and with wisdom and stability? Did the outcomes lead to better decisions or management than the stakeholder groups would have been able to achieve individually?
- Did everyone gain something from the process (e.g. increased understanding, access to information, increased capacity to contribute/participate, enhanced partnerships)?
- Was the public participation process conducted well, adequately or incompletely?
- Were there any significant omissions from the process? What were the reasons for these omissions? And
- What are the pointers for improving the public participation process?

Relevant references to existing reading material on monitoring and evaluation of the public participation process are:

- Southern African Institute for Environmental Assessment (SAIEA) 2005. Training course - Public Participation in Environmental Assessment in Southern Africa. Developed as part of the SAIEA Calabash Project. First Edition, 2005.
- Southern African Institute for Environmental Assessment (SAIEA) 2004. A One-Stop Participation Guide. A Handbook for Public Participation in Environmental Assessment in Southern Africa.
- Greyling T and Pietersen T 2006. Guide to Public Participation in Environmental Authorisation: Theory and Practice. Golder Associates Africa, Midrand, South Africa.
- Web sites: International Association for Public Participation – http://www.iap2.org.

4 ASSESSMENT, PLANNING AND MANAGEMENT

4.1 Introduction

Volume 1 of the Dolomite Guideline (**Section 1.3**) summarises the importance of integrating the assessment, planning and management functions as follows:

- Assessment that is undertaken poorly can lead to poor planning. In turn, poor planning can lead to the adoption of unsuitable options and hence the unsustainable use of the resource, and

- Poor management is an inefficient use of the time and budget of the Department's operational personnel. However, given the linked nature of the functions, poor assessment, leading to poor planning, can result in the inefficient use of the assessment, planning and management budgets. This should clearly be avoided.

It is thus important that the assessment, planning and management functions are integrated, both vertically (between functions) and horizontally (between national, catchment and site-specific levels). **Figure 14** illustrates this integration, with the national, catchment and site-specific levels defined as follows:

- **National level** is not necessarily a geographic descriptor, but rather indicates the level and type of issues that need to be addressed. For water resources in dolomitic areas, these are typically cross-boundary issues, reconciliation of demand and availability or the interests of different stakeholder groups. These functions and responsibilities may be addressed by Departmental personnel in the National Office or by delegated groups.

- **Catchment level** includes functions and responsibilities that are focussed on aquifer potential and those measures that are required to ensure sustainable development and use. These will include such aspects as defining the water balance, rate of recharge to the aquifer, storage and exploitation potential, Resource Quality Objectives, accessibility of the resource to various users or stakeholder groups, and monitoring procedures. Catchment level functions will also include such issues as defining possible target areas that are suitable for the identified water use needs, and taking into consideration the impacts/unacceptable risks to the environment. These functions will generally be assigned to Departmental personnel in the Regional Offices, or to the CMAs when established and operational. In certain instances, these functions may be delegated to, and undertaken by, the DAMC or Dolomite Committees.

- **Site-specific level** includes site-specific functions for a particular target area. These will be the responsibility of the Water Service Provider, User Group, private organisation or individual. The users will be responsible for determining the site-specific aquifer potential, water balance, potential impacts, etc. Various well-fields could thus exist and be developed for use in one target area of the aquifer.

Figure 14 indicates the linkages between the various functions. The functions are summarised as follows:

- Assessment to a reconnaissance level (desk-top) of detail is undertaken at the national level, where the focus is on water availability (both quantity and quality) and water requirements in an area that typically spans more than one WMA. This assessment is refined to a pre-feasibility level at the catchment level, where the focus will be on defining the resource capability of the target aquifers in the geographical area of interest. A feasibility level assessment of the target area for development (and the ability to use the resource) is the focus at the site-specific level,

- Planning is undertaken at a reconnaissance level of detail at the national level where various options are weighed for further detailed study. The level of detail and accuracy is improved during a pre-feasibility study at the catchment level, where specific options are assessed. A full feasibility study and optimisation of designs is undertaken at the site-specific level, and

- Management of water resources is enabled through water allocation and water use authorisation. Management at site-specific level entails, among others, maintenance and control, monitoring and measurement, data management and reporting, auditing and management of impacts. Review of compliance with water use authorisation conditions is undertaken at the catchment level, as well as managing the cumulative impacts of the various water user groups on the system. The auditing of compliance with strategic goals and strategic reviews is undertaken at the national level.

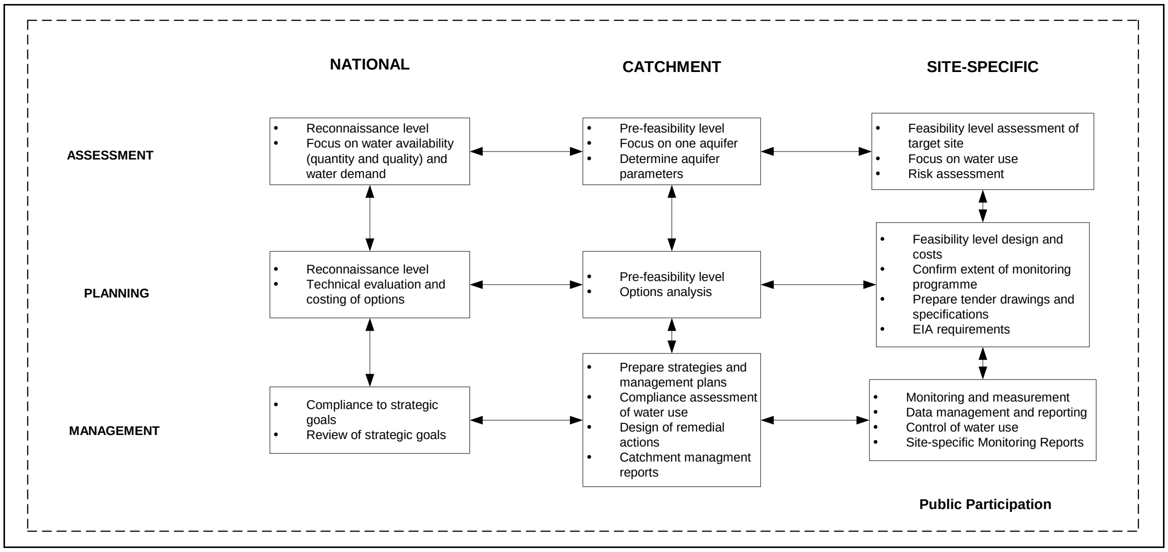

Figure 14: Linkages between assessment, planning and management

4.2 Integration between assessment, planning and management

Figure 15 illustrates the overall recommended process in the integration of the assessment, planning and management functions at the various levels. The diagram illustrates the inputs (from the various catchment level ISPs), the process for assessment, planning and management, and the outputs. In reality, not all steps may need to be followed. For example, the reconnaissance level national assessment may provide sufficient catchment information for the site-specific planning functions. However, if more data is needed for site-specific planning, then it will be gathered at the site-specific level, due to the scale of the area and the level of detail that is required.

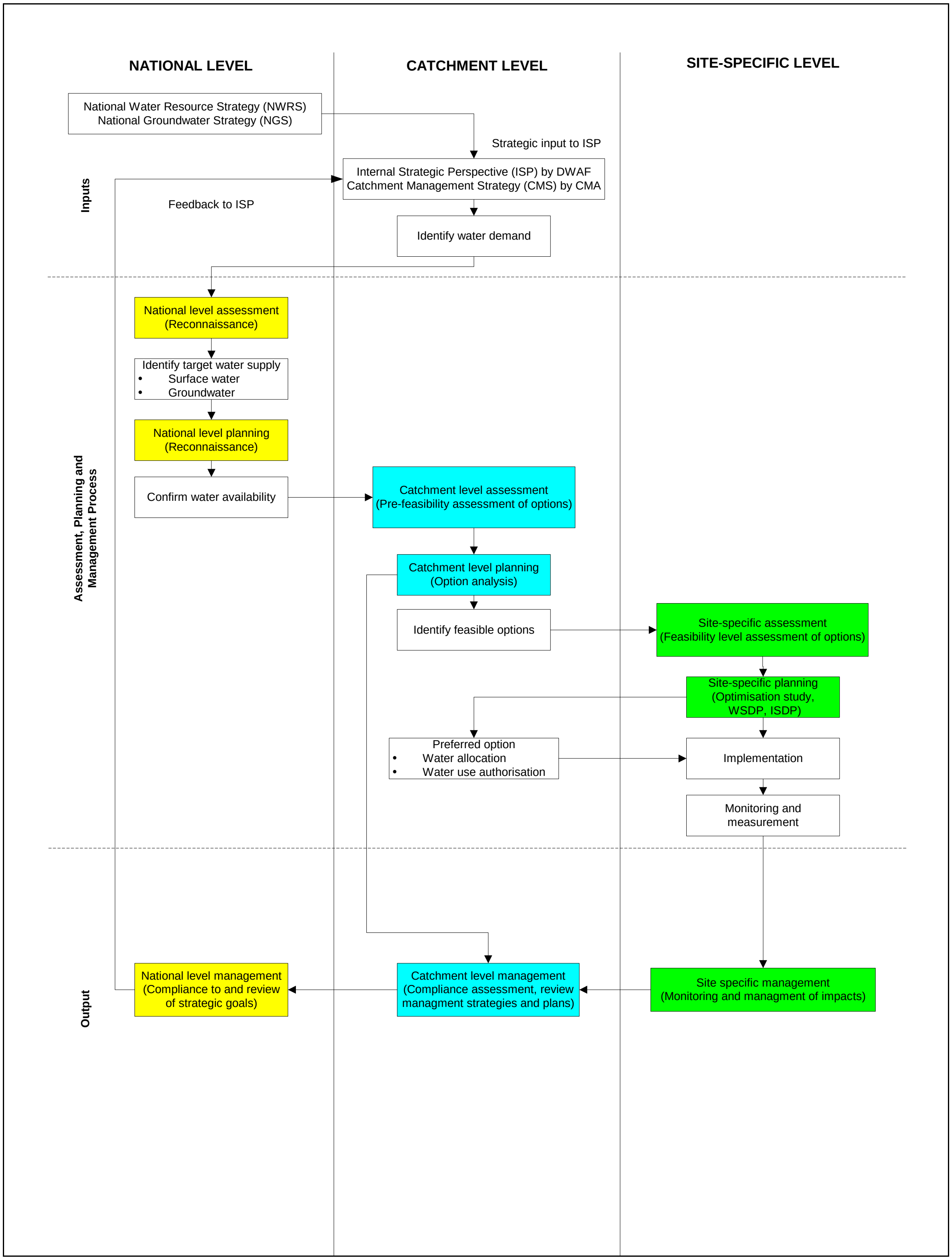

Figure 15: Process for the integration of assessment, planning and management

5 ASSESSMENT

5.1 What is meant by assessment?

Assessment is the first step in the IWRM process. It determines the status quo (in terms of both water quantity and quality) of the water resources in the dolomite areas of a particular WMA or catchment, and defines the geographic extent of the dolomite aquifer. Assessment includes the determination of the dolomitic aquifer resource capability with respect not only to sustainable, economic and technically feasible abstraction but also to the impact of such abstraction on spring and river flow, ecological requirements and ground stability. Assessment also summarises existing water requirements for all sector users, taking into account demographic and socio-economic changes.

