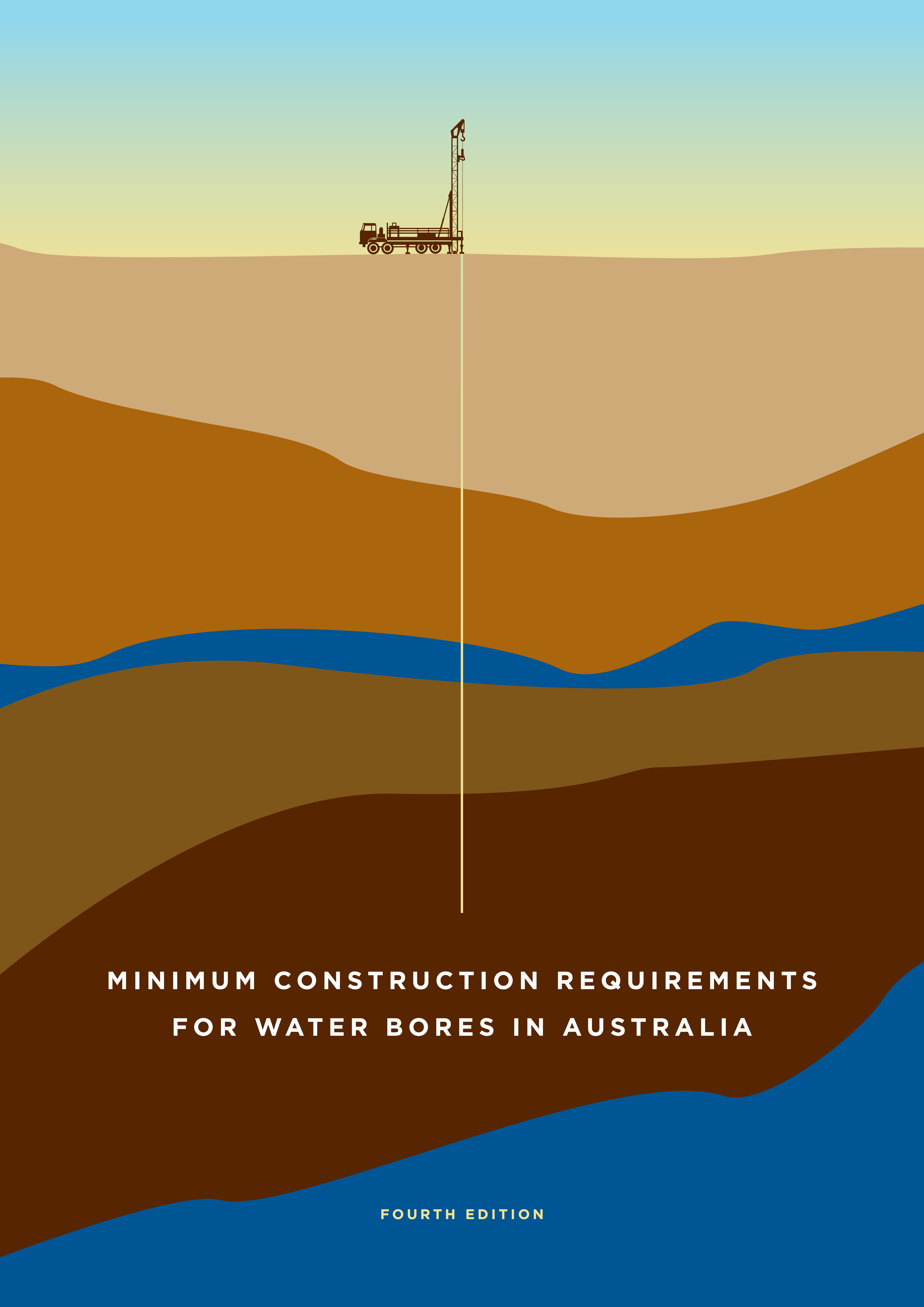

MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA

FOURTH EDITION

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Contacts

Specific enquiries about the material contained in this publication should be directed to the appropriate authorities listed on pages 8 and 9.

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Foreword

The fourth edition of *Minimum Construction Requirements for Water Bores in Australia (MCR)* has been developed by the National Uniform Drillers Licensing Committee.

This book outlines the minimum requirements for constructing, maintaining, rehabilitating, and decommissioning water bores in Australia. It is used extensively by regulators and the drilling industry, and provides a consistent standard reference across Australia for the licensing of authorised activities on bores and the licensing of drillers.

The requirements focus on protecting groundwater resources from contamination, deterioration, and uncontrolled flow associated with poorly constructed bores; and on the construction of bores to provide a good water supply.

The first edition was published in 1997 and it has been reviewed periodically to keep it current. This fourth edition is the outcome of an extensive review process. It draws on the combined experience and knowledge of the drilling industry and regulators, and incorporates submissions from both groups. The authorities listed in Section 2 can direct you to further copies and/or respond to your enquiries.

The major features of this edition are:

- Improving the bore casing specifications
- Clarifying confusion and removing ambiguity to assist with improving driller compliance
- Maintaining relevance by updating the MCR to reflect changes in bore construction material, processes and techniques and changing legislative requirements
- Improved bore specification designs.

Earlier editions have been well received and well supported by the drilling community and regulators. On behalf of the National Uniform Drillers Licensing Committee, I recommend the fourth edition of *Minimum Construction Requirements for Water Bores in Australia* to you.

Peter Hall

Chair
National Uniform Drillers Licensing Committee

National Uniform Drillers Licensing Committee (NUDLC)

The members of the NUDLC are listed below:

- Australian Drilling Industry Association (ADIA)
- Department of Environment and Natural Resources, Northern Territory
- Department of Natural Resources, Mines and Energy, Queensland
- Department for Environment and Water, South Australia
- Department of Primary Industries, Parks, Water & Environment, Tasmania
- Department of Environment, Land, Water and Planning, Victoria
- Department of Water and Environmental Regulation, Western Australia
- New South Wales Department of Planning, Industry, and Environment, Water Group, NSW
- Drilling industry representatives and drilling contractors.

Project Team

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- Stan Gricks
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- Nathan Statton
- Blake Topp
- Andy Tuffs

In addition to these contributors, the NUDLC wish to acknowledge the generous financial assistance provided by State Regulators and the ADIA, and thank the many people who made detailed submissions, provided valuable feedback, and participated in review sessions across Australia as this fourth edition was being developed.

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1 Introduction

Need for Minimum Bore Construction Requirements

A high percentage of Australia's total water use is from groundwater, and this percentage is increasing as surface water resources become less available.

Water bores are the most common means of tapping groundwater. The siting, design, materials, and construction method used all influence the quantity and quality of water obtained.

Purpose of this Book

The purpose of this book is to provide a technical basis for, and a description of, the minimum requirements for constructing water bores in Australia. It both complements and underpins the national drillers' licensing system by providing a bore construction standard that is consistent across Australia.

Although it is mainly for the use of the water drilling industry, this book should also be of interest to anyone intending to construct a water bore.

In prescribing the minimum acceptable construction requirements, it is not intended to be viewed as a substitute for formal training.

Drillers play a vital role in the development, use, and protection of the groundwater resource. They provide a service to clients, and thus have a responsibility to ensure that this role is fulfilled through high standards of work and the use of materials appropriate to the particular work involved.

These minimum requirements provide the technical base for licensed drillers, for bore permits, and as a reference for bore construction. This edition separates these requirements into mandatory requirements and recommendations for good industry practice.

Aquifer terminology

An aquifer is a geological formation, group of formations, or part of a formation capable of transmitting and yielding quantities of water. Aquifers can vary in scale and may occur as relatively uniform geological units, or as complex layered systems. Within each state and territory aquifers will be characterised by the licensing authority or regulators, taking into account local conditions for resource management. In this book we have used the term 'aquifer', however the term 'aquifer system' may also be used in some states and territories. These two terms carry the same meaning within this book.

Mandatory Requirements

Mandatory requirements are enforceable by regulators for the protection of the groundwater resource. All drilling activities shall be conducted in accordance with applicable state and/or territory regulatory requirements.

Principles

Although every hole is usually slightly different, there are some critical elements that go towards constructing a water bore that will provide a good supply of water to the end-user for many years to come, without affecting the capacity or quality of nearby aquifers.

The following principles are not exhaustive but are included because they are known to be effective in protecting such a precious resource. Adherence to the principles is crucial to protect the water resource capacity and quality for other users, the environment, and the community in general.

The principles are:

Chapter 2	The driller and owner of the bore shall adhere to all relevant state or territory legislative requirements.
Chapter 3	Bore design shall: • suit the hydrogeological conditions • be appropriate to protect the aquifers • be suitable for the intended purpose of the bore • meet the client's requirements.
Chapter 4	The bore shall be constructed by a suitably qualified driller who possesses the appropriate experience and the relevant class of licence that the state or territory deem necessary.
Chapter 5	A bore is sited to provide a reliable and useful water supply. Information should be sought about the hydrogeological conditions in the area before drilling. Water supply bores shall be positioned a suitable distance from known possible sources of contamination, or designed and constructed to eliminate all sources of contamination. The driller shall ensure the location complies with any conditions specified in the bore permit.
Chapter 6	Formation samples shall be taken to determine the nature and type of strata, and to confirm any changes in the formation. Water samples should be taken to provide a guide to water quality encountered during drilling operations. Any water samples taken during or immediately following construction and development should be representative of the groundwater.
Chapter 7	Drilling fluids should be selected and managed to: • facilitate the drilling process • ensure the removal of cuttings from the borehole • minimise damage to the formations. Chemicals and other drilling fluid additives that could leave a residual toxicity shall not be added to any drilling fluids or cement slurries (i.e. grouts) used to drill and complete any water bore.

Chapter 8	Bores should be sufficiently plumb and straight to ensure that there will be no interference with the installation, alignment, long-term operation, or future removal of the pump.
Chapter 9	Water bore casings and joints shall: • prevent the collapse of the strata penetrated • assist in construction and sealing, and prevent intermixing • be strong enough to withstand installation, construction, and operational pressures • provide access to the water-producing zone • be of sufficient diameter and length to act as a safe housing for the pump selected for the hole • provide an adequate operational life.
Chapter 10	The method of completion across the water entry zone of the bore should: • allow efficient entry of water into the bore • stabilise the formation • prevent unacceptable ingress of materials from the formation.
Chapter 11	Bores are sealed to: • protect the groundwater resource from contamination • maintain aquifer pressures and groundwater quality • isolate the targeted production zone from other formations.
Chapter 12	Bores are developed to: • remove introduced products • improve near well permeability • reduce entry losses • reduce entry of suspended solids • increase well efficiency.
Chapter 13	All water supply bores should be tested to establish their indicative yield.
Chapter 14	Drilling equipment that has been used should be disinfected to prevent the transfer of microbiological organisms (bacteria) between sites. After completing drilling, the bore should be free of any introduced microbiological organisms (bacteria).
Chapter 15	Accurate information on the drilling, construction, reconditioning, and decommissioning is recorded to be available for the use of drillers, landholders, and regulators.
Chapter 16	Headworks shall control the flow of water. The protruding casing should be completed so that it: • is protected from damage • prevents surface run-off or potentially contaminated fluids from entering the bore. After completion of the job the site should be restored as close as possible to its original condition.

Chapter 17	Bore maintenance is intended to preserve the performance of the bore and its component parts in good repair. Rehabilitation is intended to repair a bore that has failed.
Chapter 18	Failed or unwanted bores should be decommissioned to restore, as far as possible, the aquifer isolation that existed before the bore was drilled and constructed.

Good Industry Practice

Good industry practice describes methods and techniques recommended to:

- help satisfy mandatory requirements
- provide efficient and cost-effective water bores
- ensure the long-term efficiency and operation of the water bore.

These requirements are not designed to meet the specific needs of landholders or purchasers, or to replace the specifications that various state and territory water authorities currently use.

In the context of this book, the term 'drilling operations' encompasses:

- drilling
- bore construction
- development
- maintenance and rehabilitation
- decommissioning.

This book considers the design, materials, reporting, and recording requirements for all aspects of drilling operations. In doing so, these requirements aim to ensure the:

- protection of the groundwater resource from contamination, intermixing, and uncontrolled flow
- long-term economic production of groundwater of the best possible quality and quantity.

The finished bore is a result of a number of considerations and decisions. These include:

- the intended purpose of the bore
- geological and hydrogeological conditions, including groundwater quality
- drilling methods
- construction methods
- bore performance improvements (e.g. bore development and disinfection)
- bore performance indicators (e.g. pumping test and water quality test).

The finished bore is further affected by the inherent nature of drilling, which disrupts the native environment. Bores drilled to intersect multiple aquifers will disturb the aquifers by providing a vertical connection between aquifers if not sealed correctly, and a connection can mix different groundwater heads and qualities.

Where drilling intersects groundwater held under pressure, uncontrolled flowing (artesian) bores can result, causing surface flooding, wastage of the groundwater resource and the loss of hydrostatic pressure. All non-flowing bores can potentially provide a means of contaminating groundwater by acting as a conduit for surface run-off.

Deteriorated or abandoned bores will threaten the groundwater resource and should be decommissioned in such a way that the hydrogeological environment is maintained or is returned as near as possible to the condition that existed before drilling.

This book was originally prepared in 1997 and reviewed in 2003 and 2012 by a steering committee comprising representatives from all state and territory governments, the Australian Drilling Industry Association, and the Australian Drilling Industry Training Committee.

