

APPENDIX A
RISK MANAGEMENT

APPENDIX A

Minimum requirements and mandatory precautionary measure in areas underlain by dolomites (Butrick, DB, van Schalkwyk, A, Kleywegt, RJ & Watermeyer RB, 2001. Proposed method for dolomite land hazard and risk assessment in South Africa. Journal of The South African Institution of Civil Engineers, 43(2).

The joint Structural Division established the following minimum requirements and mandatory precautionary measures for areas designated as being D2 and D3. These minimum and mandatory precautionary measures have been adopted by the National Home Builders Registration Council (NHBRC) in their Home Building Manual.

General

- The site and surrounding area shall be shaped to permit the ready drainage of surface water and to prevent ponding. Drainage ports should be incorporated in boundary walls particularly at the lowest point of the site, to permit the passage of surface runoff.
- Natural ponds and water courses located within 10m of any structure shall be rendered impervious.
- Sanitation system shall not incorporate soak aways.
- Backwash and other water from swimming pools shall be discharged into either the storm water or drainage systems as required by the local authority. The dolomitic stability over the route of any bulk water bearing service should be evaluated.

Township services

- Underground services shall be designed and constructed so as to minimize maintenance requirements and any potential leakage points in wet services and shall, as far as possible, be designed to avoid possible disturbance of the underground environment.
- The relevant provision of SABS 1200 DB, L, LB, LD and LE shall be observed in the installation of all underground services.
- The backfilling to service trenches and other excavations shall, except in rock, not be more permeable than the surrounding material.
- The storm water drainage and sewerage system shall incorporate measures to ensure water tightness of consults and other compartments. Whenever possible, storm water should be channeled in lined, surface canals. *Concrete non-pressure pipes should be of the spigot and socket type with rubber ring seals. Joints in box culverts, channels, etc, should be sealed.*

- Storm water drainage conduits shall be constructed at gradients, which will not permit the deposition of silt, or sand, of the type present in the catchment area.
- Water mains shall be laid only in road reserves.
- Water piping materials shall be one or more of the following:
 - Pipes of 75 mm and larger diameter: high impact PVC pipes with vitaulic joints steel pipes with internal and external corrosion protection or other flexible (as defined in SABS 0102 Part1) water pipes with flexible, self anchoring connections.
 - Pipes having a diameter of less than 75mm: HDPE type IV piping polypropylene piping
 - *The piping used in mains and communication pipes should be flexible, joints should be minimal in number and, be of the flexible, self- anchoring type, i.e. not reliant on thrust blocks or friction for their anchorage.*
- Provision for future connections shall be made in order to minimize the cutting into pipes to provide such connections.
- Provisions shall be made in all water bearing pipelines to accommodate any potential differential movement without causing the pipeline or joints to leak.
- Road surfaces shall be located sufficiently low so as to permit the drainage of erven onto them.
- Roadways which have a gradient of less than 1:80 shall be surfaced/sealed.
- Where un-surfaced roads are the sole storm water system in a township, the roadways which act as major storm water collectors shall be surfaced.
- The velocity of the 1 in 20 year storm water flowing along unsurfaced roadways shall not exceed 1, 5 m/s.

Plumbing

- Water pipe entries into the buildings shall be in accordance with **Figure S3**.
- All sewer and water pipes and fittings shall be provided with flexible, water tight joints.
- No plumbing and drainage pipes shall be placed under floor slabs, as far as is practicable.
- The fall of the trenches shall be away from the buildings.
- Pipes through walls shall be sleeved to permit relative movement.
- WC pans shall be provided with a flexible connection at the junction with the outlet pipe.

- The selection of piping material shall take cognizance of corrosion (both external and internal).
- Water pipes shall have a minimum cover of 500mm.
- Wherever practical, service trenches shall not be excavated along the length of housing units within the first 3, 0 m beyond the perimeter of such units.

Site precautions

- Down pipes, if provided, shall discharge into concrete line drainage channels, which drainage channels discharge the water at least 1, 5 m away from buildings.
- Where guttering is not provided, a 1, 5 m wide impervious apron slab shall be provided.
- The ground immediately against the buildings shall be shaped to fall in excess of 75mm over the first 1, 5 m beyond the perimeter of the building, from where it shall drain freely away from housing units. Apron slabs, where provided, shall have the same fall.

Matters to be considered when establishing and maintaining a Risk Management System

New townships

- Bulk and internal services in new townships must be installed in accordance with the provisions of **Appendix A** and any additional provisions provided in the geotechnical report.
- A register of Townships in areas designated as being D1, D2, D3, and D4 (Risk Classes 1-81) should be opened. Specified precautionary measures should be entered into the register where they differ from the minimum requirements set out in **Appendix A**.
- The local authority must ensure that bulk services are upgraded appropriately in relation to increasing residential densification.

Raising awareness

- A map of all known dolomite areas within the local authorities' area of jurisdiction should be prepared and maintained. This map should provide a composite stability zonation based on the Dolomite Area Designations and the related Dolomite Risk Class, e.g. D2 (Risk Class 1) and D3 (Risk Class 5). The Dolomite Area Designation will be of immediate importance to civil engineers involved in service design and maintenance, whereas the Dolomite Risk Class will be of value to the dolomite risk specialists from a development perspective.

- The section/departments of local authorities responsible for the maintenance of the water, sewer and electrical reticulation and bulk services as well as the building control section should be issued with maps showing the D2, D3, or D4 (Dolomite Risk Classes 1 to 8) areas and must be informed of the potential risks and maintenance requirements for services in these areas.
- Councillors whose wards fall within D1, D2, D3 and D4 (Dolomite Risk Class 1 to 8) areas, as well as leaders of community structures and organizations whose constituents reside in D2 (Classes 1 to 4) and D3 (Classes 3 to 5) areas, should be informed of the potential risks and maintenance requirement for services in these areas and the necessity to report any leakage/blockages/ponding of water in these areas to designated council officials.
- Officials who receive and log reports from the public on disruptions in services, etc, must be provided with contingency plans including maps showing D2 (Classes 1 to 5), D3 (Classes 3 to 5) and D4 (Classes 6 to 8) areas and must be briefed on the implications of leaks and the like in these areas. Special reporting procedures must be established to ensure that maintenance teams are promptly advised of leaks and the like in areas designated as being D2, D3 and D4.
- The local authority should inform residents in area designated D2 (Classes 1 to 5) and D3 (Classes 3 to 5), every two years in a written communication, of the risks and their responsibilities which will include:
 - Prompt reporting of leaks and any subsidence.
 - Refraining from making illegal connections and proceeding with the erection of new buildings on properties and the installation of swimming pools without permission
 - Ensuring that water does not dam up on their properties.

Maintenance of services

- A proactive maintenance strategy for water bearing infrastructure should be developed. This can be readily done by superimposing the water bearing infrastructure on the stability risk zonation map described in **Section 2.1** above. Priority in terms of vigilance, general maintenance, repair of leaks and expenditure of funds for upgrading or service replacement can be assigned on the basis of risk exposure. In this manner a prioritized, co-ordinate and proactive strategy for maintenance and review of water – bearing infrastructure can be developed by the local authority.
- Areas designated as being D2, D3 and D4 (Dolomite Risk Classes 1 to 8) must receive priority in the repair of leaks arising from the sewer and water reticulation.

- Sewer mains in areas designated as D2,D3, or D4 (Dolomite Risk Classes 1 to 8) should be checked for water tightness by means of an air test at intervals not exceeding two years and repairs undertaken where necessary.
- The storm water systems in areas designated as being D2,D3, or D4 (Risk Classes 1 to 8) should be inspected for blockages and leaks at intervals not exceeding one year and repairs/cleaning undertaken where required.
- All bulk services which are located in areas designated as being D2,D3 and D4 should be inspected for water tightness/blockages at interval not exceeding one years and cleared/repared where required.
- Priority should be given to the upgrading of services in areas designated as being D2, D3, and D4 in order to minimize sewer overflows ponding of water, bursts, water losses, etc.

Management of improvements to properties

- Building control officers must, in areas designated as being D2 and D3, enforce any restriction regarding swimming pools and must ensure that alterations and additions are in accordance with the NHBRC requirement.
- Building control officers should once every two years visually inspect properties in areas designated as being D2 and D3 to ensure that water is not damming up on properties.
- Building control officers must not permit any densification of properties in areas designated as being D1, D2 or D3 unless it is confirmed by a competent Person that such densification does not change the area designation.

Measures to prevent land invasion

The local authority must put in place a policy and measures to preclude land invasions and to act positively where such invasions have accrued.

Groundwater control measures

Artificially induced fluctuations in the dolomite ground water level, particularly where shallow, may trigger sinkhole or doline formation. Consequently, it is essential that local authorities liaise with the Department of Water Affairs and Forestry and set up appropriate ground water monitoring procedures. Depending on the Dolomite Risk Class and Dolomite Area Designation (e.g. D4 or Class 7 and 8) of an area, in certain sensitive groundwater compartments, an outright ban on the sinking of abstraction boreholes may be required.

Emergency reaction plan in the event of a sink-hole or doline occurring

The local authority should set in place an emergency reaction plan to be followed in the event of a sinkhole or doline occurring in their area of jurisdiction. Managers of emergency services should be provided with the dolomitic zone designation and risk map and briefed on the implications thereof. It is essential that these managers and emergency services personnel fully understand what a sinkhole is, possible stages of development and how large an area to evacuate around a potential event.

Database of ground subsidence events and structural damage

The local authority should establish a database of ground subsidence events and reported structural damage. Detailed records of this nature are useful in developing a clear perspective of the stability situation in a township, highlight areas of weakness and assists in the installation and management of a proactive maintenance strategy.

APPENDIX B 1

MODEL DRILLING CONTRACT

MODEL TECHNICAL SPECIFICATIONS FOR THE DRILLING OF BOREHOLES

1 DOCUMENTS

This Specification shall be read in conjunction with the Invitation of Tender, Conditions of Contract, the Bill of Estimated Quantities and Rates, and other relevant documents and the whole be deemed to constitute one document.

2 DRAWINGS

The following drawings accompanying and referred to in these specifications shall consist of:

- (i) Locality Map (Fig.)
- (iii) Construction of boreholes - Open hole hard rock design (Drawing No.)
- (iii) Construction of boreholes - Slotted casing hard rock design (Drawing No.)
- (iv) Jetting tool (Drawing No.)
- (v) Typical slotted casing (Drawing No.)

3 LOCALITY

The works are required in situated as illustrated on Locality Map (Fig.)

4 SCOPE OF CONTRACT

The Works comprise the construction of boreholes. The actual number of boreholes will be decided by the Client but no guarantee is given as to the actual number finally ordered. Additional boreholes could be required under the specifications contained herein, and if so will be paid at the rates tendered.

5 GEOLOGICAL AND HYDROGEOLOGICAL DATA

Hydrogeological data may be inspected at the offices of the Catchment Management Agency. The Contractor shall form his own assessment of the anticipated drilling conditions from the available data and no claims for misinterpretation will be entertained.

No claims for extra payment for such variations will be entertained nor do such variations relieve the Contractor from any responsibility hereunder nor from fulfilling any or all of the terms and requirements of this Contract.

6 NATURE OF CONTRACT

The specifications are for a Schedule of Quantities and Rates Contract for the drilling, construction and development of boreholes.

The Contractor shall provide all labour, transport, plant, tools, materials and appurtenances, and shall perform all work necessary to satisfactorily construct and complete the boreholes in accordance with this Specification. The borehole depths will be dependent on results and the strata intersected.

The Contractor shall employ only competent workmen for the execution of his work, and all work shall be performed under direct supervision of an experienced water well driller.

7 CONTRACTOR'S PLANT

The Contractor shall specify in the Schedule of Plant and Equipment the type of plant to be used and the method of operation. Its capacity shall be sufficient to cope with the work within the contract time. It shall be kept at all times in full working order and good repair.

No extra payment shall be made for Contractor's plant, labour or equipment to complete the work specified, nor for any incidentals thereto, the cost being deemed to be included in the Contractor's prices.

It is noted that drilling rig(s) equipped for air percussion, including foam, is (are) required on site.

8 ASSIGNMENT

The Contractor may not assign this Contract not sub-let any part of this Contract or any of its obligations hereunder without the prior written consent of the Client.

9 TIME SCHEDULE

The contractor shall position and start operation on site within 7 calendar days after written communication to proceed with the Works have been received from the Client.

10 SAFETY STANDARDS

The Contractor shall adhere to applicable safety regulations at all times.

11 DRILLING POSITIONS AND ACCESS

The drilling positions will be marked on the ground and pointed out to the Contractor by the Client or his representative. Should access to site prove to be difficult the onus is on the Contractor to make a genuine attempt in reaching the site.

12 MATERIAL

The used materials shall be new and undamaged. The materials used shall be paid for at the rates tendered by the Contractor in the Schedule of Quantities and Rates.

13 CASING

13.1 Steel Casing - Plain

The plain casing will be of an approved standard and shall be as specified in the Schedule of Estimated Quantities and Rates. All casing will have a minimum wall thickness of 4mm and shall be bevel edged with lugs or threaded to accomplish positive mechanical interlocking.

13.2 Steel or PVC Casing - Slotted

Where collapsing conditions are present at the water bearing horizon, slotted steel or PVC casing shall be installed over the affected zone. The manner in which the slots are to be cut is shown in Drawing No: The width of the slots shall be 3mm minimum and 4mm maximum. Wall thickness shall be 4mm minimum. The slots shall be of uniform width with no resultant protrusions and shall be clear of debris.

13.3 Equipment and Chemicals

It will be the responsibility of the contractor to bring on site with all equipment and chemicals required to complete the Work without interruption.

13.4 Other Materials

Casing clamps and all other such items as are required in the construction of the boreholes shall be constructed in accordance with normal groundwater engineering practice.

13.5 Formation Stabiliser

Gravel pack material shall be well rounded, uniform and clean quartzitic gravel with a grain size varying between 6 and 10 mm. Sieved and washed river gravel can also be accepted. Samples of the gravel pack must be submitted to the Client approval before placement.

14 BOREHOLE CONSTRUCTION

14.1 Design and Depth

Two separate designs, one requiring the installation of plain casings and the second requiring the installation of both plain and slotted casing and formation stabiliser may be used. Borehole designs are shown schematically on drawing Nos.and

The anticipated depth is unlikely to exceedm.