5.2 Why is assessment important?

The assessment function is important because:

- The dolomitic aquifer is an important, widespread and easily exploitable groundwater resource and thus has high potential availability with good water quality
- Information is not currently, or readily, available in the correct detail and format to answer questions on groundwater availability and quality
- It enables the planning and management functions
- It helps to understand local dependence on the dolomitic resource
- It confirms the current impact on, and use or abuse of, the dolomitic resource
- It helps to determine what questions are to be addressed at the various levels, and
- It enables risk management (e.g. the use of groundwater during severe drought).

5.3 Methodology and details for assessment

The steps required to assess the water resources in dolomitic areas and to prepare inputs for the subsequent planning phases are similar irrespective of the scale (i.e. national level, catchment level or site-specific/local level). The process includes such aspects as existing use, development potential as a bulk or local water supply, importance of springs and baseflow, dependence of ecology and identifying potential impacts. This common methodology and the steps involved are described below. It should be noted that the application of this methodology will vary at the national, catchment or site-specific level due to the scale and/or spatial intensity of the investigations.

National level assessment is likely to be undertaken by personnel of the Department's National Office, with assistance from the Water Manager/Planner. The assessment includes a desk study to obtain information on water availability and requirements over various catchments/ compartments. Depending on the amount and nature of the date available it might be necessary to undertake the collation of information from boreholes and springs. From this study, the Water Manager will be able to identify issues, areas of water shortage and areas where additional information is required.

Catchment level assessment has its focus on one or more aquifers in a catchment. The aim is to determine the parameters of the target aquifer(s) in sufficient detail to enable catchment level planning (pre-feasibility) studies of these aquifers. Catchment level assessment will therefore require the collection of information from existing boreholes and the siting, drilling and testing of exploratory/monitoring boreholes in key localities to provide the necessary data.

Site-specific assessment includes a detailed assessment of the target area to determine the ability of the aquifer in that area to support the requirements on a sustainable basis. Site-specific assessment thus involves substantial on-site drilling and testing, and may include detailed numerical groundwater modelling.

Figure 16 provides details on the assessment process. The various steps in the process are described in the following sections.

5.3.1 Step 1: Undertake desk study and remote sensing

The objective of a desk study is the collation, scrutiny and evaluation of available and relevant meteorological, geographical, geological, hydrogeological and groundwater quality data. The tasks involved in gathering available data/information will typically include:

- Obtaining information related to groundwater, including:
  - Geological and hydrogeological maps
  - Hydrogeological reports
  - Borehole logs
  - Geophysical profiles of exploration and/or monitoring boreholes previously drilled in the area
  - Test pumping results
  - Groundwater quality data, and
  - Monitoring data, studied to gather direct hydrogeological information across the area of investigation

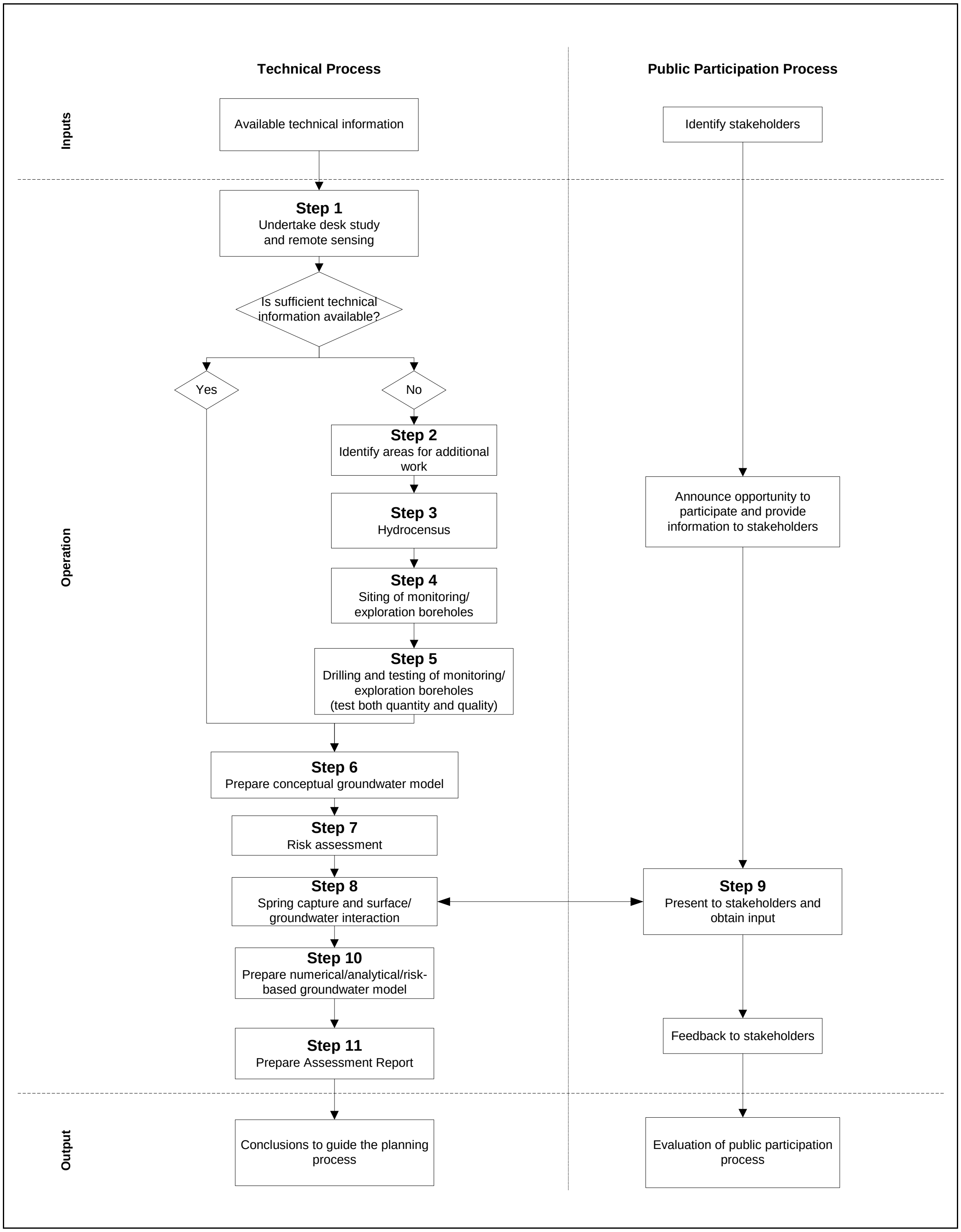

Figure 16: Assessment Process

- Collating all available information into a water balance, indicating water availability (quantity and quality) and water requirements, and
- Other aspects, including land use planning and use and potential water requirements.

Aerial photography, satellite imagery, geological and hydrogeological maps form the basis of remote sensing. These may be supplemented with airborne digital terrain mapping and aeromagnetic surveys. Airborne radiometrics may also be of value in areas where the potential of contamination by radionucleids is known or suspected.

This information is used to establish a background or baseline geological and hydrogeological reference for the identified study area, including possible boundaries of the dolomite aquifer and distribution of compartmentalising dykes, together with any other potential aquifers within the catchment. Once the desk study has been undertaken, the level of input required and the necessary programme(s) are identified for further assessment and / or the planning phases.

> **NOTE:**
>
> Further details concerning data requirements are available in the Standard Descriptors for Geosites, DWAF/NORAD, 2004.

> **NOTE:**
>
> The WRC report No. 1090-2/2/03 contains details on assessing terrestrial groundwater dependent ecosystems in South Africa.

5.3.2 Step 2: Identify areas for additional work

Using the results from the desk study, undertake a gap analysis to identify:

- The catchment(s) where there is sufficient information with which to reconcile water availability and requirements (quantity and quality); in these instances, the personnel will proceed to Step 5; or
- The catchment(s) where there is insufficient information for the assessment of water availability and requirements; in these instances, the personnel will list the required information and the methods recommended to obtain the information.

5.3.3 Step 3: Hydrocensus

A hydrocensus is essentially site familiarisation and the collection of data from the study area and surrounding environs. It comprises a census of key boreholes, wells, springs and sinkholes. The extent (intensity and area covered) of the hydrocensus will depend upon the level of the study (national, local or site-specific) and the particular requirements of the study, but must provide wide coverage of the catchment(s) to allow an overview of the dolomite aquifer to be captured at the necessary level of detail. The Department's National Office, CMA or Water Manager will be responsible for the hydrocensus.

The hydrocensus involves the collection of data from each facility, including:

- GPS co-ordinates
- Owner
- Current use
- Reported yield
- Reported or measured borehole or well depth
- Static water level
- Field measurements of pH and conductivity
- Collection of water samples from key selected boreholes, wells or springs for quality analysis
- Existing equipment, and
- Surface water quality should also be considered as part of the hydrocensus for use in surface water - groundwater interactions.

All field data must be recorded on standard hydrocensus sheets (refer to the example in **Appendix C**) and captured in the relevant electronic database.

The Water Manager will use the hydrocensus data to determine the prevailing hydrogeological conditions, order of magnitude of existing groundwater use and dependence, areas of intensive irrigation, etc.

The success of any hydrocensus is almost entirely dependant on the cooperation of the local communities and private landowners. The Water Manager should thus ensure that prior and considered communication is undertaken by means of public participation channels to inform landowners of the proposed hydrocensus.

NOTE:

Further details are available in the DWAF/NORAD, 2004 document, **Section 3.1**: Involving community members in a hydrocensus.

5.3.4 Step 4: Siting of monitoring/exploration boreholes

Monitoring and exploration boreholes may be required in order to provide sufficient information on the target aquifer(s). The number and location of these boreholes will be determined by the level of the study, the nature of the dolomite aquifer(s), the results of the desk study and the hydrocensus data.

The Water Manager will ensure that the siting of groundwater exploration and monitoring boreholes is undertaken by a qualified and experienced Hydrogeophysicist/Hydrogeologist. Siting of boreholes for any use by a diviner is **not** permitted.