It has recently been revised and reprinted following another review, which sought submissions from the drilling industry and other stakeholders.

All four editions of this book have included information from Australia and other parts of the world, drilling industry reference materials, and relevant Australian and overseas standards.

Definitions of terms used in this book are in Appendix A, and useful resources are listed in Appendix B.

2 Administrative Requirements and Responsibilities

Principle

The driller and owner of the bore shall adhere to all relevant state or territory legislative requirements.

At every stage during construction, all parties should take action to minimise the risks to the environment. Considerations include:

- materials used for construction and discharged from the bore
- responsible disposal of all waste.

General legislative provisions and policies are administered by water agencies in each of the states and territories.

It is essential that the drillers, consultants, and clients become fully conversant with the requirements of the state or territory in which they intend the work to be undertaken, because the relevant legislation varies between authorities.

It should be noted that it is the individual driller who is licensed, not the drilling company.

Mandatory Requirements

2.1 Only drillers licensed for the class of work proposed and endorsed for the drilling method to be used shall carry out work on a water bore unless state or territory legislation provides an exemption.

2.2 An appropriately licensed driller shall be on site at all times during bore construction and decommissioning activities

2.3 Within each state and territory aquifers settings and required drilling class for works shall be determined by the licensing authority or regulators.

2.4 The owner or legal occupier of the land on which a bore is to be constructed shall obtain the appropriate bore permit from the licensing authority in the relevant state or territory.

2.5 Work shall not commence on a bore until such approval has been obtained.

2.6 The driller shall sight the bore permit before commencing any work and comply with the conditions relating to the particular bore. The bore permit will stipulate the nature of the work and the reporting requirements.

2.7 Where an applicant wishes to use materials or technologies not referred to in this document, the applicant must submit a proposal in writing to the relevant state or territory regulator and obtain approval before using the material or technology.

In the absence of any prior written approval from the regulator, the conditions of this document or the bore permit shall be adhered to.

2.8 When drilling into sediments of the Great Artesian Basin (GAB) all water bores shall be constructed in accordance with this document and relevant state and territory legislation.

Australian government agencies and drilling associations from whom further information may be obtained regarding this book or drilling requirements generally are listed below.

This list was correct at the time of publication. An up-to-date list is on the ADIA website **www.adia.com.au**.

New South Wales

New South Wales Department of Planning, Industry and Environment
Locked Bag 5022
Parramatta NSW 2124
www.dpie.nsw.gov.au

Northern Territory

Department of Environment and Natural Resources
PO Box 496
Palmerston NT 0831
www.denr.nt.gov.au

Queensland

Department of Natural Resources, Mines and Energy
PO Box 156
Mareeba Qld 4880
www.dnrme.qld.gov.au

South Australia

Department for Environment and Water
GPO Box 1047
Adelaide SA 5001
www.environment.sa.gov.au

Tasmania

Water Management and Assessment Branch
Department of Primary Industries, Parks,
Water & Environment
GPO Box 44
Hobart Tasmania 7001
www.dpipwe.tas.gov.au

Victoria

Department of Environment, Land, Water and Planning
8 Nicholson Street
East Melbourne, Victoria 3002
www.delwp.vic.gov.au

Goulburn Murray Water Corporation
PO Box 165
Tatura Vic. 3616
www.g-mwater.com.au

Grampians Wimmera Mallee Water Corporation
PO Box 481
Horsham Vic. 3402
www.gwmwater.org.au

Southern Rural Water Corporation
Box 153
Maffra Vic. 3860
www.srw.com.au

Western Australia

Department of Water and Environmental Regulation
Locked Bag 10, Joondalup DC
Perth WA 6919
www.dwer.wa.gov.au

Industry

Australian Drilling Industry Association Ltd
5 Profit Pass Wangara
WA 6065 Australia
www.adia.com.au

Responsibilities

When a bore is to be constructed, both the driller and the client are responsible for various aspects of the work. It is in the interests of both parties that a written agreement or contract be entered into detailing all aspects of the work to be performed.

The following is a general guide to the responsibilities of the driller and the client. It must be emphasised that some responsibilities relate to legislative requirements, which can vary between state and territory water licensing authorities.

When in doubt the respective authority should be contacted at the address shown above.

Driller responsibilities

The driller generally has responsibility for:

- giving the client accurate and competent technical advice on the work
- providing references
- giving the client a written quotation for work to be performed and materials to be supplied (Note: see Appendix C for a sample contract)
- deciding the construction method to be used
- offering a warranty on completed and tested works, including materials and the quality of work undertaken
- the standard of work, including ensuring that the quantity and quality of materials used are suitable for the job
- providing the client with regular and timely reports of progress and any other information that may be relevant to the work and its cost
- where legislation exists, ensuring that the client holds a current bore permit for the type of bore being constructed. The driller shall comply with the conditions of the bore permit
- providing the client and the state or territory water licensing authority with a written log of the details of each bore
- providing advice on the flow and quality of water on completion of a bore
- leaving the site in a clean and tidy manner and free from contamination.

At all times during the progress of the work the driller shall use reasonable precautions to prevent:

- tampering with the bore
- the entry of foreign material
- the entry of surface water into the bore.

NOTE: It is unwise for a driller to warrant or guarantee the quantity or quality of water before drilling is carried out.

Client responsibilities

In general, the client has the following responsibilities:

- seeking advice on the likely availability of a water supply and its quality
- obtaining the necessary bore permit to construct the bore and complying with the bore permit conditions
- arriving at a written agreement/contract with the driller on the work to be carried out and the materials to be supplied
- where legislation requires, ensuring that the driller holds a current driller's licence for the class of work and drilling method to be employed
- being readily contactable during the drilling operation
- selecting and, if necessary, preparing or clearing the site, often in consultation with the driller
- providing suitable access to the bore site(s)
- submitting reports and water samples to the relevant authority where required.

NOTE: It is unwise for a driller to warrant or guarantee the quantity or quality of water before drilling is carried out.

High concentrations of individual ions may render the water unsuitable, even if the conductivity value is within limits suggested in the relevant Australian standard. The suitability of water for continued irrigation will depend on plant species, soil type, climate, and soil leaching conditions.

The client or bore owner should be aware of any water quality requirements for the intended crop types or proposed water use.

Shared responsibilities

The type and nature of bore construction should be discussed fully between the driller and the bore owner before the work commences. The following matters should be taken into account:

- state or territory legislative requirements
- protection of the aquifer
- materials required
- the desired yield or purpose of the bore
- known geological conditions
- the desired life and future maintenance of the bore
- the cost
- the duration of the contract
- checking for the existence and location of underground and overhead services

- provision of detailed strata logs, strata samples, and water samples as specified by the relevant state or territory water licensing authority
- preferred pumping equipment and power source options.

NOTE: It is unwise for a driller to warrant or guarantee the quantity or quality of water before drilling is carried out.

Differing geological formations encountered may present difficulties that even the most experienced driller could not anticipate. In such situations the driller may need to consult the client again.

The client (or a representative) should be on site for a substantial amount of the construction period, or at least be readily contactable when absence is necessary.

The driller should ensure that the client is fully aware of the more critical phases of construction of the bore, including responsibility for the storage of material and removal of waste.

Flowing artesian bore

3 Bore Design and Common Types

Principle

Bore design shall:

- **suit the hydrogeological conditions**
- **be appropriate to protect the aquifers**
- **be suitable for the intended purpose of the bore**
- **meet the client's requirements**

The siting, design, materials, and construction method used in a bore all influence the quantity and quality of water obtained and the protection of the groundwater resource. The chosen bore design is the result of a number of considerations and decisions. These include the:

- intended purpose of the bore
- geological and hydrogeological conditions, including the groundwater quality
- drilling methods and construction methods.

Bore design for aquifer protection

The bore design should take into account the protection of the groundwater resource. Bores drilled to intersect an aquifer will disturb that aquifer and can provide a vertical connection between aquifers of different head or groundwater qualities.

Where drilling intersects groundwater held under pressure, uncontrolled flowing (artesian) bores can result, causing wastage of the groundwater resource and the loss of hydrostatic pressure.

The design of the typical types of water bores are discussed below, according to the protection of aquifer conditions.

Single aquifer

Many bores are constructed into the upper-most aquifer system. These are single aquifer bores. All non-flowing bores can potentially provide a means of contaminating groundwater by acting as a conduit for surface run-off. Importantly, the bore design should aim to ensure the protection of the groundwater resource from surface contamination. This means that the headworks and casing are sealed so that there is no potential for flow outside the casing.

Multiple aquifer

Where multiple aquifers are encountered the key element of the bore design for aquifer protection is to ensure that waters of different aquifers do not mix, either in the bore casing or in the annulus between the casing and the borehole. Sometimes multiple aquifers may be penetrated before the targeted aquifer. In these instances it is often easier to ensure there is no possible mixing of waters by grouting the annulus from the production aquifer to the surface.

Where the upper aquifer contains poor-quality water, or is fully committed to other users, the deeper aquifer may be targeted instead for water supplies. In these cases bores are drilled through the upper aquifers to allow tapping of the better quality or under-allocated lower aquifers. Any unsuitable waters are excluded from the bore by grout sealing. To protect any steel casing from possible corrosive waters, grouting of the casing to the surface is carried out, if necessary.

Figure 3.1 Single aquifer bore

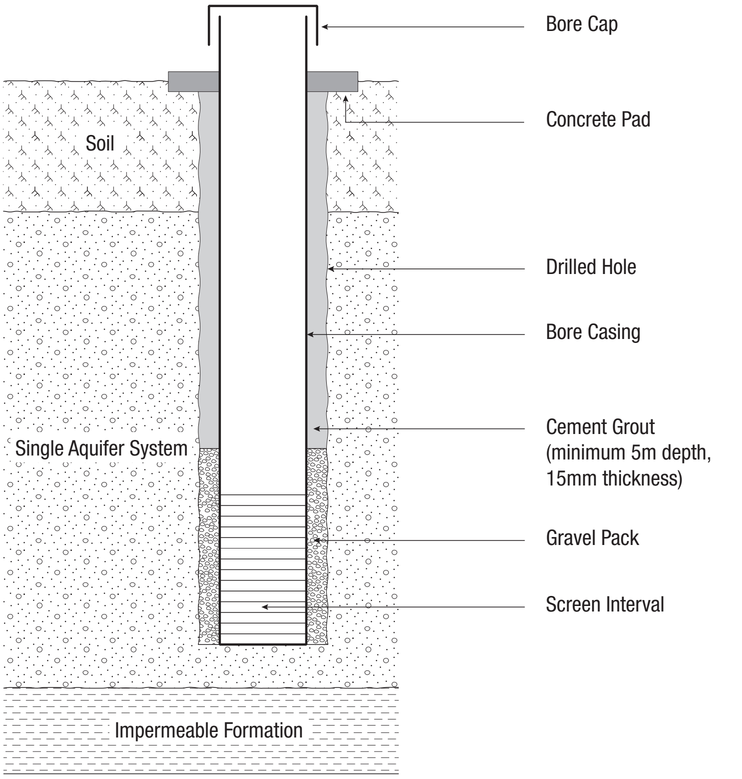
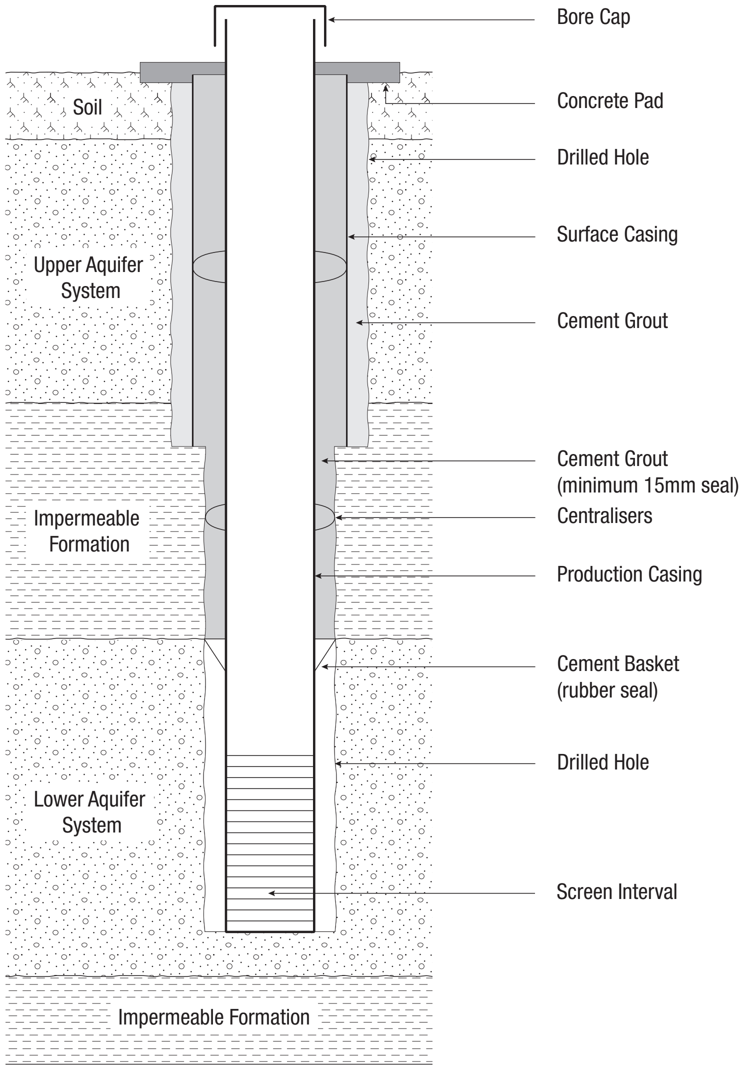


Figure 3.2 Multiple aquifer bore

NOTE: Multiple aquifer bores can be completed either as flowing or non-flowing.