14.2 Diameter

Drilling diameters may vary from 165mm to 420mm. Anticipated drilling diameters are those indicated on Drawing Nos. and

14.3 Drilling Technique(s)

The drilling technique will be air percussion. Provision must be made for the use of foam, as required. A stabiliser of a minimum length of 6m must be used to ensure the straightness and verticality of the borehole. The stabiliser forms the first drilling rod and is attached immediately above the hammer.

14.4 DRILLING MEDIA

The Contractor may not use drilling media which may cause hole erosion or involve the use of clay, oil, salt or any lost circulation agent, sawdust, cement, or any form of plugging that could affect the production capacity of the water bearing strata intersected or contaminate groundwater.

The use of foam may be required. It will be the responsibility of the driller to use a foam mix compatible with and suitable for the geological conditions being experienced.

14.5 Sanitary seal

Each borehole shall be completed with 3m of cement grout extending from ground level to the top of the gravel pack.

The sanitary seal shall be mixed in the following ratio, 30 litres of water to 50kg cement.

14.6 Concrete slab

Each borehole shall, be completed with a concrete slab of dimensions 1m x 1m x 0,5m, sunk into the ground for 0,3m. The slab will be made of aggregate, river sand and cement in the ratio 3:2:1. The strength must be 20KPA minimum after 28 days.

14.7 Sampling

Representative samples of the strata intersected shall be collected every one metre and at geological contacts. The Contractor will take every possible precaution to guard against sample contamination due to poor circulation, hole erosion, or caving.

14.8 Drilling and Construction of Boreholes

The drilling shall be carried out with the least possible delay in order to run the casing as required, and to remove any drilling fluid from the borehole in the shortest possible time.

All boreholes shall be presented for testing free of all bridging and obstructions to bottom. Any time spent in conditioning holes or removing obstructions shall be at the contractor's expense.

14.9 Straightness and Verticality

All boreholes shall be drilled and cased straight and vertical and all casings liners shall be set round, plumb and true to line. The Client shall have the right to reject any or all casing which fails to meet the requirements of this Specification, and the casing rejected will be replaced at the Contractor's expense.

Any delays encountered in running casing considered to be due to poor hole alignment, shall be at the Contractor's expense.

To demonstrate the compliance of his work with this requirement the Contractor, when called upon to do so, shall furnish all labour, tools and equipment and shall make the tests described herein in the manner prescribed by, and to the satisfaction

of the Client. Tests for plumbness and alignment will be made after the complete construction of the borehole before its acceptance.

Plumbness and alignment shall be tested by lowering into the borehole to a depth as directed by the Client, a section of pipe 12m long. The outer diameter of the plumb shall not be greater than 15mm smaller than the diameter of the cased/screened hole to be tested. Should the plumb fail to move freely throughout the length of the casing to the required depth, or should the well vary from the vertical in excess of two-thirds of the smallest inside diameter of that part of the borehole being tested per 30m of depth, or beyond limitations of this test, the plumbness and diameter of the well shall be corrected by the contractor at his own expense. Should the contractor fail to correct such faulty straightness or plumbness, the Client may refuse to accept the borehole and no payment of the work and materials shall be made.

14.10 Protection

During the contract period when work is not in progress, the boreholes shall be kept capped in such a manner as to prevent the entrance of foreign material. The Contractor shall remove any foreign matter at his own expense. On completion of each borehole, the Contractor shall supply and fit an approved permanent cap as per drawing No.

15 EXPERTISE

The Contractor under this Contract is considered to be an expert water well driller and is expected to organise and carry out the work specified hereunder in an expert manner. Drilling problems encountered will be overcome entirely within the framework of this Specification and Schedule of Estimated Quantities and rates, and no claim for extra payments will be entertained for problems foreshadowed in the Specification or due to limitations placed by this Specification.

16 ABANDONMENT

The Client shall have the right at any time during the progress of the work to order the abandonment of the borehole. The Contractor thereupon shall remove the plant, withdraw the casing, if applicable, and salvage or attempt to salvage all such materials as the Client shall direct and/or up until the Client revokes such direction, and shall fill or leave the borehole to the satisfaction of the Client.

Payment shall be made for such abandoned borehole at the appropriate rates as detailed in the Schedule Estimated Quantities and Rates.

17 LOST BOREHOLE

Should accident to the plant, behaviour of the ground, jamming of the tools or casing, or any other cause, prevent the satisfactory completion of the works, the borehole shall be deemed to be lost and no payment shall be made for the drilling costs nor for any materials not recovered in good order therefrom, nor for any time.

In the event of a lost borehole, the Contractor shall construct a new borehole adjacent to the lost borehole, on a site indicated by the Client. The option of declaring any borehole lost shall rest with the Contractor, subject to directions from the Client.

18 DEVELOPMENT

On completion the borehole shall be developed to a maximum yield of water, free of suspended materials. Development will be carried out using air lift pumping, jetting and block surging, or such other standard techniques as may be directed by the Client. The standard jetting tool is shown on Drawing No.

Development will be continued for the period directed by the Client.

19 DISINFECTION

On completion of development the screen area will be disinfected by pumping a solution of 5 kg of HTH in 200 litres of water through the jetting tool.

20 REPORTS

At the end of the Works, the Contractor shall provide all information necessary to complete the data form.

21 ALLOWABLE PAYMENT

21.1 Establishment and subsequent removal thereof

This is payment to cover the establishment of all the required drilling equipment, personnel, camping and general equipment necessary to carry out and complete the Works described in this specification and any extensions, and to cover the removal of all plant, equipment and personnel permanently from the project and the restoration of the sites to a level and reasonably tidy stage. This rate can be either a lump sum or a Km rate.

21.2 Drilling

The rates for drilling are based on diameter and are to cover all the costs involved in drilling, including mud and foam mixing, injection mixers, bit sharpening, conditioning of the drilling mud for logging, tripping in and out of hole and all other such works as are associated with the drilling, and are not covered under other allowable payments.

21.3 Supply and delivery of materials on site

The rates for materials are to cover purchase cost, transport and safe storage on site of all materials required for drilling, construction, development and use in the boreholes, ref. to letter of invitation. Payment will be made only for materials used and shall be calculated for each completed hole. No claim for extra payment will be entertained by reason of remoteness, wharfage, insurance etc. or by reason of omission in calculating the quoted rate. No payment will be made for those materials which may be provided by the Client.

21.4 Standby time

This time rate, which is provisional and estimated in the Bill of Quantities, is to cover only those items when the rig and crew are idle waiting for decisions by the Client, where those decisions or whose presence is required before further work is possible. Under no circumstances will standby be payable for any other delays or hold ups other than those incurred by the Client's decision.

21.5 Development time

The borehole development time rate is to cover all the time effectively spent on borehole development, except where included under other time rates. Contractors will note that time rates do not allow for building standard development tools on site.

21.6 Work time

The work time rate which is provisional and estimated in the Bill of Quantities, is to cover time spent where the rig is held up waiting for on site manufacture of special non-standard tools as requested, or any other directive by the Client for non-standard work which requires the use of the rig and is not included in the Specification or covered under any other rate. It does not include mud mixing time or fishing time.

21.7 Casing installation

This rate covers the installation of permanent casing into production or abandoned boreholes and the pulling of temporary casing and casing from abandoned boreholes. It does not cover the running and pulling of casing in boreholes declared

lost or in which the casing cannot be set in position due to misalignment or other operational problems.

21.8 Moving between borehole sites

This item is to cover the movement of the rig and ancillary equipment from one borehole site to the next. Payment may be claimed per site move after the initial site establishment to the first borehole.

21.9 Payments

All payments will be made on the basis of measured quantities only.

22 SUPERVISION OF WORKS

The Contractor shall have a senior tool pusher on site at all times to manage and organise the contract and to liaise with the Client.

23 SITE CLEARING

The Contractor is responsible to clean and restore the site as far as possible to the natural state by:-levelling drilling cuttings; cleaning up rubbish, waste materials, debris and oil spills.

EXAMPLE OF SCHEDULE OF ESTIMATED QUANTITIES AND RATES FOR THE DRILLING OF BOREHOLES

ITE	DESCRIPTION	UNIT	QTY	RATE	TOTAL
	NOTE: All materials specified here to be purchased by the contractor. The estimated quantities refer to the construction of boreholes.				
1.	Establishment to and removal from site of all plant (one drilling machine equipped air				
	Percussion drilling) and ancillary	LUM	SUM		
2.	Moving from site to site	No			
3.	Drilling				
3.1.	Drilling of 420mm diameter				
3.2.	Drilling of 355mm diameter				
3.3.	Drilling of 254mm diameter	m			
3.4.	Drilling of 203mm diameter	m			
3.5.	Drilling of 165mm diameter	m			
4.	Casing				
	Supply and delivery of plain threaded/ bevel ended steel casing wall thickness minimum				
4.1	355mm ID				
4.2	254mm ID				
4.3	203mm ID	m			
4.4.	165mm ID	m			
	Supply and delivery of slotted threaded/ bevel ended steel casing wall thickness minimum				
4.5	355mm ID				
4.6	254mm ID				
4.7	203mm ID				
4.8	165mm ID				
5.	Installation				
5.1.	Installation of m ID	m			
5.2.	Installation of m	m			
6	Supply and insertion of gravel	m			
7.	Sanitary seal	m			
8.	Cap and concrete block	No.			
9.	Disinfection	No.			
10.	Work Time	hr	Prov.		
11.	Standby Time	hr	Prov.		
12.	Development Time	hr			
	AMOUNT CARRIED FORWARD TO				R

APPENDIX B 2

MODEL PUMPING TEST CONTRACT

**MODEL TECHNICAL SPECIFICATIONS FOR THE PUMPING TESTS OF
BOREHOLES**

1 DOCUMENTS

This Specification shall be read in conjunction with the Invitation of Tender, Conditions of Contract, Bill of Quantities and Rates, and other relevant documents and the whole be deemed to constitute one document.

2 DRAWINGS

The following drawings accompanying and referred to in these Specifications shall consist of:

- (i) General Locality Map. (Fig.).

3 LOCALITY

The works are required in , situated as illustrated on the Locality Map (Fig.).

4 NATURE OF CONTRACT

The Contractor shall provide all labour, transport, plant, tools, materials and appurtenances, and shall perform all work necessary to satisfactorily pump test the boreholes in accordance with this Specification and shall employ only competent workmen for the execution of his work.

5 CONTRACTOR'S PLANT

The Contractor shall specify in the Schedule of Plant and Equipment and type of plant to be used and the method of operation. Its capacity shall be sufficient to cope with the work within the Contract time. It shall be kept at all times in full working order and good repair.

6 ASSIGNMENT

The Contractor may not assign this Contract nor sub-let any part of this Contract or any of its obligations hereunder without the prior written consent of the Client.

7 ACCESS

Should access to site prove to be difficult the onus is on the Contractor to make a genuine attempt in reaching the site. In the event that after the attempted access is not forthcoming, the Contractor will have the right to charge standby time.

8 EXPERTISE

The Contractor under this Contract is considered to be an expert pumping test contractor and is expected to organise and carry out the work specified hereunder in an expert manner. Testing problems encountered will be overcome entirely within the framework of this specification and Bill of Quantities and Rates, and no claim for extra payments will be entertained for problems foreshadowed in the Specification or due to limitations placed by this Specification.

9 CESSATION OF TESTING ACTIVITIES

The termination, at any stage, of testing operations on a particular borehole shall rest with the Client.

10 SUPERVISION OF WORKS

The Contractor shall have a senior pumping test technician on site at all times to manage and organise the Contract and to liaise with the Client or his representative.

11 SAFETY STANDARDS

The Contractor shall adhere to applicable laws and regulations relating to safety at all times.

12 PUMPING TESTS

The services to be rendered are the execution of:

- Step drawdown test(s), followed by
- Constant discharge test(s).

It is expected that (state duration) constant discharge tests and step tests will be required on approximately **X** boreholes to be tested. However, should additional hours be required, or additional boreholes be required to be tested, the Contractor will undertake to do this at the rate quoted in the Bill of Quantities and Rates.

13 EQUIPMENT REQUIRED

The Contractor shall provide all labour, plant, tools and materials and shall perform all work to carry out the pumping tests referred to in Clause 12 above. An arc welding machine and oxy-acetylene torch must be available on site at all times.

13.1 Pump equipment

The pumps shall be positive displacement pumps capable of producing variable yields between X l/s to XX l/s at a XXm head. Power will be provided to the pump head via a motor fitted with a gearbox and clutch that can be throttled back without over loading. (Insert number) pump units are required on site. The pump units must be able to maintain a constant discharge throughout the test period. Under no circumstances shall electrical submersible, air lift or bailing techniques be acceptable.

13.2 Depth of pump installation

This is likely to be betweenm andm.

13.3 Discharge rate control

Control of the discharge will be provided by direct measurement into a tank of known capacity, supplied by the Contractor and shall form part of his standard equipment under this Contract. The discharge rates are to be quantified using the appropriate table as detailed in the operational guidelines.

14 DISCHARGE OUTLET

The discharge pipeline shall release water at least 100m from the borehole in a down gradient direction The precise distance will be determined by the Client.

15 MEASUREMENT OF WATER LEVEL

These will be carried out by the Contractor at regular intervals as per the model data sheets.

Measurement of the water level drawdown will be taken using an electrical dip meter inserted inside a 20mm diameter stilling piezometer tube. The piezometer tube will be inserted with the pump test to a similar depth as the pump inlet. The conduit shall be plugged at the bottom and shall have 10mm slots cut every 25mm over the bottom 3m.

The Contractor shall provide at least 2 water level measuring devices capable of measurements to $\pm 10\text{mm}$ accuracy and in proper working order. These water measuring devices shall be electrically operated. Air line measuring devices will not be permitted.

16 STEP DRAWDOWN TEST

This test will be carried out on each borehole prior to the commencement of the constant discharge test.

The test shall comprise a minimum of four discharge rates, with each rate being greater than the previous rate. Each discharge shall be pumped for 60 minutes or as directed by the Client, and the increased rate will be commenced immediately after the previous discharge has been pumped for the specified time.

The discharge rates will be based on blowing yield and are likely to be between X l/s and XX l/s. Water drawdown measurements during the test shall be taken on the borehole. When these tests are completed, a minimum period of 2 hours will elapse before the start of the constant discharge test to allow recovery of the water level.