The Hydrogeologist will undertake the following tasks in siting boreholes:

- Understand the scope and objectives of the assessment and the purpose of the borehole(s),
- Identify or select the general area within the dolomite aquifer where boreholes are required,
- Interpret the black and white stereo pair air photography and satellite imagery in and surrounding the area of interest to identify structural features (e.g. dykes, faults, fracture zones), weathering and karst features of importance to groundwater occurrence,
- Undertake a geological appraisal and select sites for the geophysical survey, and
- Undertake a geophysical survey involving the application of proven techniques applicable to dolomitic environments. Such techniques will involve one or more of the following, in order of preference:
    - Magnetics
    - Gravity
    - Electromagnetics
    - Electrical resisitivity, and
    - Seismics.

The gravity technique is particularly useful for delineating karst zones within the dolomite where groundwater occurrence is most favourable.

The application of seismic techniques is not recommended for groundwater exploration due to its high cost and the availability of alternative techniques (mentioned above).

NOTE:

Further information concerning geophysical techniques can be found in numerous references. The recommended references are:

A Practical Manual on the Resistivity Method, prepared by J S V Van Zijl, 1985, published by the CSIR

The Magnetic Method, a Geophysical Field Manual for Technicians, No. 1, published by the South African Geophysical Union, and

The Electromagnetic Method, a Geophysical Field Manual for Technicians, No. 3, published by the South African Geophysical Union.

Applied Geophysics by W. M. Telford, L. P. Geldart, R. E. Sheriff, ISBN 0521339383.

5.3.5 Step 5: Drilling and testing of exploratory/monitoring boreholes

Exploratory/monitoring boreholes must be drilled to the required technical specifications by an experienced contractor. The Water Manager/Hydrogeologist will ensure that the appointed contractor understands and signs the relevant technical specifications.

Field operations should be undertaken under the supervision of the Hydrogeologist appointed by the Water Manager to ensure that the boreholes are drilled:

- In the correct location
- To the required depth, and
- According to the applicable specifications (**Appendix B1** and **Appendix B2)**.

NOTE:

Additional information on groundwater protection is available in the DWAF/NORAD, 2004 document: Guidelines for protecting boreholes and wells.

The supervisor will prepare:

- A geological log of the dolomite lithology
- A construction log of the borehole, indicating drilling and casing diameters and depth, formation stabiliser inserted, grouting and completion details
- A hydrogeological log of features important to groundwater occurrence, including weathering depth, fracturing, wad, fissures, cavities, karst and information concerning depth of water strikes and blowing yield, lost circulation, and
- Signature for measured quantities agreed on site with the driller.

NOTE:

Forms for capturing data are included in **Appendix C**.

Technical details concerning the drilling of boreholes are included in **Appendix D**. The Water Manager/Hydrogeologist must ensure that the procedures described in **Appendix D** and adhered to.

IMPORTANT NOTE CONCERNING DRILLING COST

The Water Manager must be aware that drilling conditions in dolomite are often difficult due to the presence of fracturing, fissures, cavities, wad and karst. Accordingly, boreholes generally need to use larger diameters than those drilled in other lithologies, and often require the insertion of considerable quantities of casing.

Boreholes drilled in dolomite therefore tend to be more expensive than those drilled in shale, sandstone or granite.

It is often necessary to test exploratory/monitoring boreholes to obtain information on aquifer hydraulic parameters and groundwater quality. Testing should be undertaken by an experienced contractor in compliance with the required technical specifications. The Water Manager/ Hydrogeologist will ensure that the appointed contractor has signed the relevant technical specifications.

Field operations should be undertaken under the supervision of the Hydrogeologist appointed by the Water Manager to ensure that the boreholes are tested in accordance with the required specifications. The supervisor will sign for measured quantities agreed on site with the testing contractor.

Water samples should be collected from newly-drilled exploratory/monitoring boreholes according to the protocols outlined in **Appendix C** in order to provide data to supplement that collected during the hydrocensus. This data is used to determine prevailing groundwater quality across the dolomite aquifer within the catchment.

NOTE:

Forms for capturing data are included in Appendix C.

Technical details concerning the testing of boreholes (both quantity and quality) are included in **Appendix D**. The Water Manager/Hydrogeologist must ensure that the procedures described in **Appendix D** are adhered to.

5.3.6 Step 6: Prepare conceptual groundwater model

The conceptual groundwater model is prepared using the data collected during the previous steps and the model Table of Contents in **Appendix E1**.

In essence, the conceptual model describes the lithological composition of the dolomite aquifer, presence or absence of chert, aquifer boundaries, compartmentalising of the aquifer, fractures and faults, degree of weathering of the dolomite, distribution of karst features, presence or absence of springs and seepage zones, recharge potential, and distribution of water levels. The model must incorporate existing abstraction and land use (e.g. irrigation, mine waste dumps), since these have an impact or may have an impact on the available sustainable resources of the dolomite aquifer.

The model constitutes the conceptual level understanding of the aquifer and its behaviour, and provides the basis for future decision-making.

5.3.7 Step 7: Risk assessment

Proximity to existing boreholes

In order to minimise interference between adjacent boreholes, new abstraction boreholes in dolomitic aquifers should not be drilled close to any existing borehole. Recommendations concerning the minimum distance will form one of the conclusions of the assessment study. The minimum distance can vary significantly and depends on many factors, such as the type of aquifer (karst, fractured, weathered) and permeability of the aquifer. Where a group of boreholes are drilled to form a well-field, distances should be determined by the findings of the detailed hydrogeological survey.

Minimising the risk of pollution from nearby sources of contamination

In general, no water use borehole drilled in a dolomite aquifer should be located within a minimum distance of potential sources of contamination, including:

- Pit and Ventilated Improved Pit (VIP) latrines
- Animal kraals
- Effluent discharges from chicken hatcheries and piggeries
- Dip tanks
- Cemetery/graveyard/burial site
- Mine tailings dams, waste disposal sites, or
- Any other source, or potential source, of contamination.

Recommendations concerning the minimum distance will form one of the conclusions of the assessment study. The minimum distance can vary significantly and depends on many factors, such as the type of aquifer (karst, fractured, weathered), permeability of the aquifer, vulnerability of the aquifer and type of pollution source.

Water use boreholes should always be located up-gradient of a current or potential source of groundwater contamination. They should not be drilled within the floodline of a drainage channel, as these areas are prone to flooding.

NOTE:

Valuable information on various contamination risks is available in the DWAF/NORAD, 2004 document, **Section 3.4**: Guidelines on protecting groundwater from contamination, especially with regard to water sources and sanitation.

5.3.8 Step 8: Spring capture and surface water - groundwater interaction

Springs can be considered as an optional source of water to satisfy water requirements. Depending upon their yield and reliability, they can be used as stand-alone sources or in conjunction with abstraction boreholes. Springs are often vulnerable to significant variations in flow, and low-flowing springs often dry up completely during periods of drought.

Various methods of spring capture are available, ranging from small impoundments to weirs to large dams. Each method of capturing spring flow should provide protection to maintain the (pristine) water quality and impoundment.

Spring capture must involve the following considerations:

- Accurate determination of spring flow
- Seasonal/cyclic fluctuations
- Recharge to the spring flow
- Reserve requirements
- Current downstream use of spring flow
- Impact of current abstraction in the catchment/compartment contributing to the spring flow
- Impact of impoundment on wetlands
- Impact of impoundment on surface flow
- Surface water - groundwater interaction, and
- Contribution of dolomitic groundwater to streams, rivers and wetlands.

NOTE:

Further details for spring data and classification are available in the Standard Descriptors for Geosites, DWAF/NORAD, 2004.

5.3.9 Step 9: Present to stakeholders and obtain input

Present the outputs of the assessment of water availability and water requirements to the relevant stakeholders to obtain comment and feedback. The relevant stakeholders will have been identified as part of the public participation process (refer to **Section 4.4.2**).

5.3.10 Step 10: Prepare numerical/analytical/risk-based groundwater model

For some assessments, particularly at the site-specific level, it may be desirable or necessary to prepare a numerical, analytical or risk-based model of the aquifer.

Where a model is prepared, predictions of the long-term behaviour of the aquifer under the planned development can be made, and simulations of certain aspects being investigated, such as migration of pollution plumes with time, can be undertaken. Once the model has been finalised, this can be used as input to risk-based decision-making.

Various modelling packages can be selected for numerical modelling, the most common being Modflow, a three-dimensional finite difference modelling package, and FeFlow, a three-dimensional finite element modelling package.

Numerical modelling is highly specialised and will require the services of a modelling expert to advise on modelling requirements, capabilities and limitations, and to prepare and run the model. It must be noted that numerical modelling in dolomitic areas has a high data requirement, because of the 3D nature of the system and will thus only be effective where sufficient 3D information is available.

5.3.11 Step 11: Prepare Assessment Report

From the above assessments and consultation, identify issues with respect to IWRM and areas where the water balance indicates that there are current or potential water shortages. Possible water use options to meet current or future water requirements should also be identified. The Assessment Report will draw conclusions on the groundwater resources and applicable technical information. These conclusions will assist in guiding the planning process (see **Section 5**).

Finalise the assessment report detailing the conclusions reached and inputs for the planning phase. The report will include maps, borehole logs, test pumping data, water quality assessment, aquifer assessment and classification, protection zones, RDM requirements, and the delineation of potential target areas, as applicable.

> **NOTE:**
>
> A generic Table of Contents for the Assessment Report is included in **Appendix E.1** of Volume II.

5.4 Other specialist studies

In addition to providing a water source for domestic, urban, industrial and mining water use, dolomite aquifers are a vitally important link in the natural system. They sustain surface drainage through spring flow, base flow and wetlands. Because of their unique properties, they are vulnerable to groundwater pollution from domestic, industrial and mining waste.

Safety considerations are also important, as dolomite is susceptible to the formation of sinkholes which can have disastrous consequences. Sinkholes form when water levels are allowed to fluctuate by more than five to six metres or when the dolomite is dewatered. The most striking example is the numerous sinkholes that have formed in the Carletonville area due to dewatering of the aquifer by the gold mines.

The Water Manager must therefore consider all these aspects when undertaking assessment, planning and management of the dolomite groundwater resources in the catchment. Accordingly, specialist studies may be required in support of any planned development of the aquifer to confirm the ability of the aquifer to deliver the required water use, and to identify and quantify impacts. Such studies could include:

- Feasibility of implementing artificial recharge of the dolomite aquifer
- Identification of groundwater-dependant ecosystems (Colvin *et al*, 2003)
- Direct, indirect or unique/keystone ecosystems
- Determination of sensitivity of the landscape to fluctuations in water levels and resultant sinkhole formation, and
- Assessment of existing or planned infrastructure that may be affected.

These studies will require the appointment of specialist consultants and would normally form part of an overall assessment of the dolomite resources at a catchment or WMA level.

NOTE:

Additional information on groundwater protection is available in the DWAF/NORAD, 2004 document: Guidelines for protecting springs.