Flowing aquifer (artesian) bores

The drilling priority for artesian bore construction is the control of artesian pressure and flow. The requirements for an artesian bore include:

- protecting the production casing from corrosive soils
- preventing any discharge up the outside of the casing by the setting and cementing of surface control casing
- preventing any intermixing of waters of different quality or pressure from one aquifer to another
- tapping only one primary aquifer
- controlling formation pressures by selective cementing of the production casing.

One example of a flowing bore construction appears below.

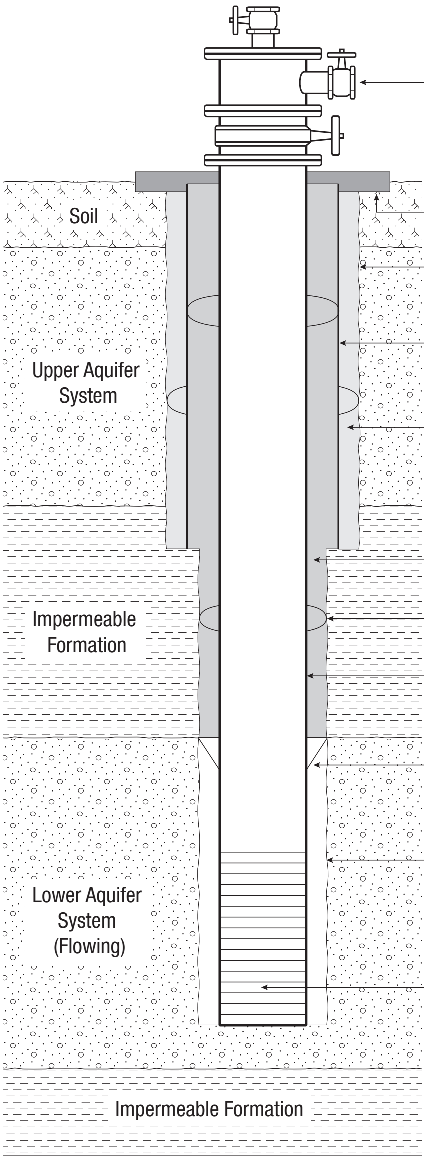


Figure 3.3 Flowing aquifer bore

During the selection process for production casing and headworks materials, consideration must be given to the depth of casing installation, grouting pressures, well head static pressure, and water temperature, together with the corrosive nature of the water and strata.

Bores must also be fitted with headworks of approved design to permit the control of flow, and for periodic maintenance and measurement.

These approved headworks must make provision for flow and pressure to be measured without having to disconnect or interfere with reticulation or surface pumping systems.

The construction requirements for artesian bores tapping the Great Artesian Basin (GAB) vary from state to state, and can be different from the minimum requirements described in this book. Local water licensing authorities should be consulted concerning artesian bore construction requirements before drilling in an artesian aquifer of the GAB.

In artesian aquifers outside the GAB, alternative construction requirements may be approved by the relevant state or territory water licensing authority to meet local requirements.

Common bore types

The chosen bore design is also the result of considerations and decisions relating to the intended purpose of the bore. Common bore types include:

Stock and domestic water supply bores

An example of a stock and domestic (low-yielding, non-flowing) bore in a single (consolidated) aquifer formation is shown below in Figure 3.4.

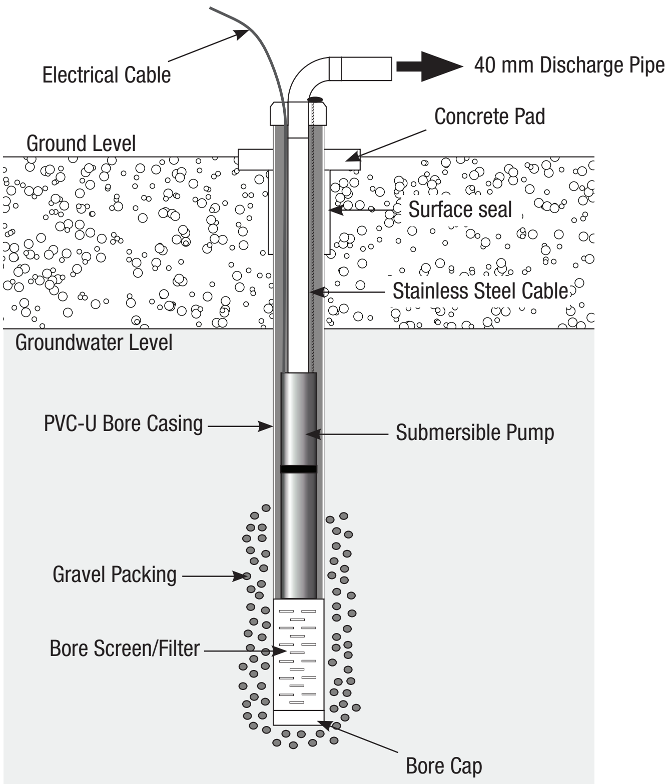


Figure 3.4 Stock and domestic (low-yielding, non-flowing) bore (incl. electric submersible pump)

Source: www.borewell.com.au/water-boring-information/diagram-of-a-bore.

Republished with permission from Borewell Pty Ltd.

Stock and Domestic bores are the most common type of water supply bore.

The drilling priority is usually to obtain a usable supply of water for livestock and/or domestic use. Such bores normally use 100–150 mm diameter casing.

The basic requirements for these bores are:

- the construction technique and water entry selected to allow for the long-term production of clear silt-free water
- adequate bore straightness to allow for the installation and reliable operation of the client's preferred pump
- a usable supply of water of acceptable quality protected from contamination, particularly from the surface.

Commercial (higher yielding) water supply bores

Commercial bores typically include industrial, irrigation, and major water supply bores. The major objective when drilling a commercial bore is to ensure that the formation remains stable and capable of being pumped at the maximum efficient water yield. To achieve this result a test hole drilling program is usually carried out to locate the optimum production bore site.

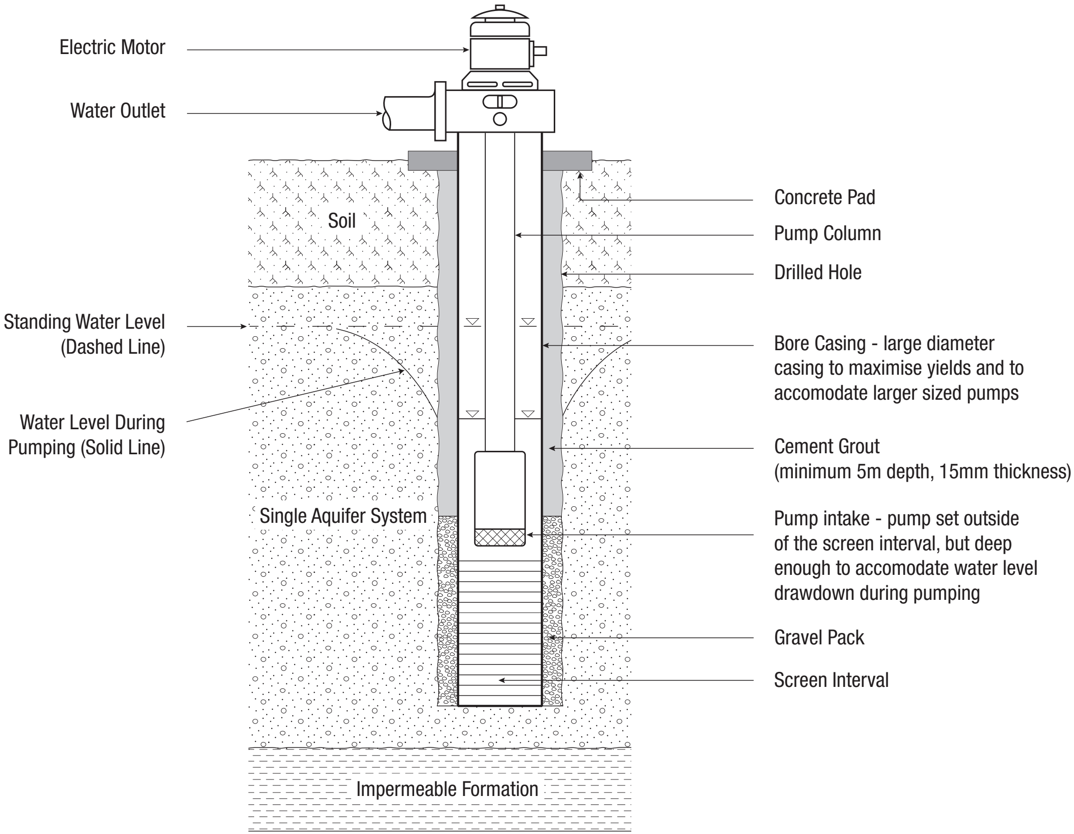
Other important factors that must be considered include:

- selecting a casing size based on the desired or potential yield and the required pump size
- selecting a screen length appropriate to the aquifer thickness being screened
- choosing the screen slots size and gravel pack size based on analysis of the gradation of the aquifer materials
- selecting a screen diameter and length that will transmit the bore yield at low entrance velocities
- selecting a large hole diameter
- selecting gravel pack material that is well rounded and clean.

It is important in constructing a commercial bore that the long-term stability and efficiency of the operation are not compromised by imprudent cost savings.

An example of a commercial bore construction is shown in Figure 3.5.

Figure 3.5
Commercial (higher yielding, non-flowing, screened, and gravel packed) bore



Double orifice meter

Groundwater monitoring bores

'Monitoring bore' has been adopted as the standard term because it is most commonly used in hydrogeological investigations throughout Australia.

Other terms often substituted are 'observation well' and 'piezometer'. Monitoring bores include bores to:

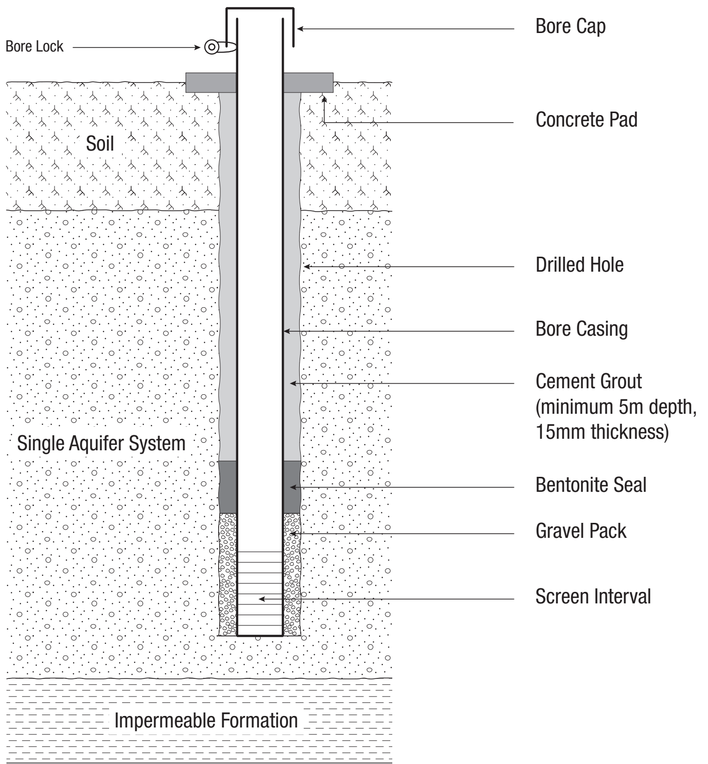
- observe water levels
- observe water quality
- intersect and monitor contaminants such as hydrocarbons, coliforms, pesticides, herbicides, and heavy metals.

Monitoring bores are drilled specifically to obtain data on groundwater. They are equipped and used for taking water samples and/or monitoring water levels. Their basic characteristic is that they are normally of low-yield construction but provide for accurate water quality sampling and water level measurements from a particular zone of interest in an aquifer.

Annular seals and gravel packs are used where necessary to isolate the zone being monitored. Care must be taken during drilling operations and in selecting the drilling method, materials, and screened interval used in bore construction, to ensure it meets monitoring requirements.

It is essential to ensure that no contaminants are introduced that may affect the monitoring or sampling results. An example of monitoring bore construction is shown below in Figure 3.6.

Figure 3.6 Water monitoring bore (non-flowing)



Experience has shown that it is sometimes quicker and more secure to drill multiple holes if room permits, as any drilling time saved with a single hole can be taken up with the setting of multiple casing strings and annular cement grout seals.

Multi-port monitoring bores

Multi-port monitoring bores are specifically designed bores to obtain data from one or more aquifers or zones in a single drill hole.

Multi-port monitoring allows testing of hydraulic conductivity, monitoring of fluid pressure, and collection of fluid samples from multiple zones within a single borehole.

Construction method
A single drill hole is cased and grouted over the total depth. The bore is then perforated at the testing zones through the casing and the grout sealing. Testing ports are installed with inflatable packers insulating the perforated zone so no intermixing or contamination can occur between aquifers or zones.