The test shall be continuous, and the Contractor will be responsible for labour, for maintaining each discharge rate constant, for increasing the discharge rate at the specified time, and for recording drawdown levels in the borehole. Interruptions exceeding 5% of the total pumping time will not be allowed. Should interruptions exceed the above limit, the test will be restarted, after allowing for water level recovery, at the expense of the Contractor.

17 CONSTANT DISCHARGE TEST

The constant discharge test will follow the step drawdown test.

The pumping tests shall have a continuous and constant yield and the Contractor shall be responsible for providing labour for maintaining the yield constant and recording drawdown levels in the pumping borehole and any observation boreholes. Interruptions exceeding 5% of the total pumping time will not be allowed. Should the interruptions exceed the above limit the test will be restarted, after allowing for water level recovery, at the expense of the Contractor.

The test(s) will last for a period ofhours tohours, unless pump suction is reached, followed by a minimum of hours of recovery. In the event that the water level is drawn down to pump suction, the pump will be stopped and recovery will commence immediately.

18 DISINFECTION OF BOREHOLES

On completion of the test and after removal of the pumping test equipment the borehole shall be disinfected with a solution of 0.5 kg of **HTH** mixed into 200 litres of clean water and this shall be poured into the borehole.

19 ALLOWABLE PAYMENTS

19.1 Site establishment

This is a payment to cover the establishment of all the required pump testing equipment, personnel, camping and general equipment necessary to carry out and complete the Works described in this specification and any extensions, and to cover the removal of all plant, equipment and personnel permanently from the project and the restoration of the sites to a reasonably tidy state. This rate can be either a lumpsum or a Km rate.

19.2 Movement between borehole sites

This is charged as a lump sum or rate per kilometre to cover movement from the one borehole to the next.

19.3 Installation and removal of pumping test unit

This payment shall cover the installation and removal of the pump testing equipment per borehole tested. The installation depths are likely to be between XX and XXm.

19.4 Pumping tests

The tendered rate shall be deemed to compensate all the time spent on pumping (measurements of drawdown) and **PAYMENT WILL BE MADE ONLY FOR THE DURATION OF A COMPLETE AND UNINTERRUPTED PUMPING PHASE, PLUS ANY UNINTERRUPTED STEP DRAWDOWN TEST.**

Any time spent on a test which is interrupted through break down or other operational problems will be at the Contractor's expense.

19.5 Recovery of measurements

The recovery measurement time shall cover all time spent by the Contractor measuring borehole recovery while the pump is still in the borehole as well as from adjacent monitoring/observation boreholes, if present.

19.6 Standby time

This rate, which is provisional, is to cover only those items when the Contractor's crew are waiting for decisions by the Client, where those decisions or whose presence is required before the commencement of testing operations or for the continuation of the Work. Under no circumstances will Standby Time be payable for any other delays other than those incurred by the Client's decisions.

20 WATER SAMPLES

A two litre water sample or a volume specified by the Client for full chemical analyses shall be collected at the end of the constant discharge test.

21 CAPPING OF BOREHOLES

After completion of the pumping test operations, the boreholes are to be closed with a welded plate 4mm thick or a cap secured with a bolt and double lock nuts.

22 FINISHING AND CLEANING UP OF SITE

On completion of the pumping test all the debris of construction, such as unsuitable or rejected materials, spillage and cuttings shall be removed. The site of the work shall be cleaned of all rubbish, excess materials, false works, temporary structural installations and abandoned equipment. All resulting construction scars from these Works shall be treated to blend with the contour and vegetation of the surroundings.

23 FORMS

At the end of the Works, the Contractor shall provide all information necessary to complete the required data forms.

EXAMPLE BILL OF ESTIMATED QUANTITIES AND RATES FOR THE PUMPING TESTS OF BOREHOLES

ITE	DESCRIPTION	UNIT	QTY	RATE	AMOUN
	General				
1.	Establishment and removal from site of testing and all ancillary	lumps um			
2.	Boreholes moves	no			
3.	Installation and removal of pumping test equipment	no			
	Testing				
4.	Step drawdown test	hrs			
5.	Constant discharge test	hrs			
6.	Recovery readings	hrs			
7.	<i>Standby time</i>	hr			
8.	Capping of boreholes	no			
9.	Collection of water sample	no			
10.	Finishing up and cleaning up of	no			
	TOTAL CARRIED FORWARD TO FORM OF TENDER				R

G:\PROJECTS\6966 - DOLOMITE MANAGEMENT GUIDELINES\REPORTS\6966-6940-3-E GUIDELINE DOC FOR DOLOMITIC AREAS IN SA\FINAL DRAFT GUIDELINE 30 JUNE 06\APPENDICES FOR VOLUME 2\APPENDIX B.2 MODEL PUMPING TEST CONTRACT.DOC

APPENDIX C

STANDARD DEPARTMENT OF WATER AFFAIRS AND FORESTRY
RECORDING SHEETS

23 UNCONSOLIDATED; 24 CONSOLIDATED
NATIONAL GROUND WATER DATA BASE

112:Customer Name	Street Address
Postal Address	Plot/Erf No. 113:Borehole No.
Farm Name	

Fill in for ALL boreholes					CONS. ONLY	UNCONSOLIDATED FORMATTONS ONLY						
Depth	1.Lithology code	Colour		4.Texture		Feature 5	6.Feature					
		2P	3S				P	S	7A	8S	9R	
1.00												
2.00												
3.00												
4.00												
5.00												
6.00												
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49.00												
50.00												

Circle one of the following:	
FOR DEPTH	1 - 50m
OR DEPTH	101 - 150m

1 LITHOLOGY CODE

Overburden	OBDN
Clay	CLAY
Clay and sand	CLSD
Coal	COAL
Boulders	BLDR
Boulderclay	BLCL
Alluvium	ALVM
Chert	CHRT
Calcrete	CLCR
Conglomerat	CLGM
Diabase	DIBS
Dolerite	DLRT
Dolomite	DLMT
Granite	GRNT
Gravel	GRVL
Lava	LAVA
Quartzite	QRTZ
Sand	SAND
Shale	SHLE
Sandstone	SNDS

2 PRIMARY COLOURS

Black	S
Blue	B
Brown	C
Green	G
Grey	H
Purple	N
Orange	O
Pink	P
Red	R
White	W
Yellow	Y
No information	

3 SECONDARY COLOURS

Bluish	B
Brownish	C
Dark	D
Greenish	G
Greyish	H
Light	L
Purple	M
Orange	O
Pinkish	P
Redish	R
Olive	V
Yellowish	Y
No information	

4 TEXTURE

Crypto	CR
Very fine	VF
Fine	FN
Fine/medium	FM
Medium	MD
Medium/Coarse	MC
Very coarse	VC

5 FEATURE (Consolidated only)

Cemented	CE
Consolidated	CS
Fractured	FC
Hard	D
Soft	SF
Unconsolid	UC
Weathered	WT

23 UNCONSOLIDATED; 24 CONSOLIDATED
NATIONAL GROUND WATER DATA BASE

Fill in for ALL boreholes					CONS. ONLY	UNCONSOLIDATED FORMATIONS ONLY					
Depth	1.Lithology code	Colour		4.Texture		Feature 5	6.Feature				
		2P	3S				P	S	7A	8S	9R
51.00											
52.00											
53.00											
54.00											
55.00											
56.00											
57.00											
58.00											
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94.00											
95.00											
96.00											
97.00											
98.00											
99.00											
50.00											

Circle one of the following:

FOR DEPTH 51 - 100m

OR DEPTH 151 - 200m

CODES FOR UNCONSOLIDATED ONLY

6 PRIMARY AND SECONDARY FEATURES	
Argillaceous	AG
Arenaceous	AR
Baked	BK
Calcareous	CA
Carbonaceous	CB
Cemented	CE
Chloritic	CL
Consolidated	CS
Clayey	CY
Dark	DK
Fractured	FC
Ferruginous	FE
Fresh	FR
Feldspatic	FS
Glauconitic	GL
Gravel-bearing	GV
Hard	HD
Heavy minerals	HM
Jointed	JD
Loose	LS
Light	LT
Micaceous	MC
Mineralised	MN
Massive	MS
Oolitic	OO
Phosphorite bearing	PO
Primary	PR
Peaty	PT
Siliceous	SC
Solid	SD
Soft	SF
Shelly	SH
Silicified	SI
Silty	SL
Sandy	SN
Secondary	SR
Unconsolidated	UC
Weathered	WT
No information	

7 FEATURE ATTRIBUTE	
Slightly	-
Very	+
No information	

8 SORTING	
Unsorted	11
Poorly sorted	22
Poorly to mod	23
Mod to poorly sorted	32
Moderately sorted	33
Mod to well sorted	34
Well to mod sorted	43
Well sorted	44
No information	

9 ROUNDNESS	
Angular	11
Angular to sub-angular	12
Angular to sub-rounded	13
Angular to rounded	14
Sub-angular	22
Sub-angular to sub-rounded	23
Sub-angular to rounded	24
Sub-rounded	33
Sub-rounded to rounded	34
Rounded	44
No information	

Company

Address/Code

Signature

Name & Position (print)

IMPORTANT : BOREHOLE OWNER

Only a complete set of 6 forms must be sent to :

Directorate : GEOHYDROLOGY

Dept. Water Affairs

P/B X313 PRETORIA 0001

DO NOT SEND ONE FORM AT A TIME.

NGA GROUNDWATER HYDROCENSUS FORM

All colored fields are mandatory.

* Notes and/or Tips are indicated with an asterisk (*).

Owner Information	
1	Ownership Date (ccyy-mm-dd)
2	Owner Surname
3	Owner Initials
Home Address	
4	Address Location <input type="checkbox"/> Home
5	Address Type <input type="checkbox"/> Postal <input type="checkbox"/> Physical
6	Address Text
7	Suburb
8	Town/City
9	Postal Code
Business Address	
10	Address Location <input type="checkbox"/> Business
11	Address Type <input type="checkbox"/> Postal <input type="checkbox"/> Physical
12	Building Name
13	Office Number
14	Street Name and Number
15	Suburb
16	Town/City
17	Postal Code
18	Telephone Number Location <input type="checkbox"/> Business <input type="checkbox"/> Home
19	Telephone Number Type <input type="checkbox"/> Switchboard <input type="checkbox"/> Fax <input type="checkbox"/> Cellular <input type="checkbox"/> Land Line
20	Dialling code
21	Telephone Number
22	Extension

Geosite													
1	Geohydrology Office <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input type="checkbox"/> Geo, Water Affairs - Eastern Cape</td> <td style="width: 50%; border: none;"><input type="checkbox"/> Geo, Water Affairs - Mpumalanga</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Free State</td> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Northern Cape</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Gauteng</td> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - North West</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Kwazulu Natal</td> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Pretoria</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Limpopo</td> <td style="border: none;"><input type="checkbox"/> Geo, Water Affairs - Western Cape</td> </tr> </table>	<input type="checkbox"/> Geo, Water Affairs - Eastern Cape	<input type="checkbox"/> Geo, Water Affairs - Mpumalanga	<input type="checkbox"/> Geo, Water Affairs - Free State	<input type="checkbox"/> Geo, Water Affairs - Northern Cape	<input type="checkbox"/> Geo, Water Affairs - Gauteng	<input type="checkbox"/> Geo, Water Affairs - North West	<input type="checkbox"/> Geo, Water Affairs - Kwazulu Natal	<input type="checkbox"/> Geo, Water Affairs - Pretoria	<input type="checkbox"/> Geo, Water Affairs - Limpopo	<input type="checkbox"/> Geo, Water Affairs - Western Cape		
<input type="checkbox"/> Geo, Water Affairs - Eastern Cape	<input type="checkbox"/> Geo, Water Affairs - Mpumalanga												
<input type="checkbox"/> Geo, Water Affairs - Free State	<input type="checkbox"/> Geo, Water Affairs - Northern Cape												
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<input type="checkbox"/> Geo, Water Affairs - Limpopo	<input type="checkbox"/> Geo, Water Affairs - Western Cape												
2	Identifier												
3	Reporting Institution												
4	Geosite Type <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input type="checkbox"/> Borehole</td> <td style="width: 50%; border: none;"><input type="checkbox"/> Seepage Pond</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Drain</td> <td style="border: none;"><input type="checkbox"/> Sinkhole</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Dug Well</td> <td style="border: none;"><input type="checkbox"/> Spring</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Lateral / Radial Arm Collector</td> <td style="border: none;"><input type="checkbox"/> Tunnel</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Mine</td> <td style="border: none;"><input type="checkbox"/> Well Point</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Prospective Borehole Site</td> <td></td> </tr> </table>	<input type="checkbox"/> Borehole	<input type="checkbox"/> Seepage Pond	<input type="checkbox"/> Drain	<input type="checkbox"/> Sinkhole	<input type="checkbox"/> Dug Well	<input type="checkbox"/> Spring	<input type="checkbox"/> Lateral / Radial Arm Collector	<input type="checkbox"/> Tunnel	<input type="checkbox"/> Mine	<input type="checkbox"/> Well Point	<input type="checkbox"/> Prospective Borehole Site	
<input type="checkbox"/> Borehole	<input type="checkbox"/> Seepage Pond												
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<input type="checkbox"/> Lateral / Radial Arm Collector	<input type="checkbox"/> Tunnel												
<input type="checkbox"/> Mine	<input type="checkbox"/> Well Point												
<input type="checkbox"/> Prospective Borehole Site													
5	Geosite Status <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input type="checkbox"/> Abandoned</td> <td style="width: 50%; border: none;"><input type="checkbox"/> Inaccessible</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Destroyed</td> <td style="border: none;"><input type="checkbox"/> Not Drilled</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Dry</td> <td style="border: none;"><input type="checkbox"/> Standby (Production)</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> In Use</td> <td></td> </tr> </table>	<input type="checkbox"/> Abandoned	<input type="checkbox"/> Inaccessible	<input type="checkbox"/> Destroyed	<input type="checkbox"/> Not Drilled	<input type="checkbox"/> Dry	<input type="checkbox"/> Standby (Production)	<input type="checkbox"/> In Use					
<input type="checkbox"/> Abandoned	<input type="checkbox"/> Inaccessible												
<input type="checkbox"/> Destroyed	<input type="checkbox"/> Not Drilled												
<input type="checkbox"/> Dry	<input type="checkbox"/> Standby (Production)												
<input type="checkbox"/> In Use													
6	Date when Status Observed (ccyy-mm-dd)												
7	Map Number												
8	Reference Datum <input type="checkbox"/> Cape Datum <input type="checkbox"/> Hartbeeshoek Datum (WGS 84)												
9	Latitude (DDMMSS / DD.dddd)												
10	Longitude (DDMMSS / DD.dddd)												
11	Coordinate Method <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input type="checkbox"/> Differential GPS with Base Station (GB1)</td> <td style="width: 50%; border: none;"><input type="checkbox"/> Global Positioning System (Hand - Held)</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Differential GPS without Base Station (GB)</td> <td style="border: none;"><input type="checkbox"/> Surveyed</td> </tr> </table>	<input type="checkbox"/> Differential GPS with Base Station (GB1)	<input type="checkbox"/> Global Positioning System (Hand - Held)	<input type="checkbox"/> Differential GPS without Base Station (GB)	<input type="checkbox"/> Surveyed								
<input type="checkbox"/> Differential GPS with Base Station (GB1)	<input type="checkbox"/> Global Positioning System (Hand - Held)												
<input type="checkbox"/> Differential GPS without Base Station (GB)	<input type="checkbox"/> Surveyed												
12	Coordinate GPS Accuracy (m) Estimated Position Error (EPE)												
13	Elevation (mamsl)												
14	Elevation Method <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input type="checkbox"/> Altimeter</td> <td style="width: 50%; border: none;"><input type="checkbox"/> Global Positioning System (Hand - Held)</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Differential GPS with Base Station (GB1)</td> <td style="border: none;"><input type="checkbox"/> Levelled or Surveyed</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> Differential GPS without Base Station (GB)</td> <td></td> </tr> </table>	<input type="checkbox"/> Altimeter	<input type="checkbox"/> Global Positioning System (Hand - Held)	<input type="checkbox"/> Differential GPS with Base Station (GB1)	<input type="checkbox"/> Levelled or Surveyed	<input type="checkbox"/> Differential GPS without Base Station (GB)							
<input type="checkbox"/> Altimeter	<input type="checkbox"/> Global Positioning System (Hand - Held)												
<input type="checkbox"/> Differential GPS with Base Station (GB1)	<input type="checkbox"/> Levelled or Surveyed												
<input type="checkbox"/> Differential GPS without Base Station (GB)													
15	Elevation GPS Accuracy (m) Estimated Position Error (EPE)												