6 PLANNING

6.1 What is meant by planning?

Planning within IWRM is a process of matching water availability with water requirements. Planning typically involves the investigation of development options to meet water requirements through a predetermined sequence of increasingly detailed phases. Planning generally follows an assessment during which the various water development options (including groundwater options) are identified. Planning ensures that the information is made clear to the decision-maker.

6.2 Why is planning important?

The planning function is important because:

- It provides the rules and guidelines to enable sustainable use of the water resource, or recommends the use of existing guidelines

- It provides the "bigger picture" within which the dolomitic water resources can be managed, both current and future, and

- It provides the motivation for funding for the implementation of a particular water development option.

6.3 Framework for water resource planning

Water resource planning in dolomitic areas is undertaken within the framework of integrated water resource planning (IWRP) and integrated water resource management (IWRM). These integrated processes include the sustainable utilisation of water resources and the equitable distribution of water. They acknowledge that groundwater is an important and integral part of South Africa's water resources and its use should be planned and managed accordingly.

The Department has identified five core strategies to promote the successful implementation of IWRM in South Africa:

- Groundwater must be integrated into the management of water resources for the benefit of all the people of South Africa
- Groundwater needs to be promoted so that water resource managers, water users and the public are more aware of the role, occurrence and value of groundwater

- Hydrogeologists need to be encouraged and enabled to work outside their line function and to be integrated in broader water resource planning and management functions
- A larger, skilled and experienced specialist hydrogeological workforce is required, and
- Groundwater monitoring and the development of a hydrogeological information system are required to assist in the provision of data and information to those who need it.

6.4 National level planning: Methodology and details

National level planning is undertaken at a reconnaissance level. It is an initial exploratory study that provides a preliminary examination of an area, and includes a desk-top evaluation of the water use options to meet particular requirements.

Figure 17 summarises the steps involved in a national (reconnaissance) level planning study. The steps are described in more detail in the following sections. The inputs into the study are:

- The recommendations from the national level assessment, and
- Details of the Resource Quality Objectives, set during a public participation and planning process. The technical contribution for the integrity of the resource will be concluded in the assessment process and used as input.

NOTE:

The GRDM training manual (WRC project 1427), available from the Departments RDM office, provides additional details on setting the Reserve and Resource Quality Objectives.

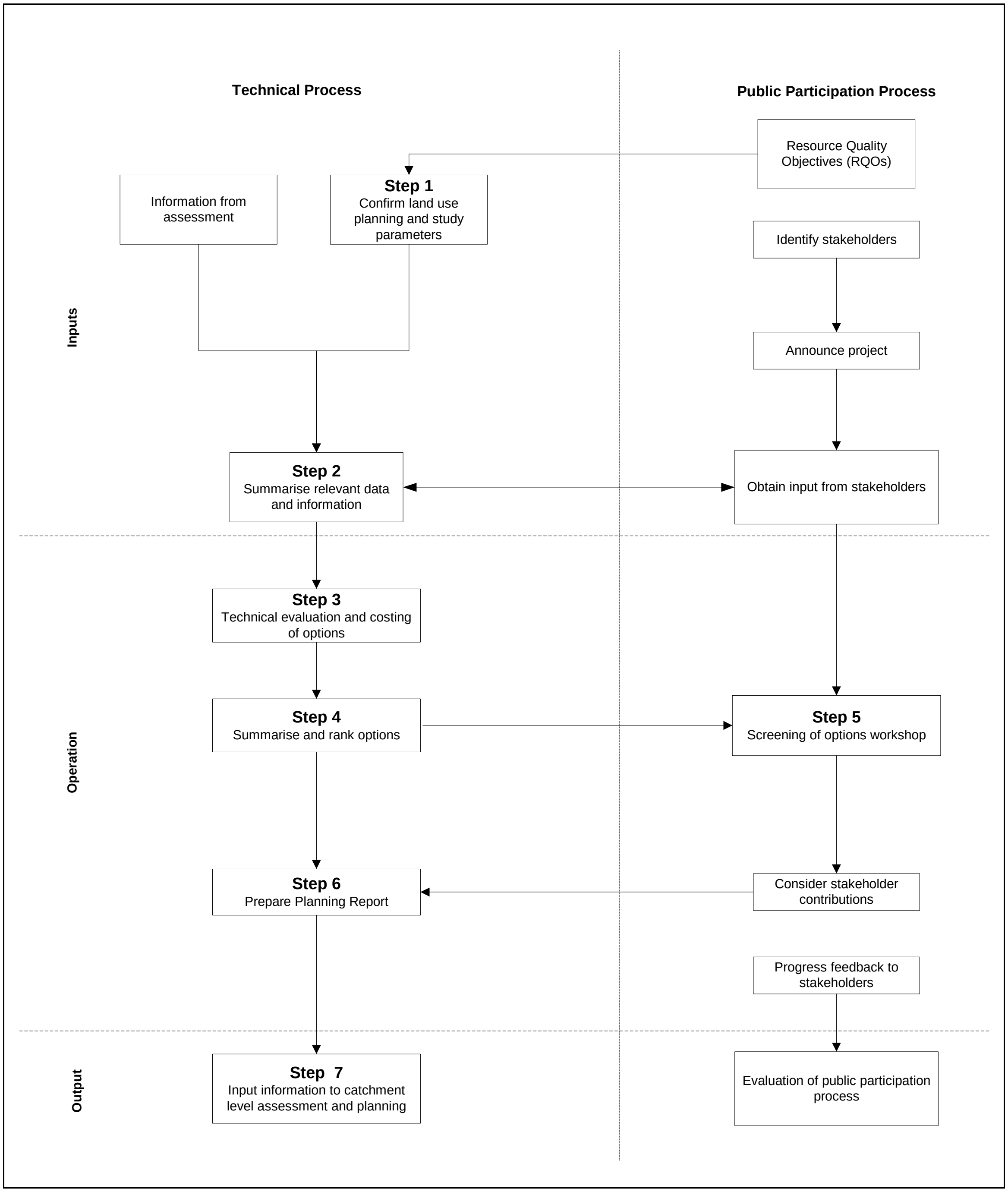

Figure 17: Process for national (reconnaissance) level planning

6.4.1 Step 1: Confirm land use planning and study parameters

In general, information on land use planning and the study parameters will be determined during the assessment phase. During this step, confirm:

- Land use planning for the study area, particularly in and around the target aquifer
- Requirements for water, including :
  - Likely geographic location for the requirements
  - Quantity of water required (m^3 per month)
  - Specifications on the quality of the water required, or any water quality constraints to be included in the planning process, and
  - The required assurance of use (i.e. the percentage of time in any given month that the water is required)
- Proposed water use options.

6.4.2 Step 2: Summarise relevant data and information

Summarise all available data and information on the water development options, as obtained during the assessment process, including:

- All existing Departmental and external reports and databases pertaining to the water use options
- Information from the national level assessment, and
- Details of the conceptual layout for the various water use options.

6.4.3 Step 3: Technical evaluation and costing of options

Evaluate the water use options at a preliminary level, including a desk-top assessment of the technical feasibility of the options, preliminary costs and potential fatal flaws. Only limited verification and field work should be required. This evaluation will thus be at a low level of accuracy and will include conceptual-level design input to address the following issues:

- Can the target aquifer meet water requirements on a sustainable basis (technical feasibility)?
- Technical details of each option and are these broadly acceptable
- Cost analysis of the various options
- Comparison of options, and
- Elimination of options with fatal flaws.

6.4.4 Step 4: Summarise and rank options

Summarise and rank the water use options in a format that can easily be presented to the stakeholders such that the stakeholders can make informed decisions.

6.4.5 Step 5: Screening of options workshop

Present the proposed water use options to stakeholders at a national and regional level to obtain information on fatal flaws and/or consensus on the perceived feasibility of the various options. This will take the form of workshops and focussed discussions. The relevant stakeholders will have been identified as part of the public participation process (refer to **Section 2.4.2**).

6.4.6 Step 6: Prepare Planning Report

Summarise the relevant information from the technical and public participation process into one report. This report will provide recommendations on which options can be taken forward to the catchment level (pre-feasibility) planning study.

> **NOTE**:
>
> A generic Table of Contents for the Planning Report is included in **Appendix E.2** of Volume II.

6.4.7 Step 7: Input information to catchment level assessment and planning

The information gathered during the national level planning process should feed into the catchment level assessment and planning processes. This will form the most basic information necessary to feed into a Catchment Management Strategy for the area.

6.5 Catchment level planning: Methodology and details

Catchment level planning is undertaken to a pre-feasibility level and is a precursor to the feasibility level study. The pre-feasibility planning study will require a level of field work that secures accurate information and data, and often requires considerable verification of aspects such as sustainable development, potential impacts, the technical feasibility and cost. This study is thus preceded by catchment level assessment and national level planning to obtain the necessary information to minimise the options to be evaluated at a pre-feasibility level.

A risk assessment of likely impacts of any proposed development will form part of the planning process, since this can be a fatal flaw in any option on dolomite.

NOTE:

Further information concerning risk assessment in dolomite can be found in Tolmachev, V, (2005), Buttrick, D B et al, (2001) and Buttrick, D B and van Schalkwyk, A, (1995).

Figure 18 summarises the steps involved in a catchment (pre-feasibility) level planning study. The steps are described in more detail in the following sections. The input into the process comprises the information from the national level planning process and the catchment level assessment.