Groundwater injection bores

Groundwater injection bores are used to inject water (by gravity or pressure) into an aquifer. They are commonly used in managed aquifer recharge schemes or groundwater remediation. The guidance here specifically covers injection bores for managed aquifer recharge (both storage and recovery), and aquifer storage transfer and recovery, with stormwater, recycled water, and groundwater. It does not address injection or infiltration of waters into aquifers for waste disposal.

The key issues in designing injection bores are:

- ensuring the injected water reaches only the target aquifer
- protecting the aquifer and aquitards from being damaged by over-pressurisation
- minimising problems such as clogging and excessive recovery of aquifer material.

Adequate development for the take of water
Injecting sediment-laden water into injection bores may result in the accumulation of particles outside the screen or within the gravel pack. The mixing of the injected water with the groundwater may cause mineral scaling if their water chemistries are not compatible.

Potential problems can be avoided at the design stage by:

- full cement sealing of surface and production casing to prevent upward migration of injection water via the annulus (This applies to both single and multiple aquifer systems.)
- using wire wound screens to improve yields and efficiencies
- applying appropriate screen apertures to minimise screen velocities and reduce encrustation potential
- ensuring gravel pack material is compatible with formation material and injected water.

Managed aquifer recharge schemes can consist of either single, multi-use bores (for both injection and extraction), or multiple specific purpose bore systems where different bores are used to inject and extract water.

Construction requirements are identical to those for a multi aquifer bore (see Figure 3.2).

Two views of headworks on an injection/extraction bore

Submersible pump being lowered into a bore

4 Drillers’ Classification System and Drilling Methods Used

Principle

The bore shall be constructed by a suitably qualified driller who possesses the appropriate experience and the relevant class of licence that the state or territory deem necessary.

Under the national system of licensing drillers, there are three licence classes and six endorsements for drilling construction methods.

The class of licence relates to the skill level required to construct bores in different types of aquifer systems, while the endorsements relate to the drilling and construction methods that a driller is licensed to use.

Drillers’ Classification System

Licence classes

Class 1 — This licence is restricted to drilling operations in non-flowing (sub-artesian) single aquifer systems.

Class 2 — This licence, in addition to operating in Class 1 conditions, permits operations in non-flowing (sub-artesian) multiple aquifer systems.

Class 3 — This licence, in addition to operating in Class 1 and Class 2 conditions, permits drilling operations in flowing (artesian) aquifer systems.

Drilling endorsements

Auger — permits drilling operations using bucket auger, hollow-stem auger, and solid-stem auger techniques.

Cable tool — permits drilling operations using cable tool or cable percussion drilling methods.

Non-drilling rig — covers operations on water bores that do not use a drilling rig. Endorsements for non-drilling methods include:

- washed down spears using water pressure
- jetting
- hand dug holes and wells
- hand dug augers
- casing repairs and modification

Rotary air — permits drilling operations that use rotary drilling methods with air or foam as the drilling fluid. This endorsement also includes the use of down-hole hammers.

Rotary mud — permits drilling operations that use rotary drilling methods with water as the drilling fluid or as the base for the drilling fluid.

Sonic — permits drilling operations which use vibration (resonation) and downward force to advance the drill string and where the formation is retrieved via a core

NOTE: State and territory water authorities may also impose further restrictions on licence classes and endorsements.

Required skills, experience, and abilities

Class 1 licence: An applicant for a Class 1 Drillers' Licence must be capable and have knowledge and skills, as they apply to the drilling method endorsement, in:

- Administrative requirements and responsibilities - the provisions of the legislation and regulations relating to groundwater and groundwater drilling in the state or territory in which they are proposing to operate; an understanding and appreciation of bore construction licence application procedures and licence conditions; and
- Bore design and common types - designing and constructing bores for domestic and stock, groundwater monitoring and irrigation purposes in single aquifer systems; and
- Siting a bore - recognising potential contamination sources to water supply bores and appropriately site a bore to prevent contamination; and
- Drilling - correctly choosing and using equipment, having regard to such factors as rotational speed and proper annular velocities having regard to the drilling method; and
- Formation sampling and description - obtaining representative lithological samples; and labelling and describing them; and
- Casing - casing types and their applications in single aquifer systems; and
- Maximising bore efficiency and water entry - selecting the appropriate slot size, screen length and diameter; and procedures for screen installation. Selection and installing stabilising fill material; and
- Bore sealing - methods of sealing casing in single aquifer systems; and
- Bore development – use of chemicals, mechanical methods, determining sand content; and
- Bore yield testing - determining static water level, drawdown and bore yield; and
- Recording and reporting data - correctly filling in a "bore completion" report; and
- Bore completion, headworks and site restoration - headworks design and completion of the bore site in single aquifer systems; and
- Bore decommissioning - designing and selecting appropriate materials for the decommissioning of bores in single non-flowing aquifers systems.

Class 2 licence: An applicant for a Class 2 licence must have the knowledge and skills required of a Class 1 driller together with knowledge and skills as they apply to the aquifer type for the licence class and drilling method endorsement, in:

- Bore design and common types - designing and constructing bores in multiple aquifers with emphasis on designs and methods used to exclude waters that are not required; and
- Casing - casing types and their applications in multiple aquifer systems; and
- Maximising bore efficiency and water entry - skill in the design of high yielding bores is required. This entails overcoming entrance velocity problems and carrying out sand sieve analysis in order to select appropriate gravel pack material and screens (i.e. screen length, diameter and aperture); and
- Bore sealing - methods of sealing casing in multiple aquifer systems, including grouting casing, plug selected zones, effect of cement additives;

ability to calculate hole volume and slurry volumes, hole preparation, casing installation and circulation requirements; and

- Bore decommissioning - designing and selecting appropriate materials for the decommissioning of bores in multiple aquifers systems.

Class 3 licence: An applicant for a Class 3 licence must have the knowledge and skills required of a Class 1 and Class 2 driller together with knowledge and skills, as they apply to the drilling method endorsement, in:

- Bore design and common types- designing and constructing bores in aquifer systems that have high pressure conditions; and
- Drilling - correctly choosing and using equipment and fluids, methods, procedures and calculations required for fluid pressure control; and
- Casing - casing types and their applications in high pressure aquifer systems; and
- Bore sealing - methods and procedures and calculations required in carrying out pressure cement jobs; and
- Bore yield testing - determining bore yield and flow and static head pressure for flowing high pressure aquifer systems; and
- Bore completion, headworks and site restoration - headworks design and completion of the bore site in flowing and high-pressure aquifer systems; and
- Bore decommissioning - designing and selecting appropriate materials and procedures for the abandonment of bores having high-pressure conditions.

Restrictions to licenses. State/Territory licencing authorities may issue a restricted licence. That licence may not be transferable to other states or territories. These may include geotechnical, monitoring bores, depth restriction or restrictions on drilling in the GAB.

Drilling Methods

Drilling methods range from simple digging with hand tools to high-speed drilling with sophisticated equipment. The most commonly used methods are briefly described below for the general information of readers who do not have a drilling background.

Table 4.1 Drilling methods and their applications

Type of formation	Auger *	Cable tool drill	Rotary mud	Rotary air	Sonic	Rotary air with DHH
Sand	Fair	Suitable	Suitable	Not suitable	Suitable	Not suitable
Loose sand and gravel	Not suitable	Difficult – fair (if casing driven)	Suitable (with fluid control)	Difficult – not suitable	Suitable	Not suitable (see ** below)
Loose coarse gravels and boulders	Not suitable	Suitable (if casing driven)	Difficult – slow sometimes impossible	Not suitable	Suitable	Not suitable (see ** below)
Loam and silt	Fair	Suitable	Suitable	Fair	Suitable	Not suitable
Clays	Fair	Suitable	Suitable	Suitable	Suitable	Fair
Puggy shale and mudstone	Slow	Fair	Suitable	Fair	Slow	Slow
Shale	Slow	Fair	Suitable	Suitable	Slow	Suitable
Sandstone	Slow	Fair	Suitable	Suitable	Slow	Suitable
Conglomerate	Not suitable	Slow	Slow	Suitable	Suitable - Slow	Suitable
Limestone and dolomite	Not suitable	Slow	Fair	Suitable	Suitable	Suitable
Limestone with small cracks or fissures	Not suitable	Fair – slow	Fair	Suitable	Suitable	Suitable
Cavernous limestone	Not suitable	Slow	Difficult	Suitable	Suitable	Suitable
Weathered basalts	Difficult	Slow	Suitable	Suitable	Suitable	Suitable
Thick layered basalts	Not suitable	Not suitable	Slow	Slow	Not Suitable	Suitable
Schists and Gniess	Not suitable	Not suitable	Slow	Slow	Slow	Suitable
Granite	Not suitable	Not suitable	Suitable	Suitable	Not Suitable	Suitable

LEGEND

Not suitable:	Normally cannot drill formation type.
Difficult:	Generally not suitable but can sometimes be adapted.
Slow:	Can be used but drilling progress is usually slow.
Fair:	Suitable with some care and/or special technique suggested in brackets.
Suitable:	Normally used to drill formation type economically.

NOTES

* Auger drilling requires high torque for rotation so depth is limited.

** Fair if top drive rig using hammer and swing out reamer and casing following bit.

Cable tool drilling

Cable tool drilling, otherwise known as percussion drilling, is probably the oldest drilling method. It involves lifting and dropping a string of solid steel drilling tools suspended from a wire rope to hit the bottom of the hole. This process drives the cutting bit, fracturing or pulverising the formation.

The crushed material forms a slurry on mixing with water that has been added to, or is naturally present in, the hole. The blow rate varies from 40–60 strokes per minute and, because of the characteristic left lay of the wire rope cable, the bit turns and strikes across a different section of the hole bottom at each blow.

When the bit can no longer fall freely through the water–cuttings mix, the drill tools are withdrawn from the hole. A tubular bailer, which is run on a separate smaller wire rope, is then used to pick up the slurry and cuttings and remove them from the hole before drilling is resumed.

Cable tool drilling

In cable tool or percussion drilling there are basically three major operations:

- drilling the hole by chiselling or crushing the rock, clay, or other material by the impact of the drill bit
- removing the cuttings with a bailer as cuttings accumulate in the hole
- driving or forcing the bore casing down into the hole as the drilling proceeds.

Because of the relatively low initial cost and simplicity of equipment used, the cost per unit drilled is relatively low. However, the technique is slow, and when the increased cost of labour is taken into account, there is usually little advantage over faster rotary drilling methods when drilling new bores.

Cable tool drill plants are used extensively for reconditioning because they:

- are usually lighter than a rotary plant with an equivalent depth capacity
- are easier to establish over a borehole
- can also lower and retrieve tools to probe a bore more quickly than with a rotary plant

- are able to work inside casings
- are able to insert casing liners more quickly because of their better access around casing strings for screwing or welding a joint.

Auger drilling

Auger drills are used mainly for soil investigation and for drilling in soils and very soft rock. The mechanical clearing of the hole eliminates any need for pumps or compressors. Types of augers include:

- Continuous-flight augers, which can be driven by any top-drive rotary machine provided it has adequate torque rating and slow rotation. When using continuous-flight augers in deep, small-diameter holes, the cuttings are supported by the hole and carried to the surface by rotation of the helical flights.
- Hollow augers, which consist of a continuous-flight auger that has a hollow centre tube. They are normally used with a bit plug held in place by a secondary internal rod string, with the augers used to drill as with a conventional continuous-flight auger to the required depth. At that point the central bit plug and rod string are withdrawn, which permits the casing to be installed before the auger flights are removed.
- Short-flight and plate augers, which are loaded with cuttings and then pulled out of the hole. At the surface the cuttings are 'spun' off the auger.
- Bucket augers, where the cuttings are picked up in a bucket, hoisted to the surface, and dumped through the hinged bottom of the bucket. Extensions are added as the hole gets deeper.

Short-flight, plate, and bucket augers are used for shallow, large-diameter holes.

Rotary drilling techniques

The principle common to all rotary techniques is that a drill bit is attached to the end of a hollow drill pipe and rotated against the bottom of the hole with either a fracturing, digging, or scraping action, depending on the bit type and the nature of the formation.

Rotary drilling techniques are compared in Table 4.1.

Rotary air drilling

The rotary air method is used to drill holes in consolidated or semi-hard formations such as sandstone or shales that are self-supporting. The cuttings that this process produces are cleared by circulating air, which is derived from a compressor and fed down the drill pipe to emerge through a bit. The recommended up-hole annular velocity must be maintained to remove cuttings effectively (see Table 4.2 below).

Compressor output, hole diameter, and drill pipe size should be matched to provide the required velocities.

Table 4.2 Recommended (optimum) up-hole velocities (UHV) (bailing velocities)

Fluid type	UHV (m/sec)	UHV (m/min)	UHV (ft/pm)
Air or mist	15–25	900–1500	3000–5000
Water	0.6	36	120
Mud	0.4	24	80
Thick mud	0.3	18	60
Foam	0.2	12	40

Rotary air drilling

Holes can be drilled using a large volume of air at high pressure. However, the equipment usually used is limited in depth once below water level.

A major advantage of the rotary air drilling method is that water is blown to the surface as soon as the water-bearing stratum is encountered. This allows the driller to obtain a progressive indication of the available supply and to monitor any changes in the quality and quantity of water as the drilling progresses.

Air is used principally in consolidated formations. Foaming additives are occasionally used to increase the up-hole carrying capacity of the return air.