16	Location Name	
17	Location Number	
18	Province	<input type="checkbox"/> Eastern Cape <input type="checkbox"/> Free State <input type="checkbox"/> Gauteng <input type="checkbox"/> Kwazulu Natal <input type="checkbox"/> Limpopo <input type="checkbox"/> Mpumalanga <input type="checkbox"/> North West <input type="checkbox"/> Northern Cape <input type="checkbox"/> Western Cape
19	Registration District	
20	Quaternary Drainage Region	
21	Water Management Area	<input type="checkbox"/> Berg <input type="checkbox"/> Breede <input type="checkbox"/> Crocodile (West) and Marico <input type="checkbox"/> Fish to Tsitsikamma <input type="checkbox"/> Gouritz <input type="checkbox"/> Inkomati <input type="checkbox"/> Limpopo <input type="checkbox"/> Lower Orange <input type="checkbox"/> Lower Vaal <input type="checkbox"/> Luvubu and Letaba <input type="checkbox"/> Middle Vaal <input type="checkbox"/> Mvoti to Umzimkulu <input type="checkbox"/> Mzimvubu to Keiskamma <input type="checkbox"/> Olifants <input type="checkbox"/> Olifants / Doorn <input type="checkbox"/> Thukela <input type="checkbox"/> Upper Orange <input type="checkbox"/> Upper Vaal <input type="checkbox"/> Usutu to Mhlatuze
22	Geomorphology	<input type="checkbox"/> Alluvial Fan <input type="checkbox"/> Flat / Gently Undulating Surface <input type="checkbox"/> Hill / Mountain Top <input type="checkbox"/> Low Gradient Hill Slope <input type="checkbox"/> Near Sinkhole <input type="checkbox"/> Raised Terrace <input type="checkbox"/> Riparian Zone <input type="checkbox"/> Steep Mountain Slope <input type="checkbox"/> Unvegetated Shifting Dunes <input type="checkbox"/> Valley Floor <input type="checkbox"/> Vegetated Dunes <input type="checkbox"/> Water Body (Wetlands, Pan, River, Spring)
23	Land cover	<input type="checkbox"/> Barren Rock <input type="checkbox"/> Cultivated: Commercial Dryland <input type="checkbox"/> Cultivated: Permanent – Commercial Irrigated <input type="checkbox"/> Cultivated: Permanent – Commercial Sugarcane <input type="checkbox"/> Cultivated: Temporary - Commercial Irrigated <input type="checkbox"/> Cultivated: Temporary – Commercial Dryland <input type="checkbox"/> Cultivated: Temporary Semi-Commercial / Subsistence Dryland <input type="checkbox"/> Degraded: Forest and Woodland <input type="checkbox"/> Degraded: Grassland <input type="checkbox"/> Degraded: Herbland <input type="checkbox"/> Degraded: Shrubland and Low Fynbos <input type="checkbox"/> Degraded: Thicket and Bushland (etc.) <input type="checkbox"/> Dongas and Sheet Erosion Scars <input type="checkbox"/> Forest plantations (Indicate Eucalyptus) <input type="checkbox"/> Forest plantations (Indicate Pine) <input type="checkbox"/> Forest plantations (Indicate Wattle) <input type="checkbox"/> Grassland <input type="checkbox"/> Herbland <input type="checkbox"/> Mines and Quarries <input type="checkbox"/> Natural Forest <input type="checkbox"/> Natural Forest and Woodland <input type="checkbox"/> Shrubland and Low Fynbos <input type="checkbox"/> Thicket and Bushland (etc.) <input type="checkbox"/> Urban / Built-Up Land: Industrial / Transport <input type="checkbox"/> Urban / Built-Up Land: Residential <input type="checkbox"/> Urban / Built-Up Land: Residential (Small Holdings: Bushland) <input type="checkbox"/> Urban / Built-Up Land: Residential (Small Holdings: Grassland) <input type="checkbox"/> Urban / Built-Up Land: Residential (Small Holdings: Shrubland) <input type="checkbox"/> Urban / Built-Up Land: Residential (Small Holdings: Woodland) <input type="checkbox"/> Urban / Built-Up: Commercial
24	Taste of Water	<input type="checkbox"/> Brack <input type="checkbox"/> Fresh <input type="checkbox"/> Salty
25	DWAF Geosite Purpose	<input type="checkbox"/> Dewatering <input type="checkbox"/> Drainage <input type="checkbox"/> Exploration <input type="checkbox"/> Observation <input type="checkbox"/> Production <input type="checkbox"/> Recharge <input type="checkbox"/> Standby <input type="checkbox"/> Waste Disposal
26	Observed / Actual Water Use	<input type="checkbox"/> Agriculture <input type="checkbox"/> Bulk Water Supply <input type="checkbox"/> Commercial <input type="checkbox"/> Domestic <input type="checkbox"/> Gardening <input type="checkbox"/> Industrial <input type="checkbox"/> Irrigation <input type="checkbox"/> Mining <input type="checkbox"/> Nature Conservation <input type="checkbox"/> Power Generation <input type="checkbox"/> Public <input type="checkbox"/> Stock Watering

Other Number Information				
1	Other Number Type, Number and Assignor	Other Number Type	Number	Assignor
	<input type="checkbox"/>	Aquabase Number		
	<input type="checkbox"/>	Borehole Number (* BHNO)		
	<input type="checkbox"/>	Boring Branch Number (* BBNO)		
	<input type="checkbox"/>	DWAF Number		
	<input type="checkbox"/>	G Number		
	<input type="checkbox"/>	Hydrocom Number (* HYDR)		
	<input type="checkbox"/>	Hydrological Station Number (* HSTA)		
	<input type="checkbox"/>	Monitoring Feature ID (* MFID)		
	<input type="checkbox"/>	Old Hydrological Station Number (* OHST)		
	<input type="checkbox"/>	Open-NGDB Number (* SITE ID)		
	<input type="checkbox"/>	Regional Borehole Number (* RBHN)		
	<input type="checkbox"/>	T Number		
	<input type="checkbox"/>	W Number		
	<input type="checkbox"/>	Water Level Monitoring Point (* WLMP)		
	<input type="checkbox"/>	ZQC QUAL Number		
	<input type="checkbox"/>	ZQM QUAL Number		

Reference Information	
1	Reference Type <input type="checkbox"/> NGA Groundwater Hydrocensus Form <input type="checkbox"/> Consultants Report
2	Report Number
2	Report Date
3	Report Name
4	Location <input type="checkbox"/> Geo, Water Affairs - Eastern Cape <input type="checkbox"/> Geo, Water Affairs - Free State <input type="checkbox"/> Geo, Water Affairs - Gauteng <input type="checkbox"/> Geo, Water Affairs - Kwazulu Natal <input type="checkbox"/> Geo, Water Affairs - Limpopo <input type="checkbox"/> Geo, Water Affairs - Mpumalanga <input type="checkbox"/> Geo, Water Affairs - Northern Cape <input type="checkbox"/> Geo, Water Affairs - North West <input type="checkbox"/> Geo, Water Affairs - Pretoria <input type="checkbox"/> Geo, Water Affairs - Western Cape

Drilling Completion and Relevant Information	
1	Construction Cost (Rand)
2	Drilling Method <input type="checkbox"/> Cable-Tool <input type="checkbox"/> Core Drilling <input type="checkbox"/> Direct Circulation (Mud Rotary) <input type="checkbox"/> Driven Well <input type="checkbox"/> Earth Augers: Bucket <input type="checkbox"/> Earth Augers: Hollow-Stem <input type="checkbox"/> Earth Augers: Solid Stem <input type="checkbox"/> Hand Dug <input type="checkbox"/> Hydraulic Rotary <input type="checkbox"/> Jetting: Percussion Drilling <input type="checkbox"/> Jetting: Well Point <input type="checkbox"/> Reverse Circulation (Mud Rotary) <input type="checkbox"/> Rotary Air Percussion <input type="checkbox"/> Tube Well
3	Drilling Company
4	Drilling Contractor
5	Drilling Fluid <input type="checkbox"/> Air <input type="checkbox"/> Air With Additives <input type="checkbox"/> Water <input type="checkbox"/> Water With Additives
6	Water Additives <input type="checkbox"/> Clay <input type="checkbox"/> Polymers
7	Air Additives <input type="checkbox"/> Clay <input type="checkbox"/> Polymers <input type="checkbox"/> Surfactant <input type="checkbox"/> Water
8	Additional Additives
9	Drilling Completion Date (ccyy-mm-dd)

Geosite Depth and Diameter Information				
	1	2	3	4
1	Date Measured (ccyy-mm-dd / ccyy-mm / ccyy)			
2	Depth to Bottom (m)			
3	Depth Qualifier <input type="checkbox"/> Blocked <input type="checkbox"/> Collapsed <input type="checkbox"/> Construction <input type="checkbox"/> Deepened <input type="checkbox"/> Measured <input type="checkbox"/> Reamed			
4	Diameter (mm) <input type="checkbox"/> 127 (5") <input type="checkbox"/> 140 (5.5") <input type="checkbox"/> 152 (6") <input type="checkbox"/> 165 (6.5") <input type="checkbox"/> 203 (8") <input type="checkbox"/> 216 (8.5") <input type="checkbox"/> 254 (10") <input type="checkbox"/> 305 (12") <input type="checkbox"/> 445 (17.5")			
5	Data Source <input type="checkbox"/> Downhole Geophysical Logging <input type="checkbox"/> Driller's Log <input type="checkbox"/> Check by Reporting Institution <input type="checkbox"/> Geo Specialist's Record <input type="checkbox"/> Memory (* Owner, Driller, Operator) <input type="checkbox"/> Owner's Record <input type="checkbox"/> Pump Operator's Record <input type="checkbox"/> Report / File			
6	Penetration Information Available <input type="checkbox"/> Yes			

Casing	
1	Casing Column Number (1 - 9)
2	Casing Height (m)
3	Observed Casing Details <input type="checkbox"/> Yes
4	Inner Diameter (mm)
5	Outer Diameter (mm)
6	Casing Wall Thickness (mm)
7	Casing Material <input type="checkbox"/> Concrete <input type="checkbox"/> Other Material <input type="checkbox"/> PVC <input type="checkbox"/> Steel <input type="checkbox"/> Stainless Steel
8	Other Material

Discharge Rate					
		1	2	3	4
1	Date Measured (ccyy-mm-dd)				
2	Time Measured (hh:mm)				
3	Discharge Rate (l/s)				
4	Determining Method	<input type="checkbox"/> Estimated <input type="checkbox"/> Flow Meter <input type="checkbox"/> Flume <input type="checkbox"/> Submerged Orifice <input type="checkbox"/> Totalling Meter		<input type="checkbox"/> Venturi Meter <input type="checkbox"/> V-Notches <input type="checkbox"/> Volumetric Measurement	
5	Type of Discharge	<input type="checkbox"/> Airlift <input type="checkbox"/> Bailer		<input type="checkbox"/> Pump <input type="checkbox"/>	
6	Data Source	<input type="checkbox"/> Driller's Log <input type="checkbox"/> Check by Reporting Institution <input type="checkbox"/> Geo Specialist's Record <input type="checkbox"/> Memory (owner, driller, operator)		<input type="checkbox"/> Owner's Record <input type="checkbox"/> Pump Operator's Record <input type="checkbox"/> Report / File	

Water Level Information					
1	Casing Column Number (1 - 9)				
2	Piezometer Number				
3	Method of Measuring	<input type="checkbox"/> Airline <input type="checkbox"/> Capacity Probe <input type="checkbox"/> Data Logger <input type="checkbox"/> Dip Meter <input type="checkbox"/> Estimated		<input type="checkbox"/> Pressure Gauge <input type="checkbox"/> Recorder <input type="checkbox"/> Reported <input type="checkbox"/> Steel Tape	
4	Water Level Status	<input type="checkbox"/> Affected By Nearby Pump <input type="checkbox"/> Artesian <input type="checkbox"/> Dry		<input type="checkbox"/> Obstructed <input type="checkbox"/> Static <input type="checkbox"/> Suspect Data	
5	Data Source	<input type="checkbox"/> Driller's Log <input type="checkbox"/> Check by Reporting Institution <input type="checkbox"/> Geo Specialist's Record <input type="checkbox"/> Memory (* Owner, Driller, Operator)		<input type="checkbox"/> Owner's record <input type="checkbox"/> Pump Operator's Record <input type="checkbox"/> Report / File	
6	Date Measured (ccyy-mm-dd)	1	2	3	4
7	Time (hh:mm)				
8	Water Level (m)				

Visitor Information	
1	Visit Date (ccyy-mm-dd)
2	Reason for Visit
3	Visitor Surname
4	Visitor Initials
Home Address	
5	Address Location <input type="checkbox"/> Home
6	Address Type <input type="checkbox"/> Postal <input type="checkbox"/> Physical
7	Address Text
8	Suburb
9	Town/City
10	Postal Code
Business Address	
11	Address Location <input type="checkbox"/> Business
12	Address Type <input type="checkbox"/> Postal <input type="checkbox"/> Physical
13	Building Name
14	Office Number
15	Street Name and Number
16	Suburb
17	Town/City
18	Postal Code
19	Telephone Number Location <input type="checkbox"/> Business <input type="checkbox"/> Home
20	Telephone Number Type <input type="checkbox"/> Switchboard <input type="checkbox"/> Fax <input type="checkbox"/> Cellular <input type="checkbox"/> Land Line
21	Dialling code
22	Telephone Number
23	Extension

Step Test Information

All colored fields are mandatory.