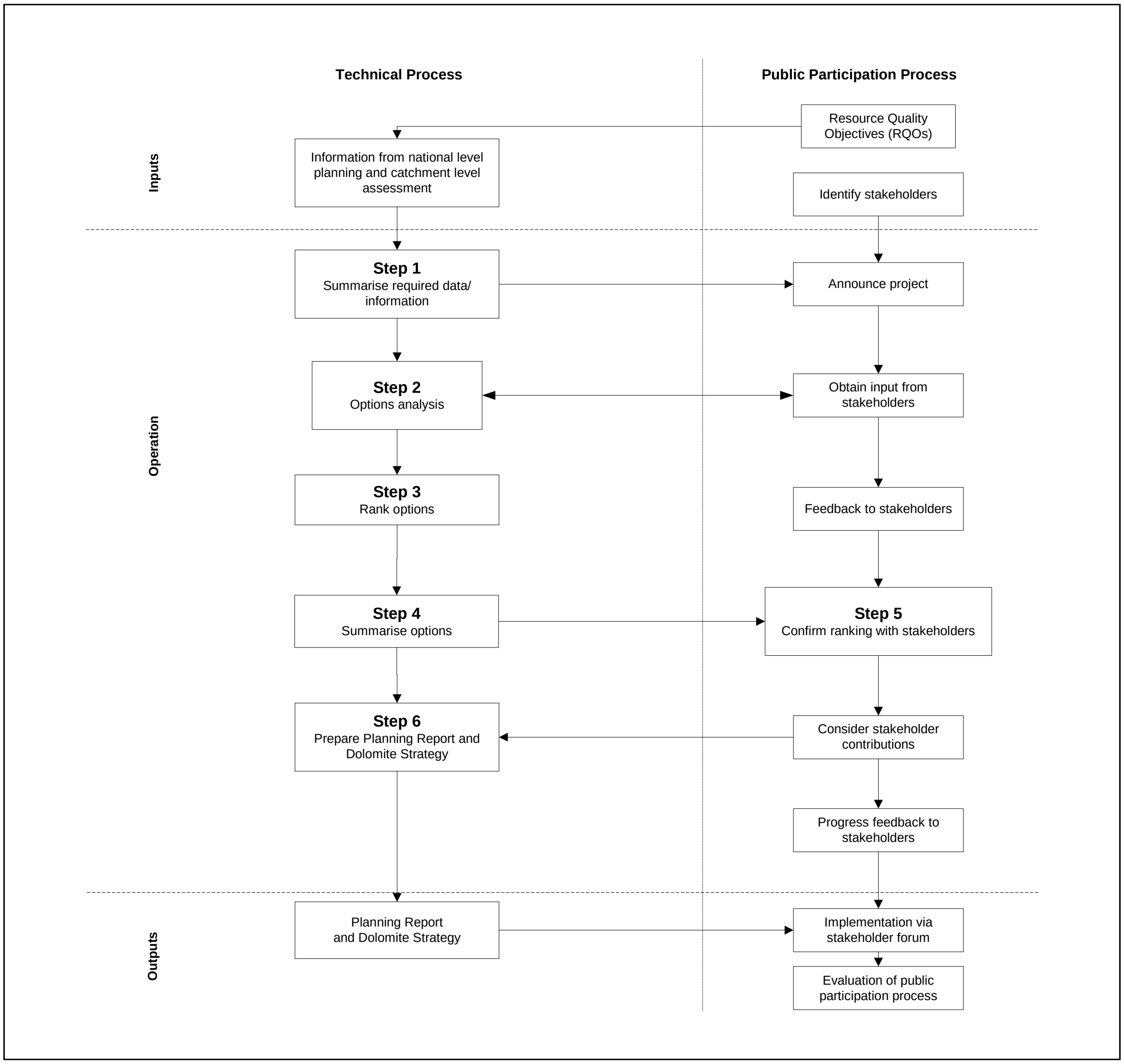

Figure 18: Process for catchment (pre-feasibility) level planning

6.5.1 Step 1: Summarise required data/information

Obtain the information and recommendations from the national level planning and catchment level assessment processes that are required for planning, design and costing purposes in the catchment level planning process.

6.5.2 Step 2: Options analysis

Undertake sufficient pre-feasibility level design and costing to be in a position to assess the various water use options. Each option should be assessed on the basis of: a) social considerations, b) potential environmental impact, c) economic and financial viability, d) technical feasibility, e) long-term land use, and f) regulatory considerations.

6.5.3 Step 3: Rank options

Rank the water use options using the results of the assessment from Step 2. **Figure 19** and **Figure 20** provide examples of an evaluation tool that can be used to rank the options at a pre-feasibility level.

	1	2	3				Consequence of success					
							Social	Environmental	Economic	Technical	Long-term land -use	Regulatory
1	1	2	3	4	5	1	No benefit to local community	Very high environmental impact	Very high cost	Not sustainable	No beneficial impact on land-use	Very difficult passage through regulatory requirements
2	2	4	6	8	10	2	Limited benefit to local community	High environmental impact	High cost	Limited sustainability	Limited beneficial impact on land-use	Difficult passage through regulatory requirements
	3	6	9	12	15	3	Some benefit to local community	Medium environmental impact	Average cost	Short-term sustainable	Some beneficial impact on land-use	Some dificulties with regulatory requirements
	4	8	12	16	20	4	Large benefit to local community	Low environmental impact	Low cost	Medium-term sustainable	Large beneficial impact on land-use	Easy passage through regulatory requirements
3	5	10	15	20	25	5	Significant benefit to local community	Very low environmental impact	Very low cost	Long-term sustainable	Significant beneficial effect on land-use	Very easy passage through regulatory requirements
	1	2	3	4	5							
Probability of success	Very Low	Low	Medium	High	Very High							

STRATEGIC ASSESSMENT MATRIX

KEY

Red	Highly undesirable
Yellow	Medium desirability
Green	Highly desirable

Figure 19: Strategic assessment matrix for water use options

Assessment of short-listed water supply options

OPTION	Weighting	1		2		3		4		5		6		7		8	
		Water supply Option # 1		Water supply Option # 2		Water supply Option # 3		Water supply Option # 4		Water supply Option # 5		Water supply Option # 6		Water supply Option # 7		Water supply Option # 8	
Evaluation criteria		Consequence	Probability	Consequence	Probability	Consequence	Probability	Consequence	Probability	Consequence	Probability	Consequence	Probability	Consequence	Probability	Consequence	Probability
Social	1	2	2	2	2	2	2	4	4	4	4	3	2	5	4	2	2
Environmental	1	2	2	5	4	2	2	4	3	4	4	5	4	4	4	4	4
Economic	1	2	3	2	3	2	3	4	3	2	3	4	3	3	3	3	3
Technical	1	2	2	4	4	5	4	4	3	4	3	4	4	4	4	2	4
Long-term land use	1	2	2	2	3	2	2	3	3	4	4	2	3	2	3	3	3
Regulatory	1	2	3	3	3	2	3	4	4	4	4	4	4	4	4	2	4

EVALUATION OF OPTIONS		Water supply Option # 1	Water supply Option # 2	Water supply Option # 3	Water supply Option # 4	Water supply Option # 5	Water supply Option # 6	Water supply Option # 7	Water supply Option # 8
Social		4	4	4	16	16	6	20	4
Environmental		4	20	4	12	16	20	16	16
Economic		6	6	6	12	6	12	9	9
Technical		4	16	20	12	12	16	16	8
Long-term land use		4	6	4	9	16	6	6	9
Regulatory		6	9	6	16	16	16	16	8
Average		4.7	10.2	7.3	12.8	13.7	12.7	13.8	9.0
Highly undesirable		1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3
Medium desirability		4 to 11	4 to 11	4 to 11	4 to 11	4 to 11	4 to 11	4 to 11	4 to 11
Highly desirable		12 to 25	12 to 25	12 to 25	12 to 25	12 to 25	12 to 25	12 to 25	12 to 25
Ranking		**8**	**5**	**7**	**3**	**2**	**4**	**1**	**6**
Fatal flaw assessment		**acceptable**	**acceptable**	**acceptable**	**acceptable**	**acceptable**	**acceptable**	**acceptable**	**acceptable**

Figure 20: Pre-feasibility level screening of options

6.5.4 Step 4: Summarise options

Summarise the water use options in terms of technical feasibility, economic and financial viability and potential environmental impact. The summary of water use options should be presented in a manner that enables the stakeholders to make informed decisions.

6.5.5 Step 5: Confirm ranking with stakeholders

Arrange interaction meetings and presentations with stakeholders at which the results of the ranking process and the pre-feasibility level designs and cost estimates can be discussed with the stakeholders and consensus reached on the options that should be pursued.

6.5.6 Step 6: Prepare Planning Report and Dolomite Strategy

Use the results of the previous steps to recommend the water use options to be taken to the feasibility level stage and prepare the Planning Report. This information will typically feed into the Catchment Management Strategy for an area.

> **NOTE**:
>
> A generic Table of Contents for the Planning Report is included in **Appendix E.2** of Volume II.

6.6 Site-specific planning: Methodology and details

Site-specific planning is undertaken at a feasibility level. The feasibility level planning study is an intensive investigation and optimisation of the most beneficial layout of the scheme under investigation, resulting in the best layout of the scheme and its major dimensions and final specifications. This study will provide sufficient information to enable detailed design of the preferred scheme.

The feasibility level planning study is preceded by a detailed assessment of the feasible options at the site-specific level. The assessment will include siting, drilling and testing of boreholes, and then using this information to derive a conceptual hydrogeological and, if necessary and applicable, a numerical model of the aquifer.

The requirements of the Environment Conservation Act (Act No. 73 of 1989) in respect to Environmental Impact Assessments (EIA) must be understood and adhered to as necessary. The National Environmental Management Act (NEMA) (Act No. 107 of 1998) contains details specifying which proposed activities require an EIA, and to what level this should be undertaken. This is in addition to any licence application that may be required for the proposed use from the Department of Water Affairs and Forestry or the CMA.

Figure 21 summarises the steps involved in a pre-feasibility level planning study. The input to the process includes the information from the catchment level planning and site-specific assessment processes. The steps in the site-specific planning process are described in more detail in the following sections.

> **NOTE:**
>
> Additional information is available in the DWAF/NORAD, 2004 document, **Section 7.2**: Introductory guide to appropriate solutions for water and sanitation and **Section 7.3**: Decision-making framework for Municipalities.