Down-hole hammer method

The down-hole hammer method involves a pneumatically operated drill bit that efficiently combines the percussion action of cable tool drilling with the turning action of rotary drilling.

A pneumatic drill bit can be used on a standard rotary rig with a high- pressure air compressor of sufficient capacity. It is used for fast and economical drilling of medium to extremely hard formations. Fast penetration results from the blows transmitted directly to the bit by the air piston. Continuous hole cleaning exposes new formation to the bit and practically no energy is wasted in re-drilling old cuttings.

Down-hole hammer drilling is generally the fastest method of penetrating hard rock. Foaming additives are occasionally used to increase the up-hole carrying capacity of the return air.

Down-hole hammers are used for hard rock drilling and enable water bores to be established from fractured hard rock aquifers.

This method is not effective for drilling loose, unconsolidated materials.

Reverse circulation drilling — air (dual tube rotary air and down-hole hammer)

For this drilling method, air is introduced through a dual swivel head on a top drive rotary rig and pumped down the annulus in the dual drill pipe to the bit or hammer being used. Cuttings are returned to the surface through the inner tube.

This method is commonly used for mineral sampling to obtain an uncontaminated strata sample. It is not a common method for water bores; however, it is sometimes used for water sampling programs.

Large-diameter dual tube rotary air drill strings permit the insertion of up to 50 mm PVC-U casing through the inner tube for the construction of monitoring bores.

Dual Rotary drilling

The Dual Rotary method of drilling typically utilises the down-hole hammer methodology whilst simultaneously advancing steel casing. The dual rotary method is highly efficient at drilling through fractured, friable formations that would not maintain stability with the down-hole hammer method.

The dual rotary method provides the efficiency of the down-hole hammer method and the stability of mud rotary methods to provide a secure environment for bore construction. The steel casing is retracted following bore construction and prior to gravel packing being completed and airlifted.

Rotary mud drilling

Rotary mud drilling uses drilling mud (mixes of water, bentonite clays, polymers, and additives) as the circulation medium. In the rotary mud system, drilling fluid or mud is pumped down through the drill pipe and out through nozzles in the bit. As the bit penetrates the formation material, the drilling fluid circulates continuously and removes the cuttings. The fluid also serves to cool and lubricate the bit. The mud fluid then flows upwards in the annular space around the drill pipe to the surface, carrying the cuttings with it in suspension.

Rotary mud drilling

Photo courtesy of Austral Drilling

At the surface, the drilling fluid is conditioned before being recirculated down the hole. Properly conditioning the mud helps to prevent down-hole problems.

The basic fluid normally used for rotary drilling is water, to which specific chemicals and other additives can be added to increase the density or viscosity to improve hole support. The fluid can also be weighted to control artesian pressures.

The mud forms a membrane that inhibits flow through the walls of the hole, and the internal pressure of the mud provides structural support to the hole wall. Drilling fluids are also used for drilling deep bores that are beyond the capacity of air compressors.

The technique is useful for drilling operations in soft, unconsolidated formations, deep bores, and pressure bores.

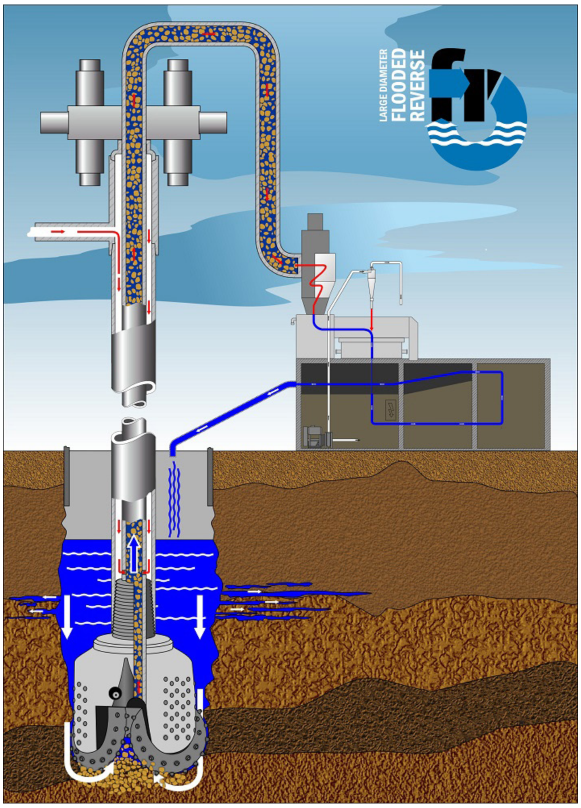
Reverse circulation drilling — mud

In the reverse circulation drilling method, instead of circulating the drilling fluid through and up the outside of the pipe, the process is reversed. Fluid is fed down through the space between the wall of the hole and the drill pipe where it is then pumped up, together with the cuttings, through the hollow part of the pipe and then out through a discharge pipe.

Of particular importance is the possible use of a light (nearly clear) drilling fluid for large diameter holes, rather than a viscous and heavy drilling mud (as used in conventional rotary mud drilling), which sometimes tends to seal-off water-bearing formations. However, a substantial quantity of fluid must be present to maintain an open hole.

This method is used for rapid drilling of large-diameter holes in soft formations where gravels are encountered.

It is possible to bring gravel to the surface through the hollow drill pipe because of the extremely high velocity of the fluid as it is drawn up by the suction pump. The walls of the hole are held in place by the pressure of the fluid against the sides of the hole.



Reverse circulation drilling — mud

Photo courtesy of Foraco

Sonic drilling

Sonic drilling uses a dual-line threaded drill pipe and casing, with the inner line being advanced with a core barrel attached to it and the outer line creating hole stability. Sonic drilling uses a high-frequency vibration in combination with rotation to advance the drill bit. The conventional core barrel is used to retrieve the sample. This technique is relatively continuous and undisturbed geological samples are obtained without the use of drilling fluids or other potential contaminants.

This technique is best suited to drilling unconsolidated formations, but its depth and diameter capability is currently limited.

Sonic drilling has the following advantages:

- Undisturbed sampling to accurately record strata
- Creates little waste due no drilling fluids and complete sample capture
- Small foot-print
- Capable of drilling through difficult subsurface materials (eg fill, landfills)

Sonic Drilling

Photo courtesy of Groundwave Drilling

Choice of Drilling Method

Each of the common drilling methods has its advantages and disadvantages (see Table 4.1 for guidance). The choice of drilling method should be based on the expected geological conditions and the type of bore to be constructed.

Mandatory Requirements

4.1 Only drillers licensed for the class of work proposed and endorsed for the drilling method to be used shall carry out work on a water bore unless state or territory legislation provides an exemption.

Good Industry Practice

4.2 Drillers should use drilling methods and techniques suited to the expected hydrogeological conditions.

4.3 Drillers should not contract for or attempt works that could be reasonably expected to exceed the capabilities and limitations of the drill plant to be used.

4.4 Drillers should maintain the optimal up-hole velocity throughout the drilling of the bore (see Table 4.2)

5 Siting a Water Supply Bore

Principle

A bore is sited to provide a reliable and useful water supply.

Information should be sought about the hydrogeological conditions in the area before drilling.

Water supply bores shall be positioned a suitable distance from known possible sources of contamination, or designed and constructed to eliminate all sources of contamination.

The driller shall ensure the location complies with any conditions specified in the bore permit.

Siting a water supply bore usually involves considering a range of factors in order to provide a cost-effective and reliable supply of water of acceptable quality.

Obtaining Information

Selecting and investigating the initial location are very important in the overall construction and performance of a bore. The depth, cost, and relative importance of a water supply bore will usually dictate the amount of investigation required.

There is a significant amount of publicly available groundwater information and data on-line for clients and drillers to access. Researching site information on-line can help save time and cost. A list of useful on-line websites are presented in Appendix B.

Hydrogeological consultants can also provide information and advice, and, if required, give an assessment of groundwater availability in a specific area of interest. This could include data that is available from previous drilling work in an area (e.g. location, depth to water, amount of water pumped, type of water-bearing formation, and water quality) and other geological and geophysical records.

Depending on the extent of the work required to provide the assessment, costs may be incurred. Local information may also be available from other drillers and from neighbouring landholders.

Driller Considerations

Drillers who have worked consistently in an area may have some knowledge of the construction, depth, quality, and yield of bores in that area.

The driller should have an understanding of the known hydrogeological conditions of the area to determine whether the drilling equipment available can do the job.

Provisions relating to licensing can vary between different state and territory water authorities, so drillers must check the requirements of the particular area in which they operate.

Client Considerations

The client should seek information from the relevant state or territory water authority so that the best site for the bore can be determined. *(See Chapter 2 for contact details (including website addresses) for state and territory water authorities).*

The client should check with the service providers (e.g. 'Dial before you dig') to ensure there are no underground or overhead services in the area of the proposed drill site.

The positioning of a water supply bore should be based on the best prospects for obtaining a successful supply and for working convenience.

Other requirements may have to be considered if the pump is to be solar- or wind-powered. A cleared area might be preferable if such pumps are to be used. State and local government requirements might limit or control the ways in which vegetation or timber can be cleared, and these should be checked before undertaking any clearing for a bore site.

The water supply bore site should allow ready access for heavy machinery for drilling and subsequent servicing of the bore and pumping equipment.

Some state and territory water licensing authorities may have a bore permit condition that stipulates a bore should be located not less than a specified distance from the property boundary and/or from a bore on a neighbouring property, channel or stream, or source of pollution. These pollution sources can include dairies, septic tanks and absorption trenches, refuse dumps, landfill and effluent discharges (e.g. from piggeries or feedlots, sewage treatment discharges, drainage ditches, cattle/stock dips, chemical spray use and/or preparation areas). This requirement is to minimise the possibility of contaminating the bore and any surrounding bores.

If the driller has any doubts about the potential problems and requirements for a particular situation, advice should be sought from the relevant state, territory, or local water licensing authority.

The client should provide access to the bore site and advise the driller if there are any particular site access requirements.

Mandatory Requirements

5.1 The driller shall obtain confirmation from the permit holder that the bore location meets the requirements specified in the bore permit.

5.2 All water supply bores shall be grout sealed to protect the production zone from contamination.

Good Industry Practice

5.3 All water supply bores should be positioned away from the influence of possible sources of contamination.

5.4 In bores where the target aquifer is deeper than the source of the contamination, the bore may be constructed providing the contaminated formation is adequately cased and cement sealed.

5.5 If the driller has any doubts concerning the potential problems and the requirements for a particular situation, advice should be sought from the client and the relevant state or territory water authority.

5.6 Bores should be positioned so that the headworks can be protected from damage, frequent flooding, and surface water drainage. (See chapter 16 for more information about headworks designs)

5.7 Site work should be planned and carried out in such a manner to minimise damage to property, infrastructure, crops, land, drainage works, and roads.

5.8 Before commencing drilling, the client/driller should contact the local service providers (e.g. gas, electricity, power, communications, water) to obtain advice on location of these services and the minimum clearance distances between the drilling rig and services. This information should be sought, as far as practical, in written form.

6 Formation Sampling and Water Sampling

FORMATION SAMPLING

Principle

Formation samples shall be taken to determine the nature and type of strata, and to confirm any changes in the formation.

Formation samples are taken to produce a comprehensive and representative picture of the bore, and to accurately confirm any changes in the formations. The driller shall record this information in the bore completion report.

To establish the optimum design for various elements of a final production bore, it is necessary to have reliable information on specific geological materials and aquifer conditions at a site.

Geophysical logging equipment can also be used and is recommended to confirm drilling depths and formation intervals. It can also provide information on the porosity of formation, clay content, hole diameter, integrity of the borehole, and best production zones within the aquifer sequence.

Information gained from good formation sampling influences the:

- selection of casing diameter and length
- selection of casing and screen material
- selection of screen interval for production zone
- aperture of the bore screen, and the gradation of the gravel pack
- construction method and cost.

Careful sampling of the water-bearing formation must be carried out during drilling in order to determine the appropriate construction procedure, screen aperture, or gravel pack size. It should be noted that any loss of fines to hole fluids can affect the accuracy of the sample test results.

Mandatory Requirements

6.1 Representative formation samples shall be taken to determine the nature and type of strata encountered. (See Chapter 15 for more information)

Good Industry Practice

6.2 So that both the driller and the client can see the formation changes, a reliable drilling log shall be completed.

6.3 Samples should be:

- collected as soon as possible after being withdrawn from the hole
- drained of excess moisture
- laid out in a regular pattern

- kept in plastic bags, or other containers of at least 500 g capacity.

Containers should be plainly marked with the bore identification number, depth interval, and date relating to that particular sample.

6.4 It is recommended that samples, whether required for collection or not, should be taken at 1-metre intervals and at each change in the formation. The depth shall be recorded in each instance.

Laying out samples of drill cuttings

Guidelines for rock and soil classifications and descriptions can be found in Tables 15.1 and 15.2.

WATER SAMPLING AND ANALYSIS

Principle

Water samples should be taken to provide a guide to water quality encountered during drilling operations.

Any water samples taken during or immediately following construction and development should be representative of the groundwater.

It is highly desirable to know and record the quality of water encountered during construction and development. Although it may not always be possible to collect samples during the construction phase, water quality sampling should at least be undertaken during development.

Determining formation water quality will assist the client to make decisions regarding water suitability, which may impact on the:

- construction requirements
- continued construction
- selection of materials (e.g. in corrosive waters)
- modifications in construction (e.g. screen setting)
- aquifer separation requirements
- suitability of the bore for the desired purpose or in the planned operation of the completed bore.