Identification number	
Duration (minutes)	
Step test start date (ccyy-mm-dd)	
Static water level (DDDD.dd)	
Step test start time (hh:mm)	
Water Level status	<input type="checkbox"/> Drawdown <input type="checkbox"/> Recovery
Abstraction measurement type	<input type="checkbox"/> Abstraction readings (l/s) <input type="checkbox"/> Abstraction quantities (m³)

	Step test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type		Abstraction measurement
			wl difference	wl actual	
Step No 1		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				
Step No 2		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				
Step No 3		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				

Step test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type	Abstraction measurement
------------------------------	----------------------	------------------------------	-------------------------

Step No	Elapsed Time (hh:mm)	Water level measurement type	Abstraction measurement
		wl difference	wl actual
4	00:01		
	00:02		
	00:03		
	00:05		
	00:07		
	00:10		
	00:15		
	00:20		
	00:25		
	00:30		
	00:35		
	00:40		
	00:50		
	01:00		
01:15			
01:30			

Step No	Elapsed Time (hh:mm)	Water level measurement type	Abstraction measurement
		wl difference	wl actual
5	00:01		
	00:02		
	00:03		
	00:05		
	00:07		
	00:10		
	00:15		
	00:20		
	00:25		
	00:30		
	00:35		
	00:40		
	00:50		
	01:00		
01:15			
01:30			

Multi-rate Test Information

Identification number	
Duration (minutes)	
Multi-rate test start date (ccyy-mm-dd)	
Static water level (DDDD.dd)	
Multi-rate test start time (hh:mm)	
Water Level status	<input type="checkbox"/> Drawdown <input type="checkbox"/> Recovery
Abstraction measurement type	<input type="checkbox"/> Abstraction readings (l/s) <input type="checkbox"/> Abstraction quantities (m ³)

Multi-rate test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type		Abstraction measurement
------------------------------------	----------------------	------------------------------	--	-------------------------

wl difference wl actual

S t e p N o 1		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				

S t e p N o 2		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				

S t e p N o 3		00:01			
		00:02			
		00:03			
		00:05			
		00:07			
		00:10			
		00:15			
		00:20			
		00:25			
		00:30			
		00:35			
		00:40			
		00:50			
		01:00			
	01:15				
	01:30				

Multi-rate test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type	Abstraction measurement
------------------------------------	----------------------	------------------------------	-------------------------

		wl difference	wl actual	
Step No 4		00:01		
		00:02		
		00:03		
		00:05		
		00:07		
		00:10		
		00:15		
		00:20		
		00:25		
		00:30		
		00:35		
		00:40		
		00:50		
		01:00		
	01:15			
	01:30			

Step No 5		00:01		
		00:02		
		00:03		
		00:05		
		00:07		
		00:10		
		00:15		
		00:20		
		00:25		
		00:30		
		00:35		
		00:40		
		00:50		
		01:00		
	01:15			
	01:30			

Constant Yield Test Information

Identification number	
Duration (minutes)	
Constant yield test start date (ccyy-mm-dd)	
Static water level (DDDD.dd)	
Constant yield test start time (hh:mm)	
Abstraction measurement type	<input type="checkbox"/> Abstraction readings (l/s) <input type="checkbox"/> Abstraction quantities (m ³)

DRAWDOWN				
Constant yield test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type		Abstraction measurement
		wl difference	wl actual	
	00:01			
	00:02			
	00:03			
	00:05			
	00:07			
	00:10			
	00:15			
	00:20			
	00:25			
	00:30			
	00:35			
	00:40			
	00:50			
	01:00			
	01:15			
	01:30			
	02:00			
	02:30			
	03:00			
	03:30			
	04:00			
	05:00			
	06:00			
	07:30			
	09:00			
	10:30			
	12:00			
	14:00			
	16:00			
	18:30			
	21:00			
	24:00			

RECOVERY			
Constant yield test start time (hh:mm)	Elapsed Time (hh:mm)	Water level measurement type	
		wl difference	wl actual
	00:01		
	00:02		
	00:03		
	00:05		
	00:07		
	00:10		
	00:15		
	00:20		
	00:25		
	00:30		
	00:35		
	00:40		
	00:50		
	01:00		
	01:15		
	01:30		
	02:00		
	02:30		
	03:00		
	03:30		
	04:00		
	05:00		
	06:00		
	07:30		
	09:00		
	10:30		
	12:00		
	14:00		
	16:00		
	18:30		
	21:00		
	24:00		

APPENDIX D

TECHNICAL PROCEDURES

APPENDIX D

TECHNICAL GUIDELINES AND PROCEDURES FOR THE DRILLING, TESTING AND SAMPLING OF BOREHOLES

1 INTRODUCTION

This sections details the technical considerations the Water Manager needs to apply when designing and implementing assessment, planning and management programmes within the dolomite aquifer. This section covers the siting, drilling testing and sampling procedures that need to be followed to ensure the implementation of a successful programme.

2 FINAL DESIGN OF BOREHOLES

Boreholes provide a means of exploring, quantifying, accessing and tapping groundwater resources. They are used for many purposes including:

- Exploration (assessment),
- Water supply,
- Monitoring,
- Dewatering, and
- Artificial recharge.

Boreholes serve as a means of obtaining invaluable subsurface geological and hydrogeological data. Information that can be obtained from drilling includes:

- Geology (dolomite, chert, dolerite, etc),
- Weathering profile,
- Position of water bearing and non-water bearing zones,
- Position of (potential) aquifer(s) within the dolomite profile,
- Water strike(s),
- Blowing yield, (from air percussion drilling),
- Hydraulic parameters, etc.

It is therefore important that boreholes are sited and drilled, pump-tested and equipped according to the set of minimum requirements as set out in this guideline. Application of these minimum requirements to boreholes drilled for whatever purpose during the assessment phase will ensure the preservation of the natural quality of the dolomite aquifer being investigated by preventing contaminated water from entering the dolomitic aquifer.

2.1 Borehole Design

The Hydrogeologist will undertake the final design of each individual borehole while on site during the drilling process. Upfront planning and preparation by the Hydrogeologist is however required to ensure that sufficient and correct materials are available on site to allow the completion of each borehole immediately following the drilling of the hole.

2.2 Technical Specifications

The Hydrogeologist and Drilling Contractor should ensure that drilling is undertaken according to the technical specifications forming part of the drilling tender. A generic technical specification suitable for drilling of boreholes in dolomite is included in **Appendix B.1**.

2.3 Drilling Diameters

The diameter of boreholes that are drilled and completed must be compatible with the expected condition of the dolomite (karst, weathering, fracturing, chert bands), anticipated final borehole depth, and type of borehole (exploration, monitoring, production).

Starting diameters will be between 8" to 15" (200mm to 380mm) or more, depending upon the anticipated drilling depth and final diameter.

Completed diameters vary between 6" to 10" (152 mm to 254 mm) depending on use, anticipated yield and size of the production pump.

Figure 1 illustrates the construction of a typical production borehole.

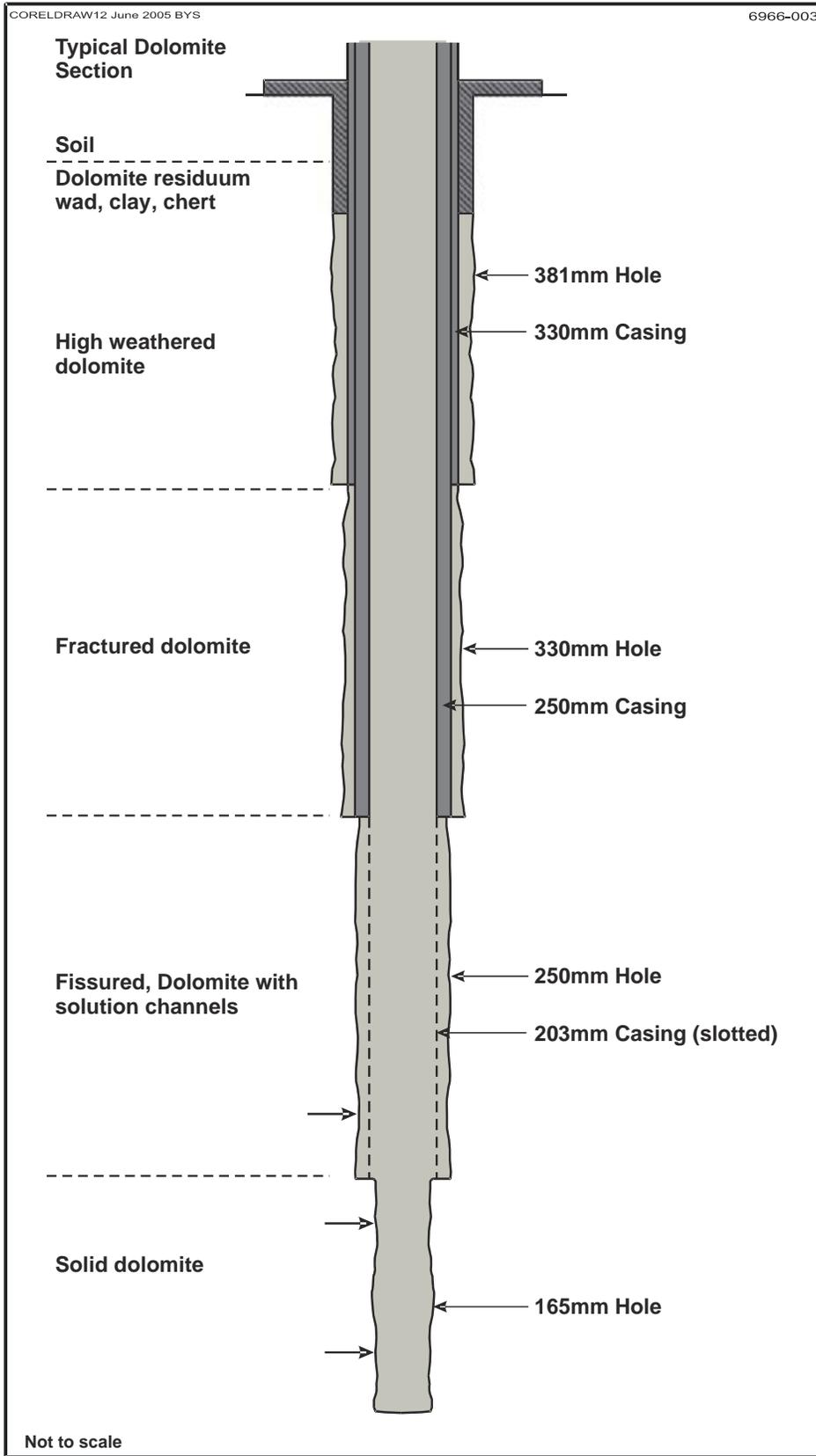


Figure 1: Completed diameters for drilling

2.4 Reaming

Reaming involves enlarging the initial drill hole to a larger diameter through unstable material, including the overburden and any collapsing formation encountered at depth, to allow insertion of casing.

2.5 Drilling Depth

Boreholes in the dolomitic aquifers should not only fully penetrate the entire saturated sequence but also a minimum of 10m into the underlying non-water bearing solid dolomite to confirm that all karst features (caverns and solution cavities) have been intersected. This latter portion of the borehole provides a sump.

As a general rule boreholes should be drilled to a minimum depth of 40m.

2.6 Casing

Casing (or borehole lining) is required to ensure the long term stability of the borehole. The function of the casing is to support unstable material from collapsing into the borehole during and after drilling.

Where casing is required below the water strike level to prevent unstable water bearing zones from collapsing, the casing must be slotted to allow inflow of the water intersected. All steel casing should have a minimum wall thickness of 4mm and should be approximately 60mm less in diameter than the drilled hole.

More than one casing diameter is often required in dolomite boreholes due to unstable conditions at depth.

Steel casing with a minimum wall thickness of 4mm should be used in dolomite boreholes. Plastic or uPVC casings are not suitable since casings made from these materials cannot be pushed past collapsing horizons.

Boreholes drilled into dolomite aquifers tend to be considerably more expensive than those drilled in other formations due to the need for large drilling diameters and amount of casing required.

2.7 Formation Stabiliser

Formation stabiliser (sometimes referred to as gravel pack) is placed in the annular space between the slotted casing and the borehole sidewall to provide a permeable zone between the dolomite and the casing, while at the same time protecting the slotted casing from clogging due to the collapse of the formation.

The formation stabiliser must comprise well sorted, sub-rounded quartzite or similar rock. The smallest grain size must be larger than the casing perforations/slots.

The formation stabiliser should extend a minimum of 10m above the top of the uppermost perforated/slotted section of casing before the borehole is developed. Drilling cuttings removed from the borehole must not be used as a formation stabiliser substitute, but can be used as backfill above the formation stabiliser.

2.8 Sanitary Seal

The sanitary seal comprises a cement or cement-bentonite mix grout and extends to a depth of 3 - 6m below ground surface. A sanitary seal is installed to:

- Prevent the inflow of potentially polluting surface water into the borehole via the annular space between the borehole sidewall and the outside of the casing, and
- Provide surface stability to the casing.