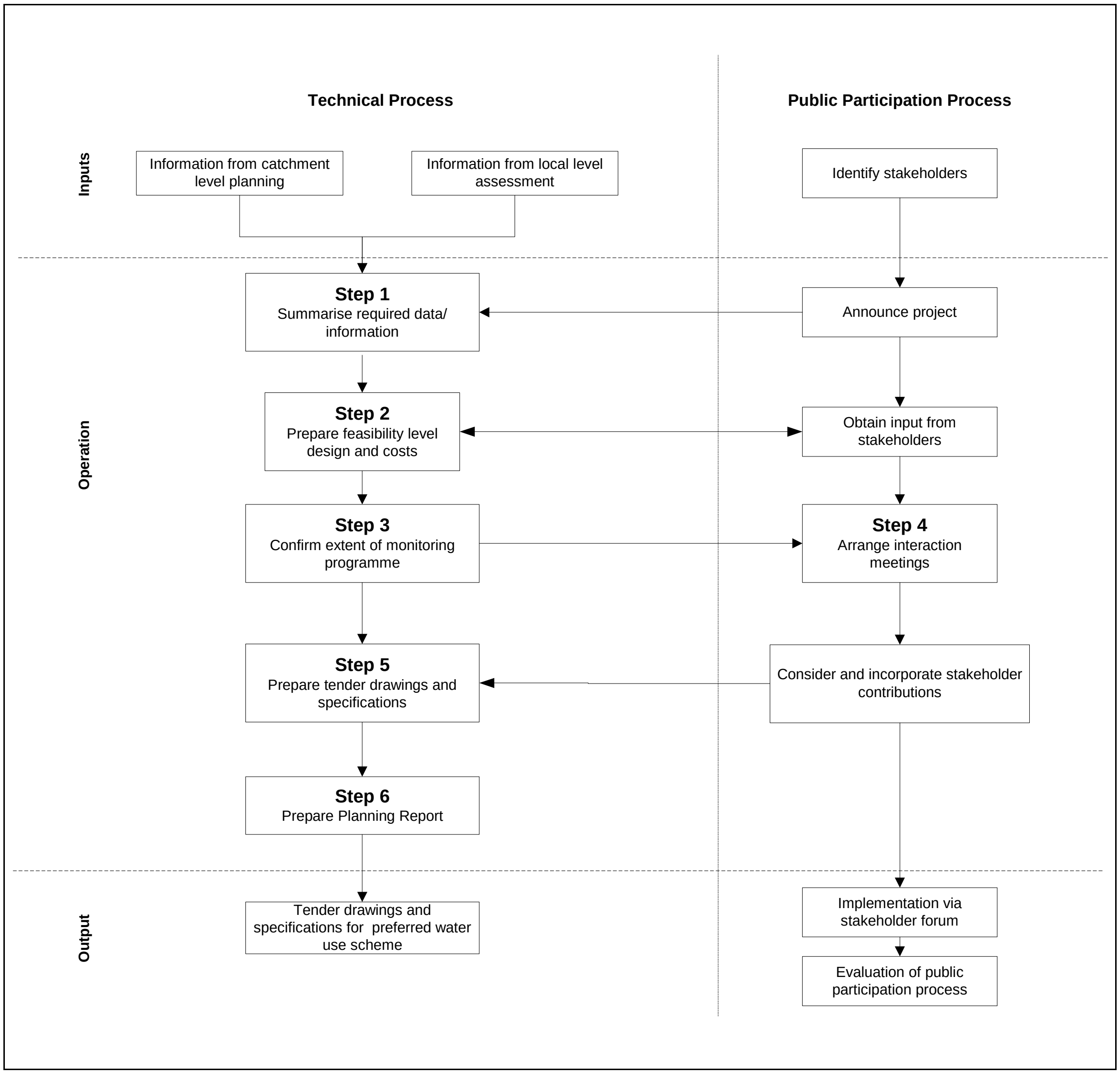

Figure 21: Process for site specific (feasibility) level planning

6.6.1 Step 1: Summarise required data/information

Obtain the information and recommendations from the national level planning and catchment level assessment processes that are required for planning and design purposes in the site-specific level planning process.

The EIA requirements applicable to the proposed project must be confirmed and EIA approval must be obtained from the relevant provincial environmental office, where required. It is important to note that obtaining a Record of Decision may take several months for a large development project, and sufficient time must therefore be allowed for this process.

NOTE:

Further information concerning the EIA process and requirements can be found in Environment Conservation Act (Act No. 73 of 1989)

6.6.2 Step 2: Prepare feasibility level design and costs

The design team will prepare the feasibility level drawings and specifications, and the associated costs, for the preferred water use options. The team will submit these drawings, specifications and costs to the Water Manager for approval.

The feasibility level design will include an optimisation of the various elements of the preferred water use option, including:

- Configuration and design of water use/monitoring boreholes
- Layout and routes for the water collection and distribution system
- Design of water use pipelines (diameter, wall thickness, etc)
- Material specifications for pipelines storage systems etc, and
- Detailed assessment of the likely impact of implementing the preferred water use scheme, waste dump and/or other land use option on the integrity of the aquifer (quantity and quality).

NOTE:

The production boreholes required for the feasibility level design will be positioned following a risk assessment.

6.6.3 Step 3: Confirm extent of the monitoring programme

The monitoring programme and plan will be prepared during the planning process, incorporating:

- Objectives to be met in the monitoring programme
- Location of the monitoring points, and
- Frequency of monitoring that should occur and constituents to be analysed.

Confirm the extent of this monitoring programme with the relevant role-players.

6.6.4 Step 4: Arrange interaction meetings

Arrange interaction meetings and presentations with stakeholders to present and discuss the design details and costs associated. Incorporate comments and suggestions from the stakeholders in the final reporting.

If at this stage, the preferred option under investigation has a fatal flaw or is too costly, the process stops and another option is investigated.

6.6.5 Step 5: Prepare tender drawings and specifications

The design team will prepare the tender drawings and specifications for the preferred water use option. This will include the following details:

- Final design, positioning and drilling of the water use boreholes
- Pumping tests of the boreholes to confirm yields
- Drilling plan for monitoring boreholes
- Construction plans for water collection and distribution pipelines
- Construction plans for water storage systems, if applicable
- Details of construction cost estimates
- Proposed construction programmes, including milestone and target date(s) to completion
- Budget for the preferred scheme, and
- Implementation Plan for the preferred scheme.

The team will submit these drawings, specifications and costs to the Water Manager for approval. Examples of generic technical specifications and drawings are included in **Appendix D.** These can be used by:

- The Water Manager as a guide for inclusion in tender documents for the specific work, and
- The field Hydrogeologist to ensure adherence and compliance by the contractor.

> **NOTE:**
>
> Additional information is available in the relevant Water Service Development Plans (WSDPs), Integrated Development Plans (IDPs) for the area and Provincial Spatial Development Frameworks.

6.6.6 Step 6: Prepare Planning Report

Prepare the Planning Report. This will include a recommendation for the preferred option for implementation.

> **NOTE**:
>
> A generic Table of Contents for the Planning Report is included in **Appendix E.2** of Volume II.

7 MANAGEMENT

7.1 What is meant by management?

Management of dolomitic groundwater resources relates to the sustainable use and development of these resources. It focuses on the sustainable development of the groundwater resources without compromising dolomitic resource integrity (quantity and quality). Management thus involves monitoring quantity and quality over a long-term period and the use of this information to determine compliance against set goals and to assess whether the strategic goals of the Department are being met.

Management is generally an iterative process that has two components:

- Setting management objectives, including strategic objectives set at a national level, the catchment management strategy (CMS) and management plans set at catchment and site-specific levels, and
- Monitoring and reporting against these objectives, as well as updating the strategies and management plans on an ongoing basis.

Monitoring and reporting will provide information to assess the operations against the strategic goals and objectives (compliance assessment). The results of the compliance auditing will be used to devise action plans and update the strategic goals, if required.

7.2 Why is management important?

The management function is important because it provides:

- A continuous record of the response of the aquifer to various inputs and outputs, including recharge, base flow, impacts, evapotranspiration, etc
- A tool to confirm the continued suitability of the aquifer for the specific water use purposes. Monitoring measures groundwater information continuously and can detect reduced yields and the induced inflow of poorer quality water. This is particularly important in dolomite aquifers due to the sensitivity of the aquifer
- Information for the characterisation of the aquifer on a regional scale
- Information for use by the Water Manager in the integrated management of the water resource to ensure sustainability, including the need for and scoping of intervention strategies
- Information for future decision-making and planning, and

- Feedback to the planning and assessment processes.

7.3 National level management: Methodology and details

National level management entails setting strategic goals, developing policies and strategies for implementation at regional level, reviewing catchment level performance against set management goals and giving support to CMAs in preparing/updating management plans to ensure ongoing compliance with the strategic goals.

National level management includes the following aspects:

- Auditing performance against NWRS objectives
- Overview of the national water quantity and quality monitoring system through monitoring ambient trends, including surface and groundwater data
- Preparing particular strategies for the management of water resources in dolomitic areas, for example:
  - Utilisation of the storage of the dolomite aquifer during drought periods. This would involve drawing the water at levels below the normal management level in order to use the storage. This would then be rapidly recharged during subsequent periods of high rainfall, in a manner akin to a surface water dam
  - Setting operational rules for the sustainable utilisation and management of the dolomitic aquifers (e.g. maximum discharge volumes, normal operation base water level, drought operation base water level), and
  - Establishing guidelines for artificial recharge where this may be feasible (i.e. when a suitable source of surplus water exists). Such a strategy will require a thorough assessment of the aquifer and of the quality of the source water before implementation
- Water Conservation/Water Demand Management and optimising the system potential
- Preparing strategies for land use management in dolomitic areas (e.g. in relation to urban and industrial development and positioning of waste disposal facilities), and
- Management of strategic issues such as inter-catchment resources and international obligations.

The Policy & Regulation Branch in the Department's National Office will be responsible for the national level management process.

Figure 22 summarises the steps involved in national level management. The inputs to national level management include the strategic management objectives and management reports from catchment level.

The steps in national level management are described in more detail in the following sections.