Representative water samples will provide a clear indication of the formation water quality. Generally the costs associated with obtaining a representative sample are insignificant in the overall cost of the bore construction.

To determine the suitability of a sample to be 'representative' of the formation in question, and to provide early 'in the field' advice to the client or bore owner on the likely quality of the formation water, an approximate indication of water quality may be obtained using portable water quality monitoring equipment.

Salinity (salt content) in groundwater is variable and is a key determinate of its suitability for various uses. There are two indicators of the salt content of groundwater:

- Total Dissolved Solids (TDS)
- Electrical Conductivity (EC)

Total Dissolved Solids (TDS) is determined from a laboratory analysis of a water sample. A more convenient field based method of estimating TDS is to measure the Electrical Conductivity (EC) of the water. The relationship between EC and TDS can vary depending on a number of factors (eg, temperature), however as a general rule TDS (mg/L) = EC (uS/cm) x 0.6 at room temperature.

A driller's basic portable water quality monitoring equipment should include at least an electrical conductivity meter. Other indicative field testing including pH and temperature can be carried out to provide the client with additional information on which to base decisions.

To accurately determine the suitability of bore water for a particular use it is recommended clients submit a water sample for laboratory analysis to record the full chemical composition of the water and the presence of potential contaminants.

State and territory water authorities can supply a range of informative publications on water quality and suitability.

Good Industry Practice

6.5 It is the driller's responsibility:

- to take care to ensure that the water sample is representative of the water body and is not contaminated by bore construction materials or the sampling procedure.
- if possible during the drilling process to regularly report on the water quality of the formation(s) intersected.
- to ensure that portable water quality monitoring equipment if provided and used is regularly calibrated, in good working order, and operated according to the manufacturer's procedures and instructions.

6.6 It is the client's responsibility to:

- determine types of analysis required.
- understand the sampling and analytical requirements and advise if specialist sampling procedures are required.
- arrange for the collection of water samples to carry out the appropriate chemical and biological analysis required to ensure that the water is suitable for the proposed purpose. (This type of testing should be carried out by a certified laboratory.)

6.7 General responsibilities:

- A clean container, rinsed with the water to be sampled, should be used unless there are specific requirements.
- Sample containers should be clearly labelled with the name and address of the licensee, bore permit number, depth to water-bearing formation, and the date the sample was taken.
- A sample of water separate from the client's sampling requirements may be required by the relevant state or territory water licensing authority for analysis.

7 Drilling Fluids

Principle

Drilling fluids shall be selected and managed to:

- **facilitate the drilling process**
- **ensure the removal of cuttings from the borehole**
- **minimise damage to the formations.**

Chemicals and other drilling fluid additives that could leave a residual toxicity should not be added to any drilling fluids or cement slurries (i.e. grouts) used to drill and complete any water bore.

Drilling fluids are used to facilitate the removal of formation cuttings, to act as a lubricant, and to stabilise the hole during drilling operations. Inappropriate fluid control may cause washouts in the borehole and clogging of the water production zone. It can also affect the sealing process, leading to a poor grout seal between the bore wall and the casing, creating problems during borehole development.

(See Chapter 10 for more information about water entry, and see Chapter 11 for more information about bore sealing)

In water-based drilling fluids the density (or weight) of a drilling fluid should be kept as low as possible to prevent loss of drilling fluid and overpressurising the formation. Dense mixes should be used only to control formation overpressure, collapse, or artesian flow.

Drilling mud viscosity should be regularly monitored and kept as thin as practicable while ensuring that the mud retains the ability to stabilise the formation and adequately clean the hole.

The equipment for testing drilling fluid includes:

- mud balance for weight fluid density
- Marsh funnel for viscosity
- filter press for filtration and wall cake
- sand content set for sand content.

The following types of drilling fluids should be considered acceptable for water bore drilling:

- water-based drilling fluids
- air-based drilling fluids.

Many products are available to enhance the performance of the drilling fluid, and they should be used in accordance with the manufacturer's recommendations.

Additives are used to assist the:

- lubrication and cooling of the drill bit
- suspension capability and removal of cuttings
- hole stability and filtration control
- control of subsurface pressures.

Mandatory Requirements

7.1 Chemicals or other substances that could leave a residual toxicity shall not be added to the drilling fluid.

Good Industry Practice

7.2 Fresh non-polluted water (or if this is not possible the best quality water that is reasonably available) should be used as the base fluid (i.e. make-up water) for all water bore drilling fluid preparations.

The conductivity and pH values of all make-up waters should be measured and recorded.

7.3 The use of drilling fluid additives should be in accordance with the manufacturer's recommendations. Additives and their uses can be obtained from drilling fluid manufacturers.

7.4 Material Safety Data Sheets (MSDS) and manufacturer's recommendations should be available on the drill site for all drilling fluid products used.

7.5 Drilling fluid properties should be tested regularly as a normal part of the drilling program, or as determined by the drilling conditions.

7.6 To maintain the cleanliness of the hole, drilling fluid circulation viscosity should be as shown in Table 7.1

7.7 Professional advice should be sought for a complex mud system.

7.8 The use of chlorides as a hydration (clay) inhibitor and weighting agent is not recommended where steel casing is used.

7.9 The drilling fluid should be removed from the hole to allow the subsequent development of the bore.

Table 7.1 Suggested Marsh funnel viscosities for unconsolidated materials

Because viscosity can often be confused with density, the specific gravity or density should be determined by means of a mud balance and not just estimated.

Material drilled	Marsh funnel viscosity (seconds)
Fine sand	30–45
Medium sand	40–55
Coarse sand	50–65
Gravel	60–75
Coarse gravel	75–85
Lost circulation	85–120

Measuring viscosity using a Marsh funnel

Measuring mud weights using a mud balance

8 Bore Plumbness and Straightness

Principle

Bores should be sufficiently plumb and straight to ensure that there will be no interference with the installation, alignment, long-term operation, or future removal of the pump.

Boreholes should be drilled and casings constructed straight and as close to vertical as possible.

Plumbness and straightness are never perfect. However, the driller should be expected to keep straight and plumb within practical limits under most conditions by exercising reasonable care and using equipment that is adequate and appropriate for the job.

Plumbness and straightness become more critical with deeper holes and where a shaft-driven turbine pump, helical screw type or rod-driven pump (such as a windmill or pumpjack) is to be installed in the bore.

A bore that is not straight can cause wear on the pump rods or pump shaft, shaft bearings, and discharge column. Under extreme conditions it may be difficult to insert a pump into, or withdraw it from, a bore.

Good Industry Practice

8.1 A stabiliser with the same diameter as, or larger than, the casing should be included in the drill string directly above the bit to keep the hole as straight as possible.

This should allow sufficient clearance to enable the insertion of the casing string.

8.2 A basic plumbness and alignment standard is that the completed bore is sufficiently plumb and straight when there is no interference with the installation, alignment, operation, or future removal of the pump.

The standard for acceptance could be that the pump is successfully installed with sufficient clearance, and does not touch the casing at any time during installation.

Good quality control by the driller should include a periodic check of the plumbness of the cable or drill string suspended in the borehole.

Before running casing in deep holes a drift-direction survey (i.e. using a deviation tool) can be run to see the direction that the hole is heading and to allow an estimate of how the casing will run.

Centring the casing

Casing centred in the bore hole with uniform grout seal around the casing

9 Casing

Principle

Water bore casings and joints shall:

- **prevent the collapse of the strata penetrated**
- **assist in construction and sealing, and prevent intermixing**
- **be strong enough to withstand installation, construction, and operational pressures**
- **provide access to the water-producing zone**
- **be of sufficient diameter and length to act as a safe housing for the pump selected for the hole**
- **provide an adequate operational life**

General Considerations

The casing provides the conduit from the water-producing zone to the surface. It is also important in assisting in the construction of the bore, and must be of sufficient strength and composition to withstand the pressure exerted by the surrounding strata and other forces imposed during installation, bore development, and any cementing operations.

It should provide a secure and leakproof conduit from the water source to the surface through unstable formations and through zones of actual or potential contamination.

Casing joints should be watertight and have the same structural integrity as the casing itself.

The selected casing material and overall diameter of the bore casing should be adequate to accommodate the size of pump that has been selected. It should take into account:

- the efficiency of the pumping unit
- the expected pump life
- the extra clearance required in the event that the casing is not perfectly straight
- the possibility of welds and other fasteners projecting inside the joints of the casing
- the possibility of weld intrusions on steel casing
- any potential corrosion issues.

A range of casing materials are available, and casing selection depends on several major factors. These include:

- strength requirements
- corrosion resistance
- ease of handling
- temperature rating
- cost considerations
- type of formation
- the particular bore design

- the method of drilling
- construction techniques
- bore permit requirements.

Where resistance to collapse is the most critical strength requirement for boreholes with unstable formations, steel or fibreglass casing is usually selected to meet the strength characteristics required.

For corrosive water, PVC-U, fibreglass, or stainless steel casing provides the longest life possible. Because of the many and sometimes conflicting factors involved in selecting the most suitable casing material, the driller should consult with the manufacturer/supplier and bore owner before selecting the casing.

Types of Casing

The main types of casing used in bores are:

- steel
- PVC-U
- Fibreglass (FRP and GRE)
- stainless steel.

Each of these has different properties in relation to column, collapse and tensile strengths, resistance to corrosion, reaction to ground and water chemistry, and temperature.

Steel

Steel is a commonly used casing material because of its greater strength. When used as a casing it can be butt welded or screwed. Steel has the following advantages over other types of materials.

- It is stronger than other materials.
- It can be pressure-cemented to greater depths because of its higher collapse strength.
- It can withstand high temperatures.
- It is available in large diameters.
- It can withstand rougher treatment.

A disadvantage of steel is that its life can be reduced in a corrosive environment. This can be through corrosive soils, water, or by galvanic action arising from the use of dissimilar materials in the bore.

Some potable waters can be very corrosive to steel because of the dissolved gases they contain. Carbon dioxide (CO_2) is the most common of these gases. Groundwater with high levels of dissolved CO_2 and oxygen (O_2) can accelerate the corrosion of steel (see Table 9.1).

The reactivity shown in the table can vary, depending on the chemistry of the particular water.

Table 9.1 Reactivity of steel casing to corrosive waters

Reactive agent	Water quality	Reaction
pH	less than 5.5	corrosive
O_2	more than 4 mg/L	corrosive
CO_2	more than 100 mg/L	corrosive
CO_2	50–100 mg/L	marginal/corrosive
CO_2	less than 50 mg/L	acceptable

Non-ferrous or plastic materials are commonly used as casing materials where corrosive waters preclude the use of steel.

PVC-U (Unplasticised polyvinyl chloride)

PVC-U piping is made for a wide range of uses including drainage and general water distribution. It is made in a variety of wall thicknesses and internal diameters.

The only PVC-U piping suitable for use as bore casing is pressure-rated pipe manufactured to conform to AS 1477. This Australian standard is for pipe that is rated for potable water supply.

PVC-U pipe (AS 1477) uses a pressure nominal (PN) rating. PN indicates the pressure rating of the PVC-U, which provides a guide to the external collapse pressure.

The collapse pressure of PN 6 pressure pipe has insufficient strength and shall not be used as bore casing. PN 9 piping can be used with care for shallow bores. PN 12 piping is the recommended casing for most bore construction applications.

PVC-U has the following advantages over other types of materials. It is:

- non-corrosive;
- readily available in some sizes, particularly small diameters;
- light and easy to handle and join;
- inert.

PVC-U casing is low in compressive strength relative to steel casing. The actual strength for any situation will depend on the uniformity of the wall thickness, the roundness of the casing, the rate of loading, and the temperature of the casing when the loading is applied.

PVC-U material is much more flexible than steel, and temperatures greater than 20°C reduce the pressure rating of the casing. It should be de-rated in accordance with the manufacturer's specifications when used with elevated water temperatures and when cementing.

The following factors should also be considered.

- PVC-U casing requires care in handling, storage, and installation to prevent breakage and/or distorting its shape.
- Plastic parts installed above the ground must be protected from damage (e.g. from moving vehicles, contact with drilling tools, fire).
- The impact strength of PVC-U casing may be reduced significantly over time from extended exposure to UV rays.
- Occasionally PVC-U casing will float in a bore during installation, thus creating special handling problems.
- The short-term strength of PVC-U casing is much higher than its strength over time. Therefore the driller should consider the long-term forces of the formation on the casing.

- Changes to differential pressure and temperature ratings may result from cementing.
- If volatile organic chemicals make contact with PVC-U casing, they may permeate the casing and enter the bore.
- It should be centred in the borehole during backfilling or gravel packing. Any voids in the backfill or gravel pack may lead to a sudden collapse of formation materials against the casing, causing the casing to collapse.

Fibreglass

Fibreglass is a generic term used to describe casing that is constructed with reinforced glass fibres. There are generally two types of fibreglass casing; Glass Reinforced Epoxy (GRE), and Fibreglass Reinforced Plastic (FRP). GRE Casing is also known as FRE Casing (Fibreglass Reinforced Epoxy), but for all intents and purposes, they are the same thing. The different types of fiberglass casing can vary in the manufacturing process used and the type of resin systems applied.