Every borehole must be completed with a sanitary seal, irrespective of its use, .i.e, monitoring, exploratory, production, dewatering, etc., unless backfilled and sealed with a concrete plug.

2.9 Borehole Verticality and Straightness

It is important that boreholes are both vertical and straight to allow for trouble free installation and operation of the production pump. The technical specifications in **Appendix B.1** detail the tests that the Drilling Contractor may be requested to carry out to confirm the borehole verticality and straightness. The Hydrogeologist should confirm these tests on site.

2.10 Unsuccessful Boreholes

Unsuccessful, abandoned or lost boreholes must be correctly plugged for safety and to protect the aquifer against pollution. Such boreholes must be backfilled to the surface with the drilling cuttings, compacted and sealed with a concrete plug to a depth of 450mm, as illustrated in **Figure 2**.

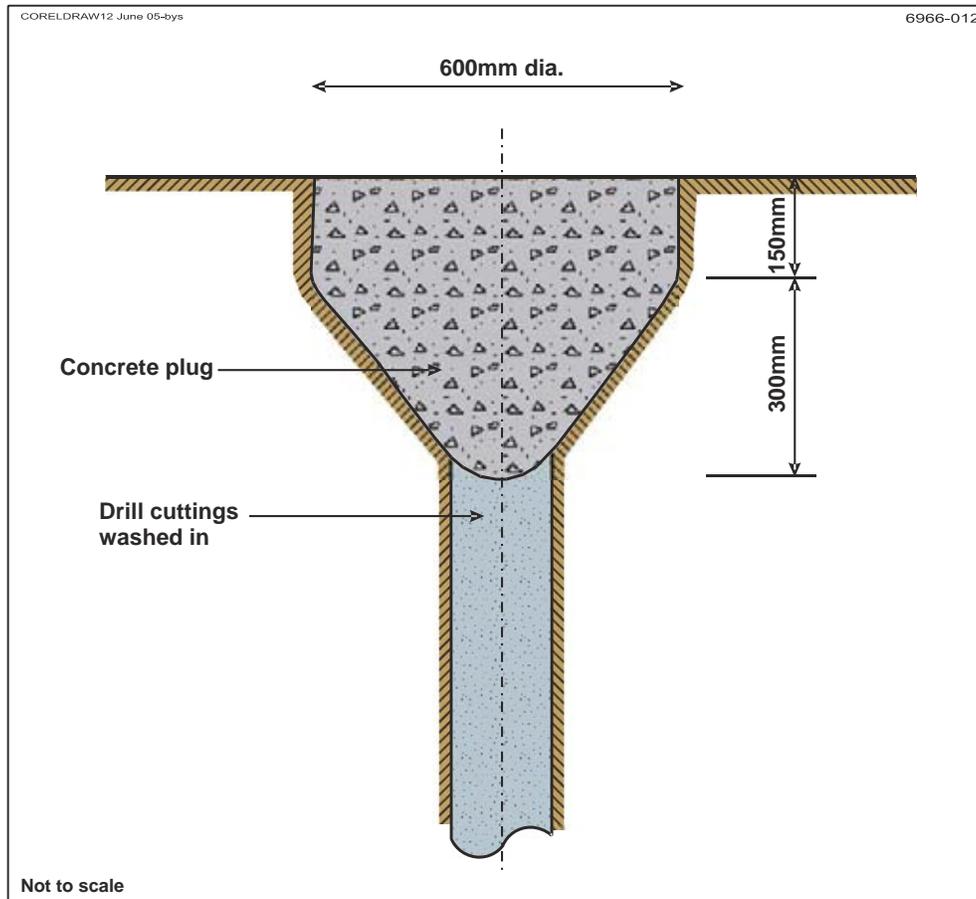


Figure 2: Sealing of boreholes

2.11 Drilling Techniques

Two drilling methods are commonly employed in South Africa, namely air percussion and mud rotary drilling. A third method, namely cable tool (Jumper) drilling is only rarely available. Each method involves different equipment and one method may be more applicable than another to overcome geological/hydrogeological conditions. The various methods are described in the sections below.

2.11.1 Down-the-Hole Air percussion drilling

This technique involves using compressed air to operate a pneumatic hammer and button bit to break up the formation as drilling advances. Air percussion drilling is suitable for the weathered and hard rock encountered in dolomitic environments and is the most commonly used technique. Difficult drilling conditions encountered through collapsing ground, and other unstable or cavernous formations can be overcome by using the Oversize Diameter (ODEX) method.

2.11.2 Mud rotary drilling

This technique involves the continuous circulation of a viscous biodegradable drilling fluid within the borehole, which prevents caving of the borehole, removes drill cuttings and cleans the tricone bit. This technique can also be used for the drilling of unconsolidated or highly weathered dolomitic formation but is not suitable for cavernous formations and very hard layers such as chert, which may occur in dolomite.

2.11.3 Cable tool percussion drilling

This technique involves the repeated lifting and dropping of a heavy string of drilling tools suspended at the end of a continuous cable. It is suitable for drilling in unconsolidated weathered and cavernous dolomite formations. Progress will be extremely slow in chert-rich layers and its use has thus been superseded by the down-the-hole air percussion method. Cable tool rigs are currently normally utilised for the cleaning and rehabilitating of existing boreholes.

2.12 Develop boreholes

Borehole development is undertaken on completion of the drilling and insertion of casing and formation stabiliser to maximise the yield. Development involves the removal of all fine and clogging material, including drilling cuttings, clay, silt, etc., from the borehole after completion of the drilling. The borehole development techniques applicable to dolomite are described below.

2.12.1 Mechanical methods

Air lifting: Air is injected into the borehole to lift the water to the surface. This is achieved by positioning the base of the drill string, with or without the hammer, to a depth between 0.5 and 3m above the bottom of the borehole and introducing air. At first, as the water reaches the surface, the air supply is cut off and the borehole allowed to recover. During the subsequent cycles the air is opened for progressively longer periods, until the water blown out becomes sediment free. The turbulence and inflow introduced into the borehole dislodges fine particles from the formation and washes the sidewalls.

Air jetting: This method is commonly used in slotted boreholes. The jetting tool is attached to the drill stem and lowered to the bottom of the required slotted section to be developed and then moved slowly up and down and rotated while high pressure air is pumped into the formation out of the jetting tool. Once the required section has been completely developed and sand and silt free water obtained, a drill rod is removed and the procedure repeated until the entire section to be developed has been jetted. A diagram of a typical jetting tool is given in **Figure 3**.

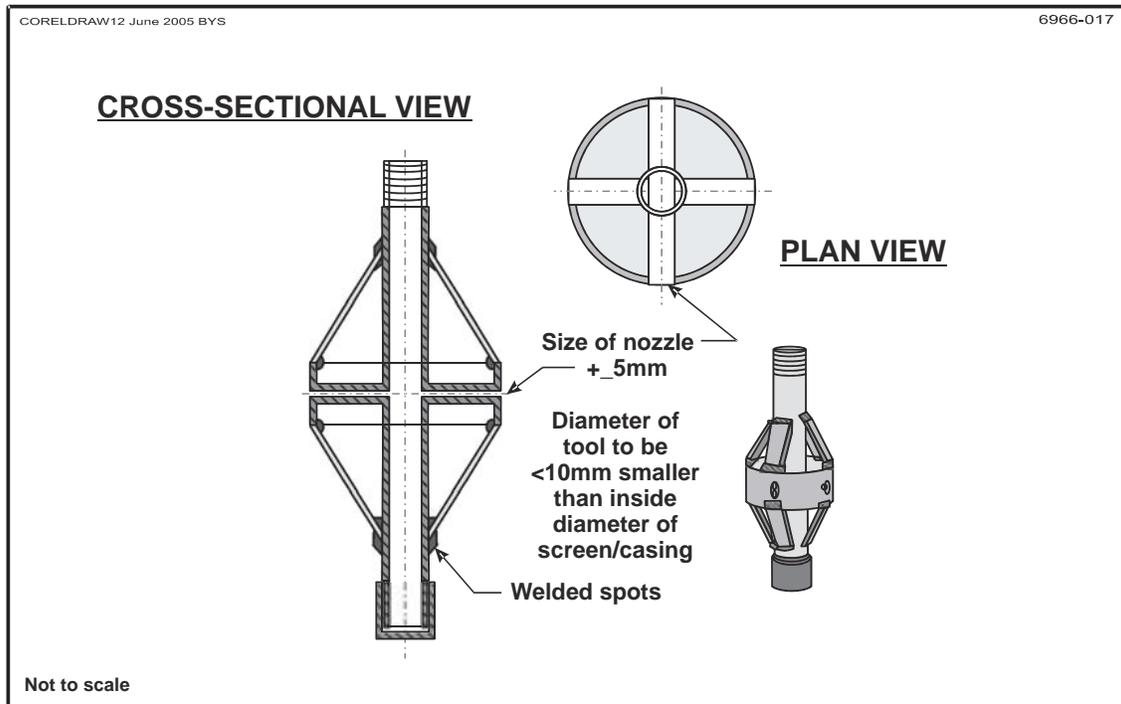


Figure 3: Typical jetting tool

Water jetting: This method employs the same principles as air jetting. Water is pumped at high pressure through the jetting tool into the dolomite instead of air.

Block surging: This technique involves the repeated lifting and lowering of a surge block below the water level and within the cased section of the borehole. The surge block comprises a plunger which fits snugly inside the casing thus forming a tight seal. Water is drawn into and forced out of the borehole through the formation stabiliser and weathered and fractured dolomite with each up and down stroke. The suction created draws fine clogging material into the borehole. Block surging is a particularly effective development technique. Air lifting or jetting will subsequently remove the material freed by the surging. A typical surging block is shown in **Figure 4**.

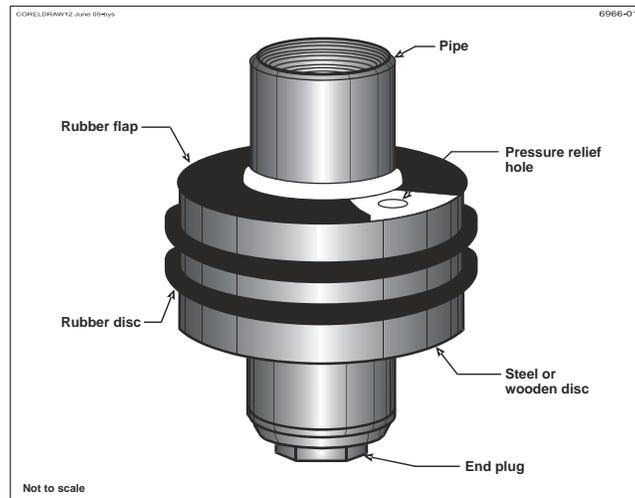


Figure 4: Typical surging block

2.12.2 Chemical methods

Polyphosphate: Adding polyphosphate (calgon) before and during development helps to remove clay and wad that occurs naturally in the dolomite aquifer by dispersing clay particles. These are later removed by air lifting.

Acidification: This development technique involves the introduction of an acid (usually hydrochloric acid for dolomite) into the borehole. The acid dissolves some of the dolomite formation thus improving permeability around the borehole. The borehole is subsequently air lifted for cleaning.

Air lifting and air jetting are the most commonly used and recommended techniques in South Africa. Development is completed when the water removed is clean and free of any visible sand, silt and/or clay.

NB: A special cautionary note is required for borehole development in dolomite aquifers. Experience has shown that if the water from a borehole in dolomite does not become clean after a reasonable period this may be as a result of a continuous feed of weathered and altered dolomite (wad) through solution cavities into the borehole. Continued development could lead to the potentially catastrophic formation of a sinkhole in close proximity to the borehole.

2.13 Disinfect boreholes

The purpose of disinfection is to cleanse the borehole of any bacteria, in particular coliform bacteria, introduced during the drilling, rehabilitation or testing operations. Disinfection can be accomplished by injecting chlorine (or chlorine-yielding compounds) into the borehole. The recommended quantities to inject are shown in **Table 1**.

Table 1: Recommended injection quantities for borehole disinfection

Nominal diameter of borehole	Volume of water (l) per metre of borehole	Volume/weight of sterilant to be used for disinfection per unit volume of water below groundwater test level		
		Sodium Hypochlorite	Calcium Hypochlorite	Chlorinated lime
152mm	18l	500 ml (2 cups)	26 g (¼ cup)	90g (1 cup)
165mm	21l	600 ml (2½ cups)	30 g (½ cup)	105g (1 cup)
203mm	33l	940 ml (4 cups)	47g (½ cup)	165g (1½ cups)
254mm	51l	1500 ml (6 cups)	73g (¾ cup)	255g (2½ cups)

NOTES:

- No distinction is made between open and cased portions of a borehole since these differences are considered to have a negligible impact on calculated unit volumes.
- The trade percentage of chlorine in the listed sterilants is taken to be:
 3.5 percent by volume (35ml/l) for sodium hypochlorite
 70 percent by weight (700g/kg) for calcium hypochlorite
 20 percent by weight (200g/kg) for chlorinated lime.

2.14 Borehole surface works

Concrete Slab

Unless a particular headwork construction is adopted, boreholes must be completed with a concrete slab, with minimum dimensions shown in **Figure 5**. The purpose of the concrete slab is to protect the sanitary seal and prevent surface erosion and thus ponding of water around the borehole head.