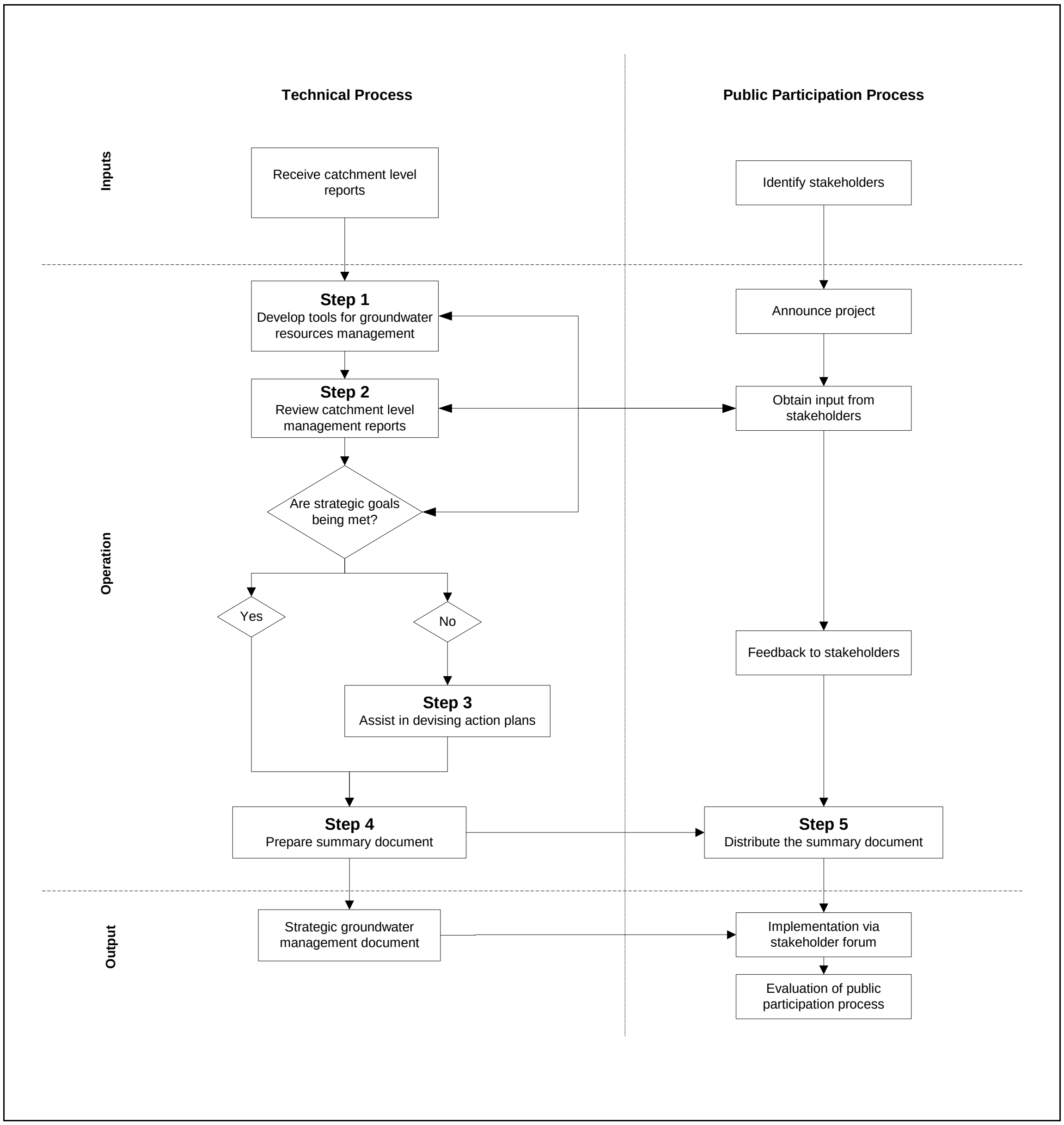

Figure 22: Process for national level management

7.3.1 Step 1: Develop tools for groundwater resources management

The groundwater resources control mechanisms for water use in a catchment will include:

- Guidelines for water use and allocation
- Guidelines for water use authorisations
- Waste discharge charges and water pricing, and
- The Dolomite Strategy.

> **NOTE:**
>
> Further information concerning water use authorisations is available from the Department: Water Affairs and Forestry website: www.dwaf.gov.za.

7.3.2 Step 2: Review catchment level management reports

Review the information received in management reports against the catchment level RQOs and strategic goals. This assessment will review whether or not the strategic goals of the Department are being met.

7.3.3 Step 3: Assist in devising actions plans

In the event that the Department's strategic goals for management of the dolomite aquifers are not being met, the Department's National Office personnel will advise and assist Water Managers in devising action plans to be implemented at catchment level. These action plans should ensure that future actions are aimed at meeting these goals.

7.3.4 Step 4: Prepare summary document

Prepare a strategic management and review document summarising:

- Performance during the previous reporting period against the strategic goals
- Areas where performance goals have been achieved
- Areas where performance improvements are required
- Performance goals for the next reporting period, and
- Strategies and action plans to achieve future performance goals.

7.3.5 Step 5: Distribute the summary document

Distribute the strategic summary document to all relevant managerial role-players in the Department for comment and sign-off. The Department may also wish to publish these documents for wider use and comment.

> **NOTE:**
>
> Further information concerning water quality components is available in the Water Quality Management Series published by DWAF in March 2003, Sub-Series No. MS 8.1, MS 8.2 and MS 8.3, Edition 1.

7.4 Catchment level management: Methodology and details

Catchment level management includes, among other functions, the following components:

- Monitoring cumulative impacts on aquifer systems and data management
- Refining the control mechanisms for the management of water use, including operational rules for aquifer utilisation and procedures for combating over-exploitation of the dolomitic aquifer resources, and
- Assessment of the aquifer behaviour as result of impacts imposed against the RQOs
- Auditing the compliance of water use against licensing conditions
- Reporting to both the national and site-specific levels, and
- Feedback to the water users.

The Water Manager will be responsible for the catchment level management function.

Figure 23 summarises the steps involved in catchment level management. The inputs to the process include the details from the site-specific management function. The steps in catchment level management are described in more detail in the following sections.

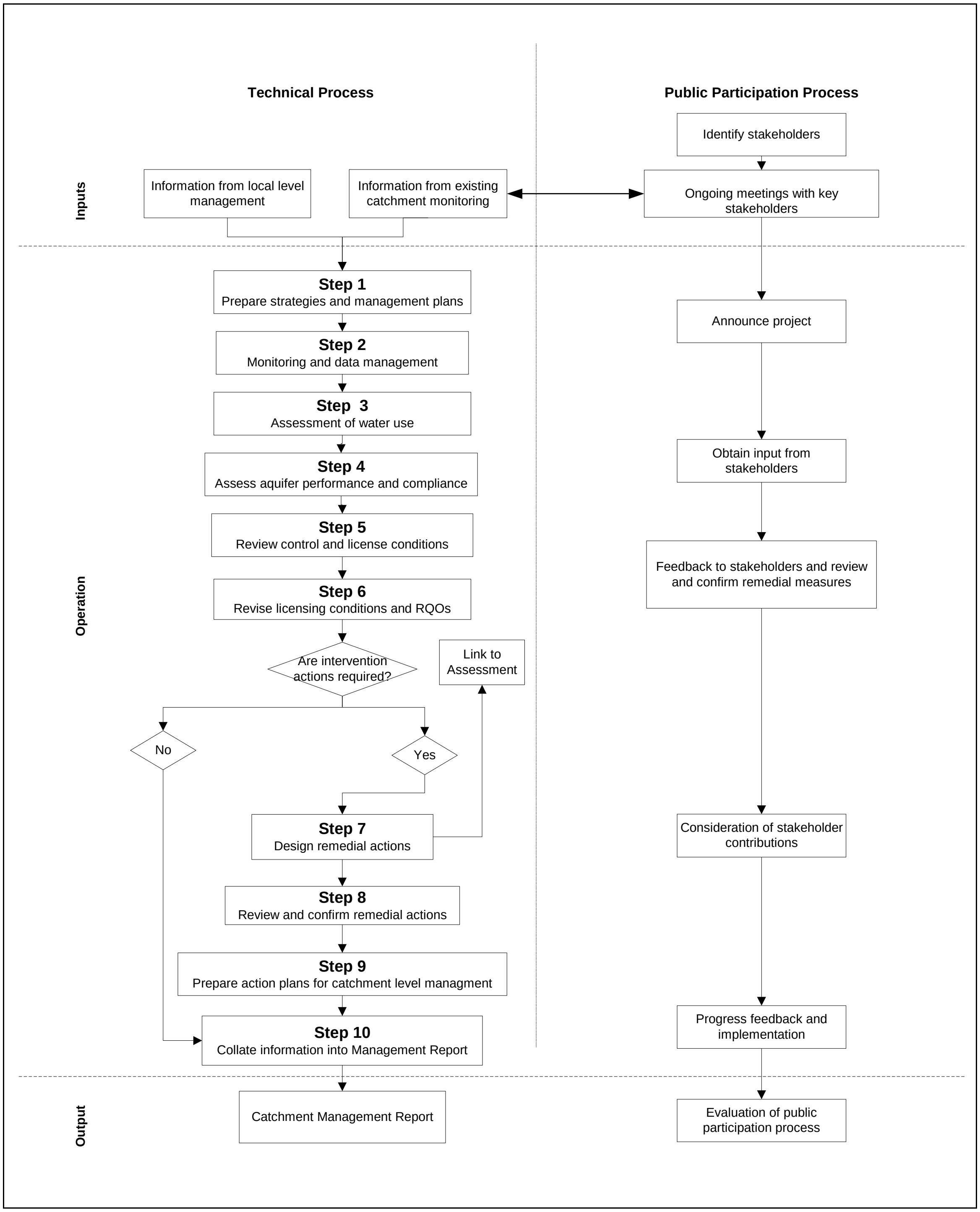

Figure 23: Process for catchment level management

7.4.1 Step 1: Prepare strategies and management plans

Prepare and/or update the Integrated Water Resources Management (IWRM) plan for use by the Water Manager and CMA personnel in the management of the catchment. This will provide the strategic direction and performance targets for the operational personnel for the next reporting period.

> **NOTE**:
>
> A generic Table of Contents for the IWRM Plan is included in **Appendix E.3** of Volume II.

> **NOTE:**
>
> Further information is available in Integrated Water Resources Development Plans, Training Manual and Operational Guide (CIDA) and Water Quality Catchment Assessment study and Catchment Management Strategy Guidelines.

7.4.2 Step 2: Monitoring and data management

Correct data management forms the basis for sustainable water management and is thus an essential component of the overall monitoring and management programme for the groundwater resources of dolomitic aquifers.

Further details on monitoring and data management are provided in site-specific management (**Section 7.5**).

7.4.3 Step 3: Assessment of water use

Assess the report received from the site-specific management process against the licensing conditions. Record water management performance within the catchment and any occurrences of non-compliance.

7.4.4 Step 4: Assess aquifer performance and compliance

Assess the monitoring data from catchment level monitoring networks against RQOs. Assess the water abstraction, water level response and water quality trends for the monitoring period. Determine aquifer behaviour against management objectives and assess aquifer performance.

On the basis of the monitoring data, determine the compliance and need for the implementation of any remedial actions.

7.4.5 Step 5: Review the control and license conditions

The groundwater resources control mechanisms for water use in a catchment are developed during the national level management process, and include guidelines for water use and allocation, guidelines for water use authorisations and waste discharge charges and water pricing. Licensing conditions are based on these control mechanisms and the RQOs set for the catchment. The control mechanisms and licensing conditions should be reviewed at a catchment level, based on:

- The catchment level strategies and management plans set in Step 1
- The information provided from the existing catchment monitoring
- The aquifer performance, and
- Water use compliance.

7.4.6 Step 6: Revise licensing conditions and RQOs

Revise the existing license conditions and RQOs for the catchment, based on the review undertaken in Step 5.

> **NOTE:**
>
> Further information is available in Parsons, R, Wentzel, J.(2006) GRDM Manual. WRC Project 1427.

7.4.7 Step 7: Design remedial actions

Together with the Hydrogeologist and design team, the Water Manager will either notify the water user of the required remedial measures, or will design these measures for implementation by the water user. The Water Manager should ensure that these measures are correctly implemented.

7.4.8 Step 8: Review and confirm remedial actions

Present the proposed remedial actions to the relevant role-players, obtain input and update the remedial actions accordingly.

7.4.9 Step 9: Prepare actions plans for catchment level management

Prepare detailed action plans for use by the Water Manager and CMA personnel for the implementation of the remedial actions. This will include monitoring frequency, well-field and borehole operational procedures and land use management.

7.4.10 Step 10: Collate information into Management Report

Collate all information collected and reviewed at the catchment level into a Management Report for use by the Policy and Regulation Branch of the Department's Head Office in the national level management process.