Glass Reinforced Epoxy (GRE) is manufactured by API Q1 licensed manufacturing facilities, which guarantee its conformance and quality. It is generally the highest grade of fiberglass casing available, with higher tensile strength, external collapse pressure and higher collapse strength to weight ratio than steel. It has been used to depths up to 3000m.

Fibre Reinforced Plastic (FRP), is a form of fiberglass casing that is not necessarily constructed to meet the API Q1 standards. FRP Casing can be custom engineered to meet different requirements and therefore unlike GRE the strength ratings (collapse and tensile) can vary. In general, FRP has high collapse strength to weight ratio, and is suitable for deep bore constructions, however casing specifications should be checked prior to use.

The minimum casing wall thickness required in GRE and FRP varies due to differences in manufacturing and the type of resin applied. FRP will usually require a larger wall thickness than GRE to achieve the same pressure rating.

Although the strength properties of different forms of fiberglass casing may vary, they all have a high level of corrosion resistance and high temperature rating. All forms of fiberglass casing are constructed with swelled joints and therefore additional annular space may be required compared to other forms of casing which may have flat joints.

Stainless steel

A range of grades of stainless steel can be matched to soil water chemistry and temperature to provide a higher corrosive resistance than steel. The two grades that are commonly available in Australia are grade 304 and grade 316. Grade 316 has a higher level of corrosion resistance than grade 304 and is more suited for use in corrosive environments. Stainless steel is also available in different wall strength classes, with Schedule 10 and schedule 40 the most commonly available classes. Schedule 40 has the higher strength and is suitable for deep bores and larger diameter bores, while schedule 10 is generally only used in shallow bores.

Collapse Resistance of Pipes or Casings

A comparison of typical strengths of casing materials is shown in Table 9.2.

Casing that is subjected to a high enough pressure externally (or differential pressure)will collapse. For any given diameter-to-wall thickness ratio, there is a critical collapse pressure at which the pipe wall will fail. Casing that is subjected to a high enough pressure externally (or differential pressure) will collapse. For any given diameter-to-wall thickness ratio, there is a critical collapse pressure at which the pipe wall will fail.

Differential pressures can arise during formation pressures, cementing, development, and pumping. The expected differential pressure in plastic casing will determine the wall thickness. *(See Mandatory Requirement 9.4 for details of maximum potential pressure differentials for PVC-U bore casing).*

For PVC-U, the maximum differential pressures that should be allowed range from 12 kPa per metre head (for an evenly compacted non-clayey- filled bore annulus) to 23 kPa per metre head (for bores in swelling clays).

Plastic casing should not be set to a depth in unconsolidated formations where the maximum potential pressure differential could exceed the collapse rating of the casing. The collapse strength of casing will be affected by slotting the casing.

Table 9.2 Comparison of strengths of bore casing materials

Material	Specific gravity	Tensile strength (MPa)	Impact strength (relative to PVC-U)	Upper temp. limits (°C)
PVC-U	1.40	55	x1	60
FRP	1.89	115	x20	80 (i)
GRE	1.95	145	high	93
Steel	7.85	415	very high (ii)	800–1000
Stainless steel	8.00	517	very high (ii)	800–1000

NOTES
i. FRP higher temperature with special resins.
ii. The impact strength of steel and stainless steel is so high relative to PVC-U and to the demands of water well work, that it is generally not a design consideration

Table 9.3 PVC-U temperature derating

Source: Groundwater & Wells, 3rd Ed, Johnson Screens, 2008

Degrees C	Maximum strength (%)
23	100
27	88
32	75
38	62
43	50
49	40
54	30
60	22

Mandatory Requirements

9.1 The minimum casing size shall be 100 mm nominal diameter, except for monitoring bores. The casing and casing joints shall withstand the pressures imposed during the installation and operation of a water bore. All casing joints shall be aligned, secure, and leakproof. The appropriate PVC cleaner and Type P solvent cement (AS/NZ 3879) shall be used to solvent weld PVC-U pipe.

9.2 The casing material used shall comply with manufacturer's standards as follows:

Casing Material	Minimum Standard
Steel	API 5L-B or AS/NZS 1396 steel casing or AS/NZS 1579 arc welded steel pipes and fittings for pressure applications
PVC-U	AS/NZS 1477 PVC pipes and fittings for pressure applications
FRP	AS 2634 or BS7159 and ISO 9001 equivalent
GRE	API Q1
Stainless Steel	ASTM A312M Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

9.3 The minimum acceptable casing wall thickness shall be:

Stainless steel casing (Grade 304/316 stainless steel)

Nominal diameter (mm)	Minimum wall thickness (mm)	
	Schedule 10	Schedule 40
80	3.05	5.49
90	3.05	5.74
100	3.05	6.02
125	3.40	6.55
150	3.40	7.11
200	3.76	8.18
250	4.19	9.27
300	4.57	9.53
350–450	4.78	9.52
500–550	5.54	9.52
600	6.35	9.52

NOTES

i. Two schedules of stainless steel are generally available in Australia: Schedule 10 and Schedule 40.

ii. Schedule 10 is the minimum acceptable schedule and is generally used for shallow wells; Schedule 40 is used for deeper applications and for larger diameter bores because of its greater wall strength.

Steel casing

Nominal diameter (mm)	Minimum wall thickness (mm)
101–105	3.6
106–114	4.5
115–219	4.8
220–323	6.4
324–457	9.5

FRP casing

Nominal diameter (mm)	Minimal wall thickness (mm)	Operating collapsible pressure (kPa)	Max operating internal pressure (kPa)	Maximum tensile load (kg)
75	5	4330	6440	3790
100	6.5	4280	6410	6760
125	6.5	2340	5190	8360
150	6.5	1410	4360	9960
200	8	1190	4100	16530
250	11	1590	4540	29290
300	12.5	1410	4360	39820
350	15.5	1630	4580	59200
400	17	1470	4420	74180
450	18.5	1450	4390	88940

NOTE
GRE casing has stronger mechanical properties than FRP and this allows a smaller wall thickness to be used in the same application. Refer to the manufacturer's guidelines.

9.4 PVC casing

PN 9 PVC-U pressure pipe is the minimum class allowed for use as bore casing.

PN 6 PVC-U pipe, PVC-U sewer, PVC–O, PVC–M, and drainage pipe shall not be used.

Maximum potential pressure differential[i] for PVC-U bore casing (head difference)

PN	Unconsolidated formation/ clays (metres head)	Consolidated formation [ii] (metres head)
9	26	60
12	56	110
15	100	200
18	200	300

NOTES

i. PVC-U should be de-rated in pressure rating when temperature exceeds 20°C.

ii. The maximum difference in metres between external and internal water level. Includes fully grouted and gravel pack.

iii. The tables for minimum wall thickness for Stainless steel and FRP and FRE are based on having similar collapse pressure to steel casing of the same diameter (see Table 9.2).

Good Industry Practice

9.5 As a general guide the diameter of the bore casing for high-yield bores shall be approximately 50 mm larger than the pump size specified for the bore.

9.6 Drillers should always case a bore to such a depth that no part of the pump or column is exposed to open-hole conditions.

9.7 A casing of inert material should be used in all areas where a corrosive problem from bore water or strata is known to exist.

9.8 When securing the joint the internal diameter of the casing should not be compromised, for example, by screws, rivets, or welding.

9.9 The base of the installed casing should be capped or sealed, except in open hole bore constructions.

10 Maximising Bore Efficiency and Water Entry

Principle

The method of completion across the water entry zone of the bore should:

- **allow efficient entry of water into the bore**
- **stabilise the formation**
- **prevent unacceptable amount of ingress of materials from the formation.**

Water can enter the bore from the water production zone via the following methods:

- open hole
- slotted or perforated casing
- screens

Selecting the correct screen and gravel pack will influence the efficiency of the bore.

Open Hole

The open-hole method is a low cost construction method that can be used if the underlying rock and water- bearing formation are consistently firm and stable.

Casing is required across the unconsolidated section of the bore and into stable formations. The remainder of the hole is then left uncased.

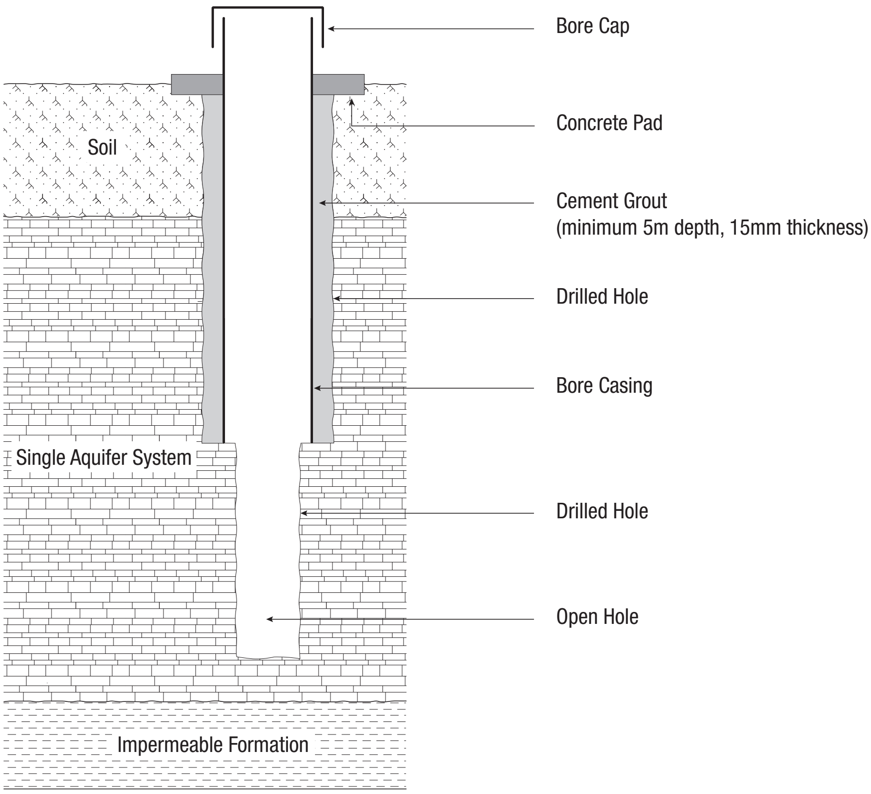
When this method is used, care must be taken to ensure that the surface casing is firmly seated and secured into the rock with grout to protect from possible surface run-off and any undesirable subsurface seepage.

For an open-hole completion to be successful, the formation must be stable. In some cases the formation may be either tiered or layered with dispersed friable or soft materials such as clays or sands. In time, these strata can collapse and bridge the hole. This can result in pump damage. An open-hole bore construction may have a shorter lifespan than a fully cased bore.

Under these conditions it is necessary to provide some form of support for the strata, while at the same time allowing adequate entry of water into the bore. This is achieved by the use of slotted casing or a screen.

An example of an open-hole bore construction is shown on the following page in Figure 10.1

Figure 10.1 Example of an open-hole bore construction



Slotted and Perforated Bore Casing

Another method of construction is to fully case the hole and use slots cut into the casing opposite the water-bearing zone(s) to allow water to enter the bore.

Slots made in the casing can be cut on-site using an oxyacetylene kit (for steel casing) or an electric drill or saw (for plastic casing). However, the preferred method is to use factory machine slotted, drilled, or perforated casing with a regular series of fine or small perforations.

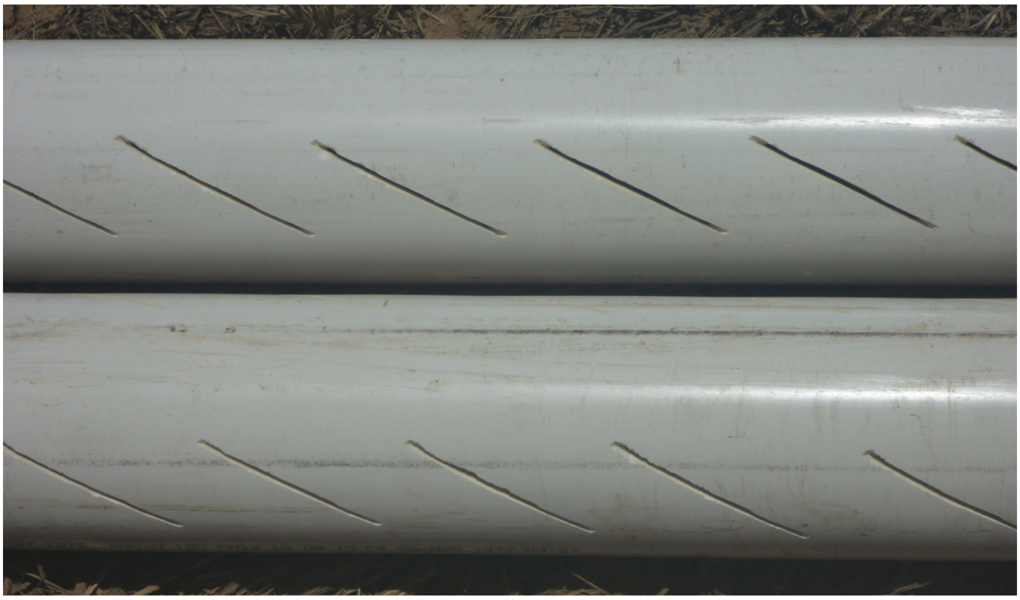
Slotted casing that corresponds to the thickness of the production zone is normally used. The use of numerous short, narrow slots located to maintain maximum compressive strength in the casing rather than a few large slots is preferable. Suitably placed perforations such as small-diameter round holes may also be used. Examples of slotting and perforations are pictured on page 59.