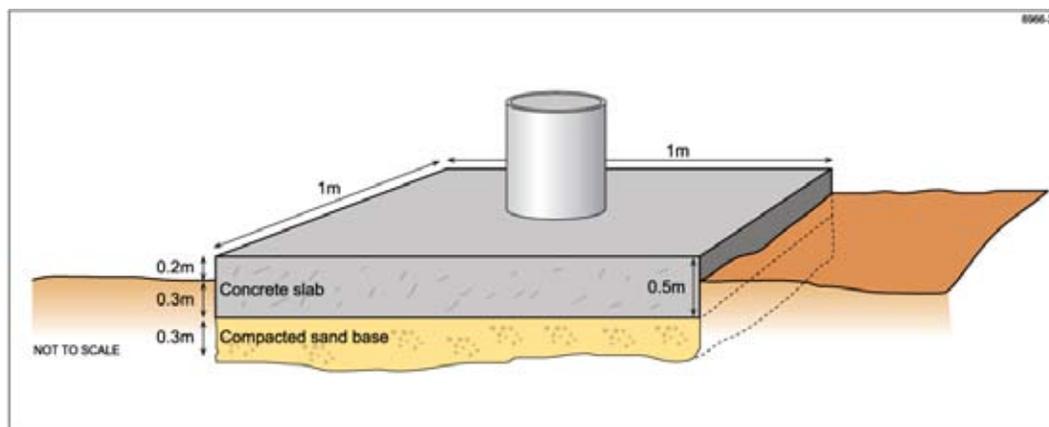
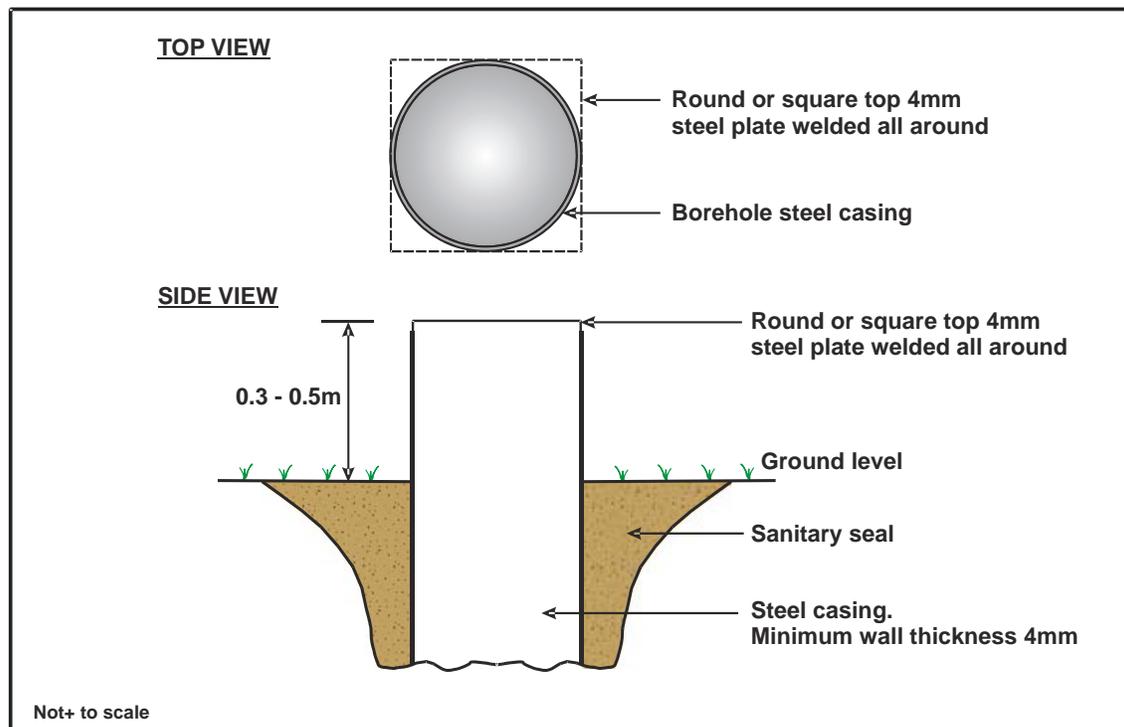
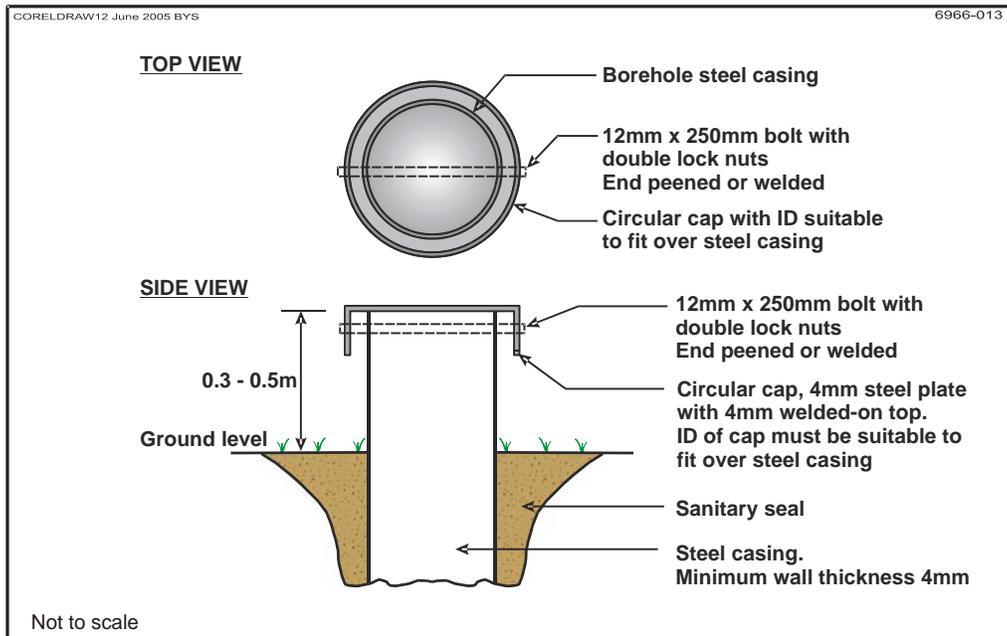


Figure 5: Typical concrete slab detail

Caps or Seals

Capping or sealing of the borehole is required to prevent introduction of foreign material. This is achieved either by the fitting of a cap and double locking nuts or Allen key bolt to the borehole casing (**Figure 6**) or by the welding of a 4 mm thick steel plate (lid) onto the borehole casing (**Figure 7**).



2.15 Borehole identification

Each borehole must be allocated a unique number according to the system approved by the DWAF. No hydrogeological consultant, drilling number or owner should use an independent numbering system. Borehole numbers are issued by the regional DWAF offices.

Each borehole should be marked in the field with its unique number, depth and drilling date. This information should be stencilled or welded:

- Onto the casing itself; or
- Onto a metal plaque set into the concrete slab; or
- On a marker pole and plate concreted into the ground close to the borehole.

2.16 Site cleaning

- Upon completion of the drilling the site must be restored as far as possible to the natural state to minimise the environmental impact of the drilling operations.

2.17 Further Information

The reader is referred to the following document should further details of drilling techniques, borehole construction, suitable materials, development techniques, etc. be required:

Driscoll, Fletcher. G., 1986 Groundwater and Wells. Second Edition. Published by Johnson Filtration Systems Inc. St. Paul, Minnesota 55112 ISBN 0-9616456-0-1

3 PUMPING TESTS

Pumping tests are an integral part of any groundwater assessment or development programme. Pumping tests are carried out to determine the hydraulic parameters of the aquifer (transmissivity, storativity, specific capacity, etc.), from which the long term yield of the tested borehole and the correct size and type of pump to be installed are determined. Data from properly conducted pumping tests are essential for groundwater assessments and aquifer management.

Pumping tests involve measuring the water level decline in the pumped borehole and in any observation/monitoring boreholes with time.

Three types of pumping test can be carried out. These are:

- Step drawdown test,

- Constant discharge rate test, and
- Recovery test.

Standard data recording sheets (No's A, B and C) for the three types of pumping tests are included in **Appendix C**.

Table 2 summarises the type of test recommended for various sectoral uses as well as the minimum test durations.

Table 2: Pumping tests and durations for various sectors (after SABS 1996)

Identification of use	Type of test	Pumping duration
Stock or domestic	Step Drawdown	4 x 1 hour
Irrigation Low cost consequence if failure occurs	Step Drawdown Constant Discharge	4 x 1 hour 24 hours
Irrigation High cost consequence if failure occurs	Step Drawdown Constant Discharge	4 x 1 hour 48 hours or more
Engine driven pump for rural village supply	Step Drawdown Constant Discharge	4 x 1 hour 48 hours
Town water supply	Step Drawdown Constant Discharge	4 x 1 hour 72 hours or more
Industry/Mining (Water supply not critical to production)	Step Drawdown Constant Discharge	4 x 1 hour 48 hours
Industry/Mining Water supply critical to production	Step Drawdown Constant Discharge	4 x 1 hour 100 hours or more
Power Station and similar water user	Step Drawdown Constant Discharge	4 x 1 hour 100 hours to 30 days

Pump testing must be carried out by a suitably experienced and equipped contractor familiar with these guidelines and in accordance with minimum technical specifications to ensure the collection of reliable data. A model technical specification for test pumping is included in **Appendix D.2**.

3.1 Step Drawdown Test

The step drawdown test generally comprises four different discharge rates, usually of 1 hour duration each. During each hour the discharge rate is maintained at a constant level, and increased at the beginning of each subsequent step. Measurements of both the discharge and the drawdown are taken at specified intervals during the test.

3.2 Constant Discharge Test

The constant discharge test follows the step drawdown test.

During the constant discharge test the borehole is tested by pumping at a constant yield for the required duration, **Table 2**. The test yield is selected from the results of the step test. During the test it is important to check the yield frequently to ensure the yield remains constant. Readings of the water level drawdown are recorded at specified intervals. An example of a data recording sheet is included in **Appendix C**.

The water level drawdown data obtained are used to:

- Determine the hydraulic parameters of the aquifer, and
- Assist in assessing the long term sustainable production yield of the tested borehole.

3.3 Recovery Test

The recovery test involves recording the recovery of the water level in the pumped and any observation boreholes on completion of the constant rate test. Readings of the water level recovery commence immediately the pumping phase described in 3.2 is completed. Water level readings are recorded at specified intervals. An example of a data recording sheet is included in **Appendix C**.

The water level recovery data obtained (often termed residual drawdown) are used to determine the hydraulic parameters of the aquifer and to assist in assessing the long term sustainable yield of the tested borehole.

3.4 Measurement Guidelines

3.4.1 Discharge

The discharge from a borehole may not vary by more than 5 % and may be measured using the following methods:-

Volumetric method: This method involves determining the time required to fill a container of a known volume. **Table 3** provides guidelines regarding the container's size per borehole yield range. All time readings must be made using a stopwatch. The volumetric method is especially recommended for low discharges in boreholes.

Table 3: Guidelines on container size per borehole yield range

Borehole Yield Range (l/s)	Container Size (l)
Less than 2	20
2 to 56	50
5 to 20	200
Greater than 20	Other suitable methods (Orifice weir or flow meter)

V-notch Weir. This is a rectangular weir of known dimensions installed in a horizontal position at the end of the discharge point of the borehole. The outlet of the weir is a rectangular plate with a 90° constriction (notch) over which the water will flow. The dimensions of the V-notch weir are shown in **Figure 8**. The height of the water flowing over the notch is related to a particular discharge. **Table 4** indicates the various discharges calibrated for the dimensions of the V-notch. The height of the water flowing over the notch must be read/measured to within 5mm accuracy.

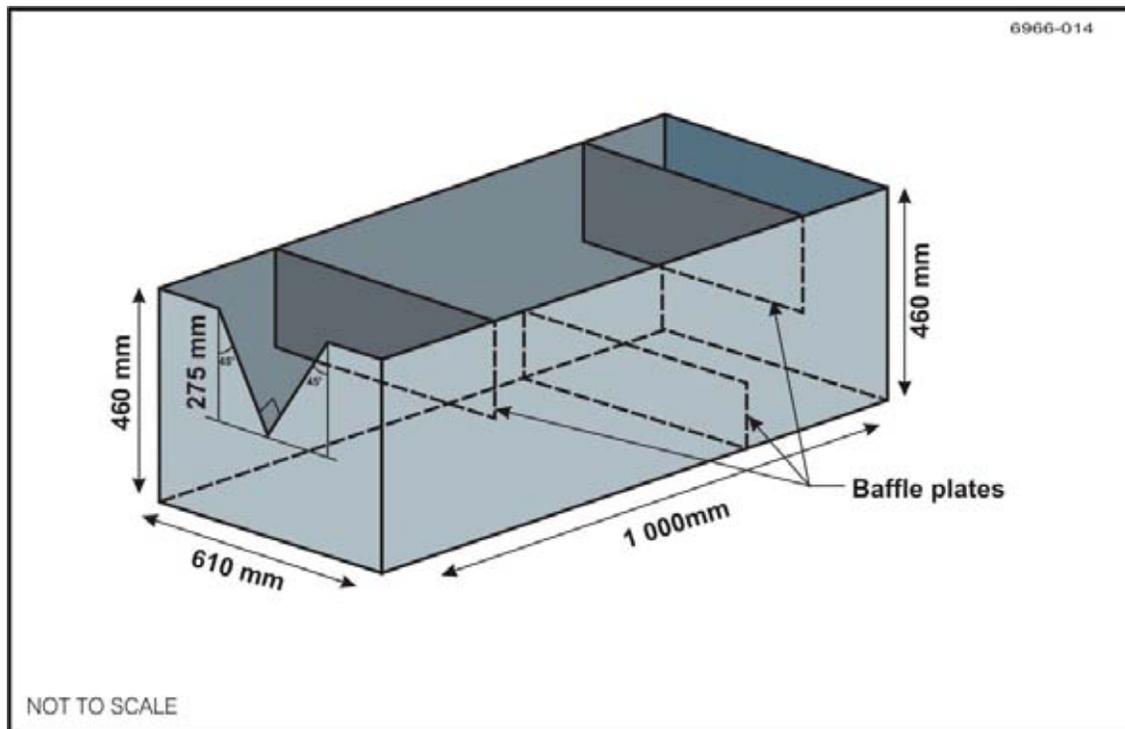


Figure 8: Typical details of a rectangular V-notch weir

Table 4: Calibration details for a rectangular V notch weir

Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)	Height over Weir (mm)	Flow rate (l/s)
10	0.013	48	0.675	86	2.90	124	7.24	162	14.12	200	23.9	238	36.9
12	0.021	50	0.747	88	3.07	126	7.53	164	14.56	202	24.5	240	37.7
14	0.031	52	0.824	90	3.25	128	7.84	166	15.01	204	25.1	242	38.5
16	0.043	54	0.91	92	3.43	130	8.15	168	15.47	206	25.8	244	39.3
18	0.058	56	0.99	94	3.62	132	8.46	170	15.93	208	26.4	246	40.1
20	0.076	58	1.08	96	3.82	134	8.79	172	16.40	210	27.0	248	41.0
22	0.096	60	1.18	98	4.02	136	9.12	174	16.89	212	27.7	250	41.8
24	0.119	62	1.28	100	4.23	138	9.46	176	17.37	214	28.3	252	42.6
26	0.146	64	1.39	102	4.44	140	9.81	178	17.87	216	29.0	254	43.5
28	0.175	66	1.50	104	4.66	142	10.16	180	18.38	218	29.7	256	44.3
30	0.208	68	1.61	106	4.89	144	10.52	182	18.89	220	30.4	258	45.2
32	0.245	70	1.73	108	5.12	146	10.89	184	19.42	222	31.0	260	46.1
34	0.285	72	1.86	110	5.37	148	11.27	186	19.95	224	31.8	262	47.0
36	0.329	74	1.99	112	5.61	150	11.65	188	20.49	226	32.5	264	47.9
38	0.376	76	2.13	114	5.87	152	12.04	190	21.04	228	33.2	266	48.8
40	0.428	78	2.27	116	6.13	154	12.44	192	21.60	230	33.9	268	49.7
42	0.483	80	2.42	118	6.39	156	12.85	194	22.16	232	34.7	270	50.5
44	0.543	82	2.57	120	6.67	158	13.27	196	22.74	234	35.4	272	51.6
46	0.807	84	2.73	122	6.95	160	13.69	198	23.32	236	36.2	274	52.5

Note: Flow calculated from Barnes Formula: $Q = 0.01337 \times H^2$ (Vs) (where H is the head of water above apex of notch in cm)

Orifice Plate with Piezometer (Orifice Weir): This is installed in a horizontal position at the end of the discharge pipe and comprises a straight length of pipe fitted with an orifice plate at the outlet and a vertical piezometer tube to record the pressure head within the pipe. The orifice plate has calibrated orifice diameters for the piezometer pressure head readings to be converted into discharge measurements. Pressure head readings are to be read to within 2mm accuracy. The minimum discharge that an orifice weir can reliably measure is 3.5 l/s, as shown in **Table 5**.