7.5 Site-specific management: Methodology and details

Site-specific management includes the following tasks:

- Collection, collation, storage and assessment of monitoring data within, and surrounding the water use(s)
- Implementation of water development options identified as part of the planning process
- Supervision, or implementation, of the remedial measures identified as part of the monitoring and management function
- Operation and maintenance
- Control of specific water uses, and
- Reporting.

> **NOTE**:
>
> Information on site-specific groundwater management is available in the NORAD toolkit, as follows:
>
> Section 1.1: A framework for groundwater management of community water supply
>
> Section 1.2: Implementing a rural groundwater management system
>
> Section 7.1: Sustainability Best Practices, Guidelines for rural services.

The water user (e.g. Local/District Municipality, WUA, mine, industry or delegated personnel) will be responsible for site-specific management.

Figure 24 summarises the steps involved in site-specific management. They are described in more detail in the following sections.

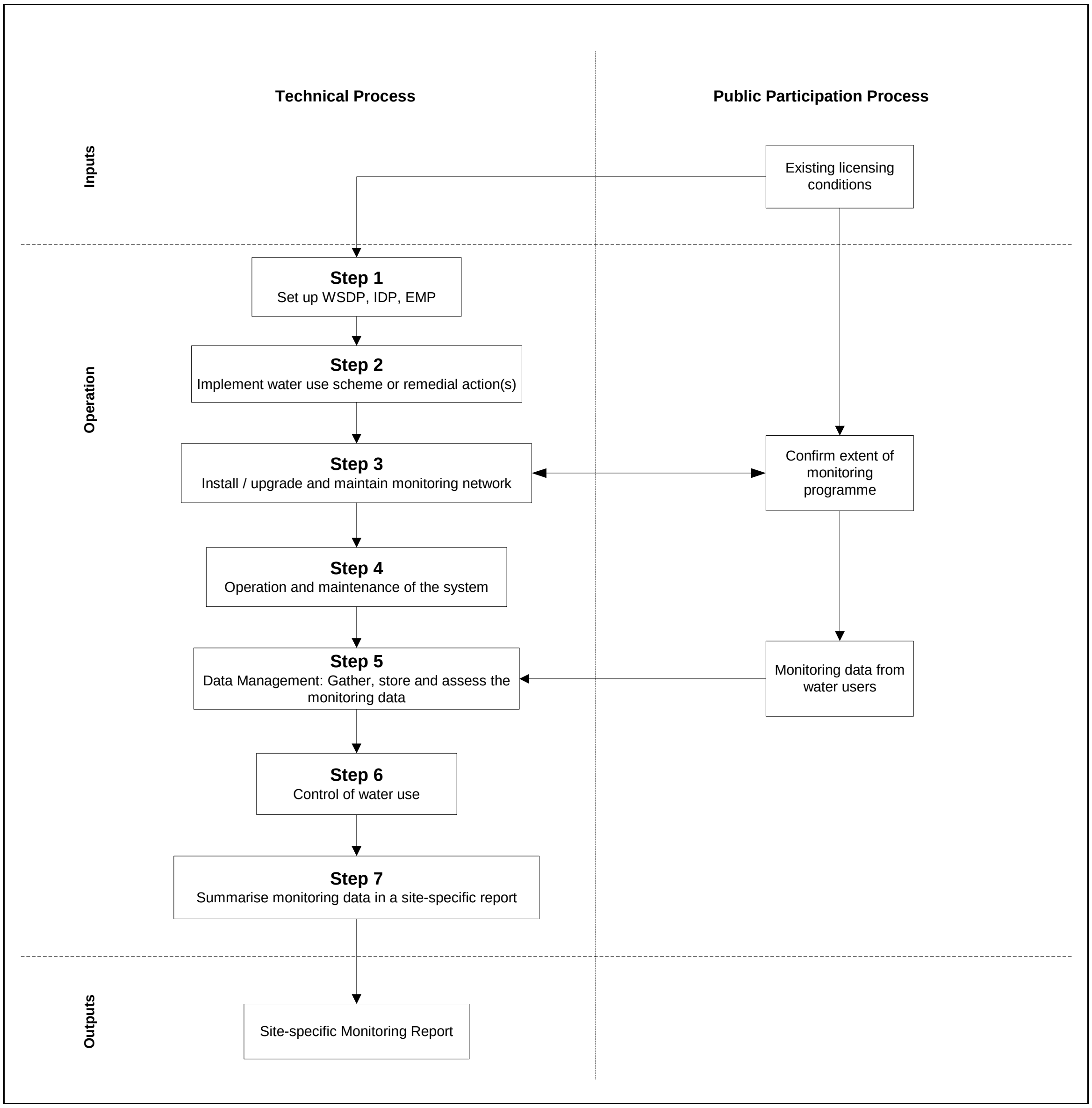

Figure 24: Process for site-specific management

7.5.1 Step 1: Set up WSDP, IDP, EMP

The Water Manager/Hydrogeologist will, together with the relevant personnel from the local municipalities, develop/update the groundwater aspects of the local WSDP and IDP as well as the Environmental Management Plan (EMP) for any new water use. This will take into consideration any information available from the catchment planning phase.

7.5.2 Step 2: Implement water use scheme or remedial action(s)

Implement approved site-specific schemes and actions, including:

- The preferred water use schemes as identified during the planning process and specified in the Planning Report, and
- Any remedial measures that have been recommended from the catchment level management function.

> **NOTE**:
>
> Additional information is available in "Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme".

7.5.3 Step 3: Install/update and maintain monitoring network

Ensure that the monitoring network installed during the implementation phase is sufficient to provide effective coverage and accurate measurements for management purposes. This includes abstraction well-fields and their monitoring boreholes, local and regional monitoring network, monitoring boreholes around individual facilities, such as sewage works, waste dumps, etc, and springs.

The monitoring network should include:

- Weather station within the study area
- In-line flow meters for monitoring water abstraction from boreholes
- Piezometer tubes to measure water levels in pumping holes at the end of a non-pumping cycle; alternatively, install continuous water level monitoring equipment, and
- Borehole sampling to monitor quality of groundwater
- Spring flow measurements, and
- Sampling of spring flow to monitor water quality

The monitoring network must be regularly maintained.

7.5.4 Step 4: Operation and maintenance of the system

The Water Manager, Hydrogeologist and other relevant personnel will ensure that the well-field for water use and the monitoring system is correctly operated and regularly maintained.

7.5.5 Step 5: Data Management: Gather, store and assess the monitoring data

Correct data management forms the basis for sustainable water management and is thus an essential component of the overall monitoring and management programme for the groundwater resources of dolomitic aquifers. Data management involves correct data collection, recording, handling, archiving and reporting according to an agreed data management system.

Data collection should be managed as part of a value chain. This value chain includes (a) *data* acquired from the monitoring system (b) *information* generated, based on this monitoring data (c) *knowledge* and insight to resolve questions (d) *strategic* and/or *operational decisions*, and (e) the organisation's *mission and objectives*. The mission and objectives of an organisation clearly provide a long-term focus, while data collection has a short-term focus.

NOTE:

Further details on Good Data Management can be obtained from "Good Data Management Practices" (2006), E. Bertram, DWAF report, unpublished.

When monitoring data is being collected, the various aspects described in the following sections should be considered.

Monitoring frequency

Borehole water level and abstraction monitoring should be undertaken on a routine basis, with the frequency of monitoring generally being set at monthly intervals.

In order to obtain information to guide preventative or remediation measures (if required), borehole monitoring will also be required on an incident-related basis.

NOTE:

The installation of continuous real-time monitoring equipment in key selected boreholes is highly recommended.

Water sample collection and frequency

Ensure that a representative groundwater borehole sample is obtained on a routine basis. Samples will generally be collected at six-monthly or yearly intervals. More frequent sampling may be specified where, for example, pollution of the dolomite aquifer is suspected.

Issues to consider during borehole sampling are:

- Purging the borehole
- Minimum container size
- Filtering
- Preservation method and sterilisation, and
- Use of an accredited laboratory.

NOTE:

Details of sampling protocol are available in: Weaver JMC, 1992. A Comprehensive Field Guide for Sampling Methods, Water Research Commission Project No. 339, TT 54/92, Pretoria.

Details are also available in the Field Manual and Desk Manual published by the Winconsin Department of Natural Resources, PUBL-DG-037 96, September 1996.

NOTE:

Water Service Authorities can obtain additional information on monitoring water levels and flow in the DWAF/NORAD, 2006 document, **Section 6.1**: Groundwater monitoring for Pump Operators.

Reporting format

All data collected must be captured and should include:

- Hydrocensus data
- Drilling data
- Testing data, and
- Analytical data.

Data should be captured on standard forms and submitted to the Water Manager, the CMA personnel or the Department's regional office. Examples of standard forms are included in **Appendix C.**

Data handling and submission

Handling and submission details for the various required datasets are:

- Abstraction data:
  - Recorded by end user, and
  - Reported monthly or according to water use authorisation conditions.
- Water level data:
  - Recorded by end user
  - Reported monthly or according to water use authorisation conditions
  - Submitted to the Department, and
  - Automatic recorders installed in key monitoring boreholes by the Department/CMA.
- Water quality data:
  - Sample collected by end user and submitted to laboratory according to water use authorisation conditions/detailed constituents
  - Recorded on the catchment level monitoring database, and
  - Submitted for inclusion on the national groundwater archive (NGA), through the Catchment Management Report.

The Water Manager (or the CMA) must arrange for the inspection of measuring devices (e.g. flow meters).

Submit all dolomite groundwater monitoring data for storage on the national groundwater database (NGDB) and/or the NGA.

Present the monitoring data in a suitable format for assessment. This is likely to be a graphical representation which will allow the assessment of short-term and long-term trends in water level and quality. The monitoring data are also used:

- To provide insight into aquifer behaviour
- To support licensing decisions and for future water use allocations
- To calibrate the existing models

- To measure the performance of the aquifer / system against licensing conditions, and
- As a basis for intervention actions.

> **NOTE**:
>
> Aquimon, detailed in the DWAF/NORAD, 2006 document, is a tool specifically designed to assist groundwater managers with organising and interpreting data.

> **NOTE**:
>
> Additional information is available in the WRC report 861/1/02a: Guidelines for the monitoring and management of groundwater resources in rural water supply schemes.

7.5.6 Step 6: Control of water use

The monitoring data and generated information will be used to control water use within the site-specific environment.

7.5.7 Step 7: Summarise monitoring data in a site-specific report

Collate all site-specific monitoring data for the dolomite catchment into a monthly report, for use in the catchment management function. A report that audits the monitoring information should be prepared on:

- Status of the water use
- Performance of use against licensing condition
- Trends in monitoring information, and
- Suspected / planned change in use in the near future.

> **NOTE**:
>
> Water Service Authorities can obtain additional information in the DWAF/NORAD, 2006 document, **Section 5.1**: Sustainability Index Tool (SuSIT) for auditing of water supply schemes.

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