Table 5: Flow rates through circular orifice weirs (after Driscoll 1986)

Head of water (cm)	4" (10.2cm) Pipe		6" (10.2cm) Pipe		4" (10.2cm) Pipe		
	2.5" (6.3cm) Orifice (l/s)	3" (7.6 cm) Orifice (l/s)	3" (7.6 cm) orifice (l/s)	4" (10.2 cm) orifice (l/s)	4" (10.1 cm) orifice (l/s)	5" (12.7 cm) orifice (l/s)	6" (15.2 cm) orifice (l/s)
12.57	3.5	5.7	4.8	9.3	8.5	14.2	22.4
15.2	3.8	6.2	5.3	10.0	9.2	15.3	25.1
17.8	4.1	6.7	5.7	10.8	9.9	16.5	26.8
20.3	4.4	7.1	6.1	11.7	10.5	17.6	28.9
22.9	4.7	7.6	6.6	12.5	11.3	18.9	30.4
25.4	4.9	8.0	6.7	13.0	11.9	19.8	32.0
30.5	5.4	8.7	7.4	14.3	13.1	21.7	35.2
35.6	5.9	9.4	8.0	15.4	14.1	23.3	38.1
40.6	6.3	10.	8.5	16.5	15.0	25.0	40.6
45.7	6.7	10.7	8.8	17.5	15.9	26.6	43.2
50.8	7.0	11.3	9.6	18.4	17.0	28.1	45.4
55.9	7.4	12.1	10.0	19.3	17.7	29.4	47.6
63.6	7.8	12.7	10.7	20.6	18.9	31.4	50.8
76.2	8.6	13.8	11.7	22.3	20.7	34.5	55.6
88.9	9.3	15.0	12.7	24.3	22.4	37.1	60.1
101.6	9.9	16.0	13.4	25.9	23.7	39.6	64.0
114.3	10.5	17.1	14.3	27.5	25.3	42.2	67.8
127.0	11.1	18.0	15.0	29.1	26.6	44.1	71.6
152.4	12.2	19.8	16.6	32.0	29.1	48.6	78.7
177.8	13.1	22.4	18.0	33.6	31.4	51.8	82.0

Note: Flow rates indicated below the line are more exact than those above because the head developed in the piezometer tube for particular pipe and orifice diameters is large enough to ensure the accuracy of the results.

Flow meter. This must be calibrated and of similar diameter to that of the discharge pipe to which it is installed. The anticipated test yield must be compatible with the measuring range of the flowmeter. An in-line flow meter is the most accurate method of determining the test yield.

3.4.2 Water Level Measurements

Water level measurements are taken within a piezometer (measuring) tube. A piezometer made of PVC/polyethylene tubing must be attached to the pump column and installed at the same time as the pump (see **Figure 9**). A piezometer made of galvanized pipe can be suspended independently within the borehole.

The piezometer tube acts as a stilling well within the borehole and water level readings are therefore not affected by turbulence and/or cascading caused by pumping. Readings of the water level must be made using an electrical dip meter with an accuracy of ± 10 mm.

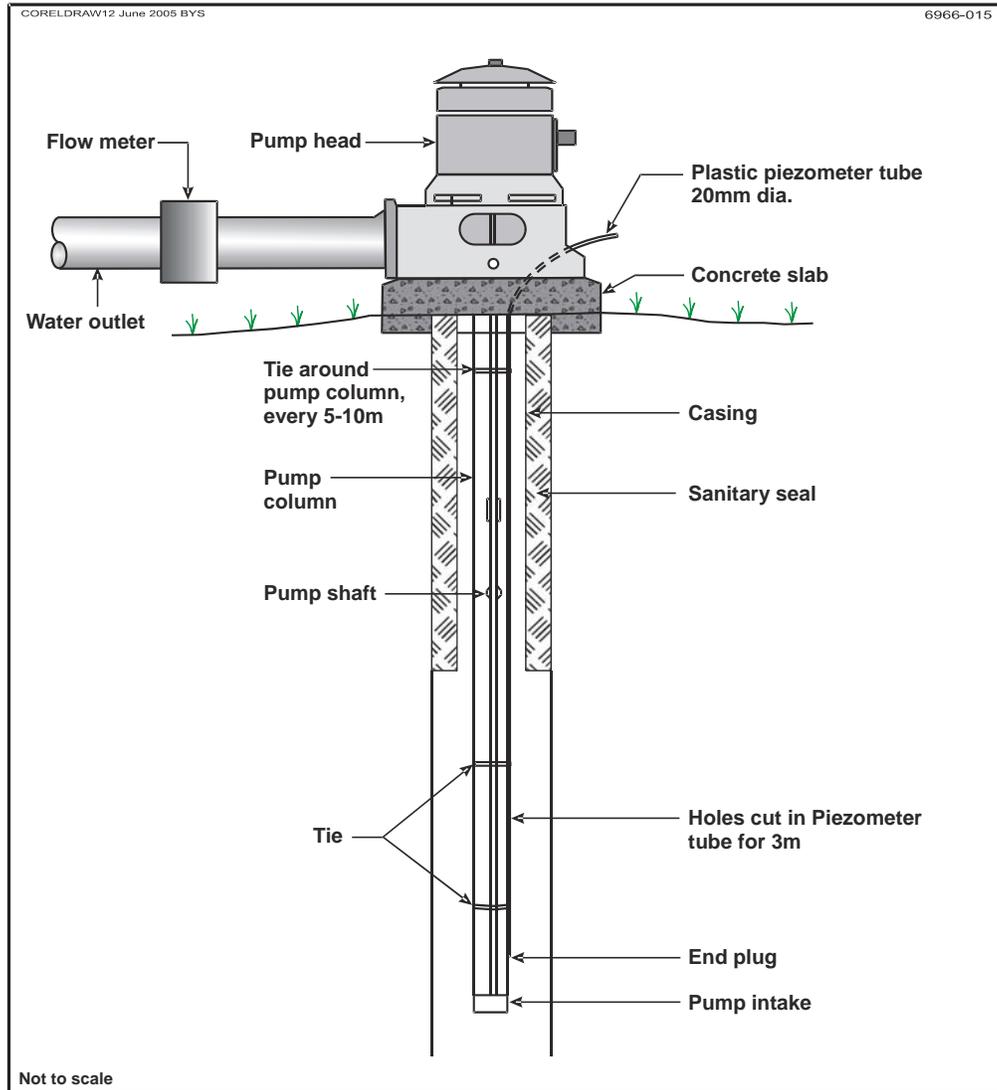


Figure 9: Typical details of the installation of a PVC/polyethylene piezometer and flow meter

3.5 Test Continuity

Pumping tests must be carried out for the minimum duration as specified in **Table 2**. In the event of a mechanical breakdown or other reason preventing the test from being completed, the test must be repeated after allowing recovery of the water level to its original level.

3.6 Further Information

The reader is referred to the following documents should further details of testing techniques be required:

*Driscoll, Fletcher. G., 1986 **Groundwater and Wells**. Second Edition. Published by Johnson Filtration Systems Inc. St. Paul, Minnesota 55112 ISBN 0-9616456-0-1*

4 WATER SAMPLING AND QUALITY

Knowledge of the groundwater chemistry and, where required, bacteriological quality, is essential to:

- Determine the suitability of the groundwater for the intended use, and
- For the overall groundwater resource management.

Measurement of temperature, electrical conductivity and pH should be taken during the constant discharge test, using field kits. These measurements should be taken at the beginning of the test, halfway through the test and a few minutes before the termination of the test. Other constituents can be measured using portable test kits as required.

A water sample should be collected before the end of the pumping test. The sample should be submitted to a reputable (accredited) laboratory to undertake the required testwork.

Each sample must be analyzed for pH, TDS, conductivity, Ca, Mg, Na, K, HCO_3/CO_2 , SO_4 , Cl, NO_3 , Fe, F, and Mn.

Where groundwater pollution is suspected, it will be necessary to also analyse samples for specific constituents associated with the suspected pollution.

Details of the correct water sampling procedures are given in Weaver 1992.

5 REHABILITATION OF BOREHOLES

Rehabilitation is necessary when the yield performance of a borehole decreases with time. It is carried out to increase the yield and/or to stabilise the borehole.

Decrease in the hydraulic performance and efficiency of borehole can be caused by:

- Chemical encrustation and/or build up slime due to iron bacteria of the slotted casing section and/or of the water bearing formation thereby reducing permeability,

- The formation and, where installed, the slotted casing, become clogged by fine particles,
- Pumping of wad and silt due to collapse of the sidewalls and/or corrosion of the casing, leading to ingress of overburden or collapsing zones.

Rehabilitation of boreholes is achieved by one or more of the following techniques:

- Chemical rehabilitation including acidification and oxygenation
- Mechanical rehabilitation (cleaning using surging, airlifting, hydrofracturing, etc)
- Replacement of the casings/screens installed in the borehole
- Inserting a smaller diameter casing inside the original casing after the borehole has been cleaned out.

The mechanical and chemical rehabilitation techniques are essentially those used for borehole development.

APPENDIX E 1

GENERIC TOC FOR ASSESSMENT REPORT

APPENDIX E

Generic Table of Contents for the Assessment Report

- Introduction
- Physiography
 - Location
 - Population
 - Climate and Precipitation
 - Topography, geomorphology and drainage
 - Vegetation (& groundwater dependent ecosystems)
- Geology
 - Structural Geology
 - Map all relevant surfaces and subsurface features
 - Drilling records / geology
- Geohydrology
 - Description of aquifer – areal extent, compartmentalisation
 - Groundwater levels
 - Groundwater quality
 - Aquifer Parameters
 - Recharge estimations
 - Dolomite springs (including capture zones and groundwater / surface water interaction)
 - Groundwater Flow Regime
 - Groundwater Resource Units
 - Resource Directed Measures
- Water use
 - Define the water users
 - Current demands on the system
 - Socio-economic impacts of water
 - Institutional links
 - Identify critical WARMS information gaps
 - Determine needs of users, including issues and concerns

- Conceptual model
- Resource monitoring
 - Evaluate existing relevant monitoring networks according to conceptual model
 - Identify critical information gaps
- Modelling
 - This can be various types of models e.g. analytical, numerical, risk-based
- Assessment and Conclusions
 - Compare water availability & requirements
 - Water quantity and quality issues
 - Risk assessment – ground stability, sinkholes.
 - Vulnerability assessment
 - Impacts
 - Groundwater protection zones

APPENDIX E 2

PLANNING REPORT EXAMPLE

**DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Directorate National Water Resource Planning**

WESTERN CAPE WATER SUPPLY SYSTEM RECONCILIATION STRATEGY

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LIST OF APPENDICES

No Appendices have been included in this draft version of the strategy.

APPENDIX E 3

GENERIC TOC FOR IWRM PLAN

Generic Table of Contents for the Integrated Water Resources Management Plan (IWRMP)

- Summary of existing information
 - Problems, Issues & Concerns
 - Progress in IWRM
- Resource Management Units
 - Define the resource management units according to the technical and socio-economic information supplied
 - Describe the monitoring networks according to the RMUs, including shortcomings
 - Extend groundwater monitoring networks if needed
 - Integrate monitoring networks – link this to a monitoring plan
- Management goals
 - Prioritise management goals
 - Recommendations
- Define Management Instrument
- Analyse various Options / Solutions
 - Options need to be ranked by the technical expertise before presenting it to the stakeholders.
 - At national level this will typically be WMA scale or cross-boundary type of issues.
 - At catchment level looking at which options to develop to address a specific need.
 - At site-specific level mostly 2 or 3 options which needs detail level study and optimising designs.
- STRATEGY TABLES
 - Strategy tables are useful tools to enable implementing the strategies. The ISPs can be used as an example of the strategies that take priority in a WMA and further work can be built on this
 - Management/Development Plan according to the outcome of the strategy phase,
- IWRM in the area
 - A description of the approach that will be followed in managing the area
- Purpose of the plan
- Water resource situation
 - A very brief description of the most relevant information in the area summarised from the situation analysis and strategy
 - Set RQOs according to this information

- Management action plan
 - From the actions that were defined in the strategy the following should be developed for implementation.
 - Management Activities
 - Management Responsibilities
 - Management Timeframes & Budget
 - Progress Indicators
- Conclusions
- MANAGEMENT TABLES
 - Populate management tables according to strategy tables, summarising the activities, responsibilities, time frames and budget.
- Summary

It is helpful to summarise the management tables according to the various stakeholders, then one can see upfront what your next task will be in this overall framework.