A major problem in using slotted casing is finding the optimum size and shape of slot that will permit adequate flow but continue to retain the water-bearing strata over time.

Slots alone may not be sufficient in relatively fine, loose formations. In these instances, placing a suitable graded well-rounded (not crushed) gravel pack in the annulus between the casing and hole wall will assist in retaining the strata while allowing the water to pass through. This technique is called gravel packing. If gravel packing is used, the bottom open end of the casing must be capped to prevent gravel from entering the casing.

STEEL: Perforated steel casing

PVC: Slotted PVC casing



The slots should be narrow enough to hold out the gravel.

Where gravel fill is to be placed in and above a slotted zone or screen, the annulus must be greater than four times the graded size of the gravel. That is, for 6 mm gravel the hole size must be at least 48 mm larger than the largest outside diameter on the casing used (24 mm larger on each side), usually found to be at the joint, to avoid bridging.

Screens

Many of the larger supplies of bore water are obtained from loose, unconsolidated formations such as sands or gravels, which must be supported if the bore is to remain open. Sands and gravels are not suited to open-hole bore construction. Where bore design requires greater open area than slotted casing, screens should be used.

Screens are normally manufactured from stainless steel but are also available in other materials in a number of designs.

Screens usually consist of wedge-shaped wires wound around a frame of axial rods of open cylindrical form. The gap or slot between adjacent turns of the winding is adjusted during manufacture to provide the desired aperture size.

The screen is placed into the borehole within a string of casing and adjacent to the water-bearing formation. It provides support for the formation material and retains an open framework of sand or gravel particles naturally occurring in the formation or deliberately placed around the screen. This arrangement provides for maximum water entry where screens are used.

A hole drilled only slightly larger than the casing and screen diameter is satisfactory if the water-bearing formation is a reasonable mix of sand, coarse sand, and gravels, with no silt or clay layers, and less than 10 per cent fine sand.

For this type of formation and construction it is usual to select a screen aperture size that will retain approximately 40–60 per cent of the sieved water-bearing formation. This allows the fines within the formation, which slow and restrict water entry, to be flushed through the screen into the bore and to be removed during subsequent development of the bore.

A zone of higher material permeability is created around the screen and this increases the yield of water from the bore.

Sometimes a screen is selected with a number of different aperture sizes to match finer or coarser layers in the water-bearing formation. Screens can be either:

- telescopic — where the screen slides inside the casing or
- in-line — where the casing and the screen are a continuous string.

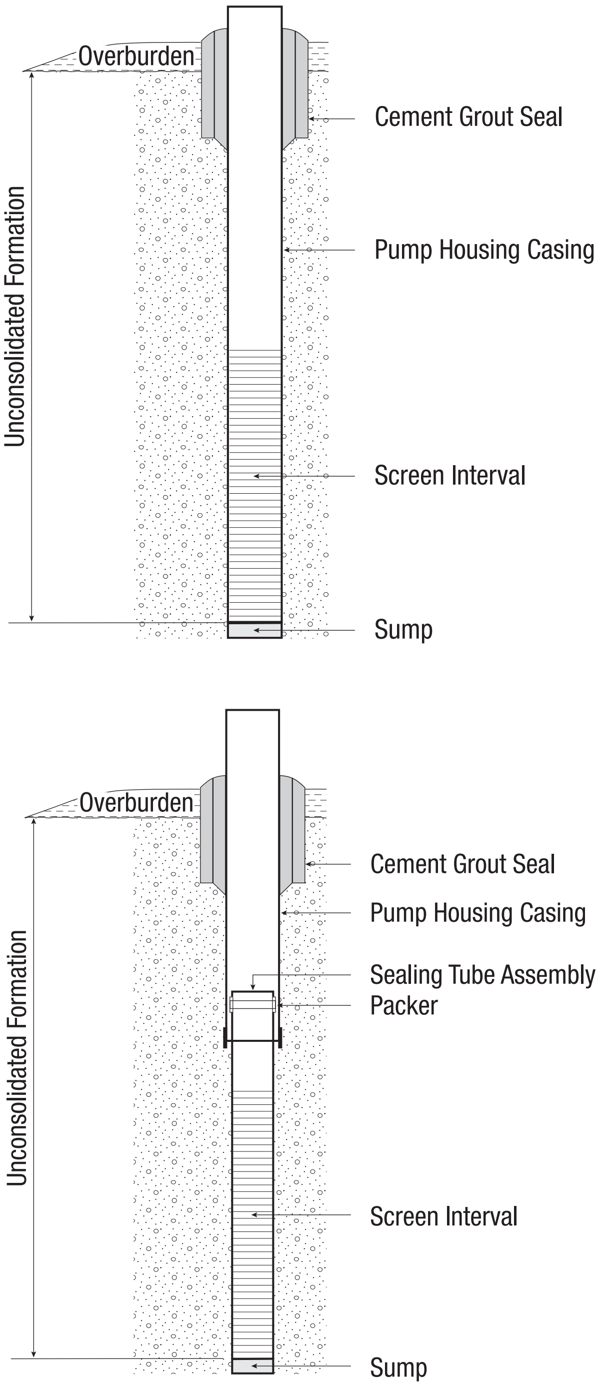
The screen diameter either permits a slide fit inside the selected casing for a telescopic setting or the same outside diameter as the bore casing, where the hole can be drilled first and then the casing and the screen run into the hole as a continuous string.

When using telescopic screens, care should be taken with all down-hole measurements as they are critical to the success of the bore.

Screens should always be sealed at the bottom.

The hole bottom should be accurately measured and be clean and proven to be stable enough to support the screen. The sealing tube on the telescoped screen should be designed to overlap into the casing by at least 1 metre. Overexposure of the screen seal tube can result in loss of the screen or loss of the bore.

Figure 10.2 Naturally developed bore with in-line screen (top) and telescopic screen (bottom)



If the water-bearing formation is thick enough, the screen length is calculated by checking the ability of the selected screen (diameter and aperture) to allow the desired water supply into the bore at a reasonable entrance velocity. The recommended design entrance velocity of water through the screen is 30 mm per second.

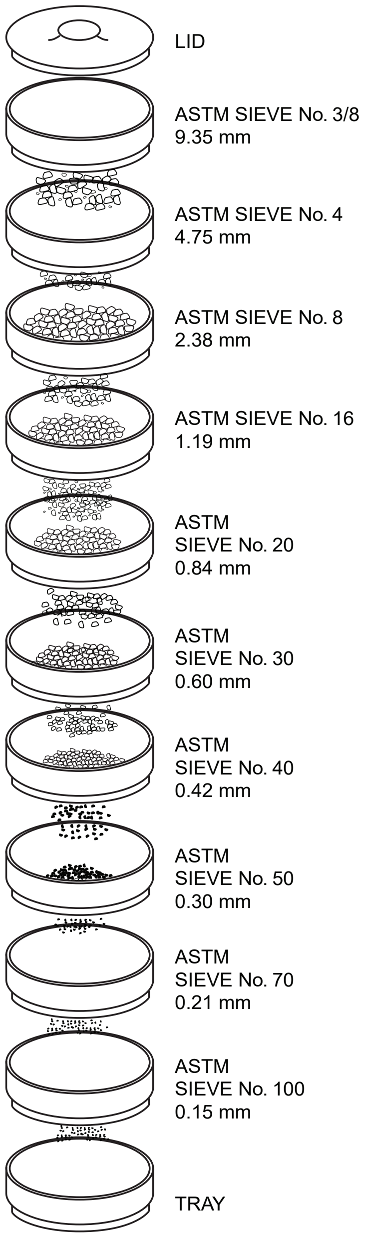
The screen is usually set in the most permeable section of the formation, and geophysical testing may be required to locate the most productive zones. Where a high level of accuracy is required geophysical logging should be considered. Salinity may also be a factor in determining where screens are set.

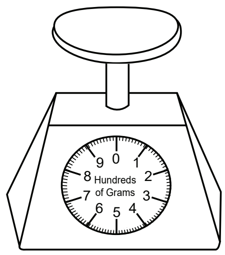
Sieve Analysis

Careful sampling of the water-bearing formation must be carried out during drilling in order to determine the appropriate construction procedure, screen aperture, or gravel pack size. It should be noted that any loss of fines to hole fluids can affect the accuracy of the sample test results.

The samples should be checked and, if necessary, dried and sieved through a nest of sieves so that an accurate analysis of grain size of the formation can be made. This involves the stacked set of brass or stainless steel sieves usually of 200 mm diameter (see Figure 10.3).

Figure 10.3 Stacked set of sieves used to provide a grain distribution curve





Scale showing hundreds of grams with 10 gram divisions up to 1 kg

SIEVE ANALYSIS REPORT

SAR0719

Client: Bill Brown

Bore No: 123456 Sample No: 1

Company Reference No: 413

Remarks:

EXAMPLE

Modal Size = Greatest Mass Retained
= 0.21mm on Sieve No. 70

Then 0.21 x 5 = 1.05mm Pack Material
Screen Aperture selected is 20% smaller
than pack material i.e. 1.05 x 0.8 = 0.84mm

METHOD OF BORE CONSTRUCTION:

- ☐ Natural Pack
- ☑ Gravel Pack

Recommended Screen Slot Size: 0.8mm

% Passing:

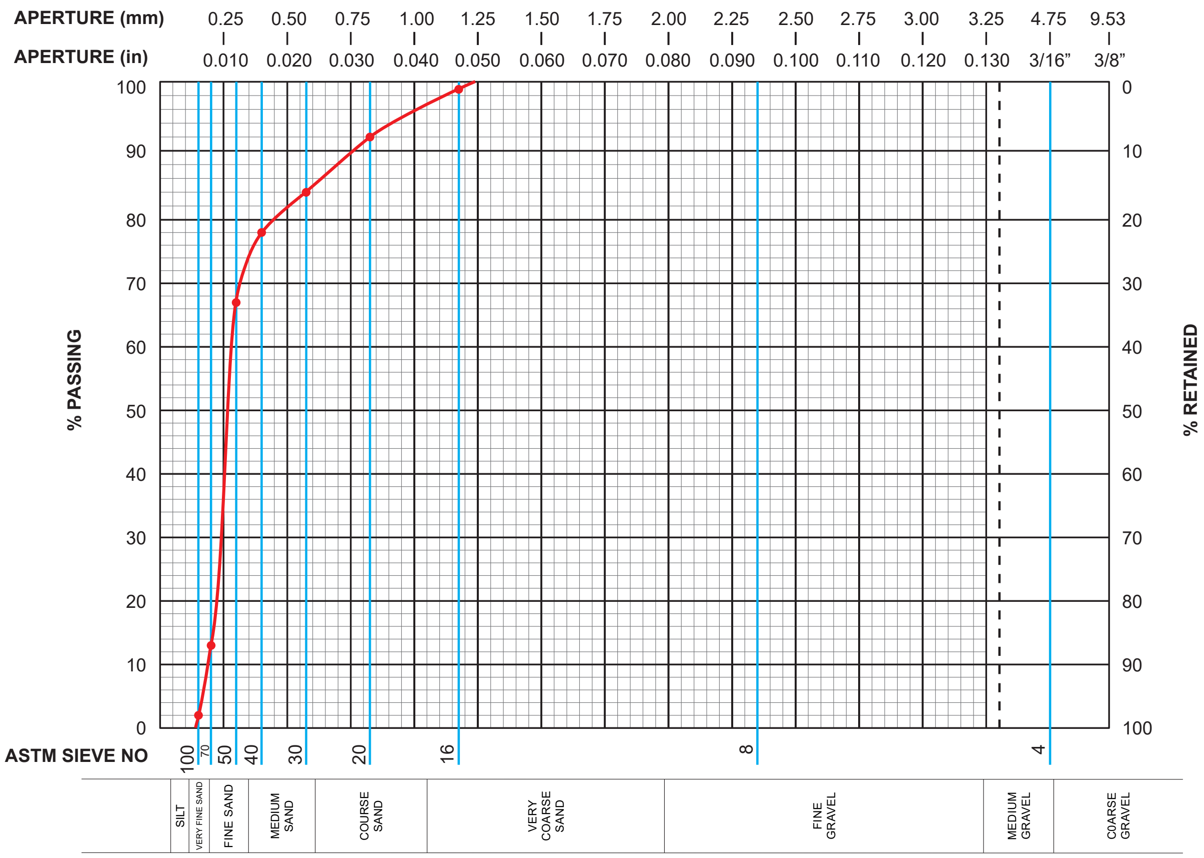
Gravel Pack Grain Size: 1mm

SIEVE ANALYSIS

Sample Mass: 448.7 g

ASTM SIEVE NO.	APERTURE		INDIVIDUAL	CUMULATIVE	
	mm	in	WT. RETAINED	WT. RETAINED	% RETAINED
3/8”	9.53	0.375	0	0	0
4	4.75	0.187	0	0	0
8	2.38	0.094	0	0	0
16	1.19	0.047	8.8	8.8	2
20	0.84	0.033	28.3	37.1	8
30	0.60	0.023	35.0	72.1	16
40	0.42	0.016	26.3	98.4	22
50	0.30	0.012	48.2	146.6	33
70	0.21	0.008	245.3	391.9	87
100	0.15	0.006	48.2	440.1	98
TRAY			8.6	448.7	100

GRAPH OF ANALYSIS



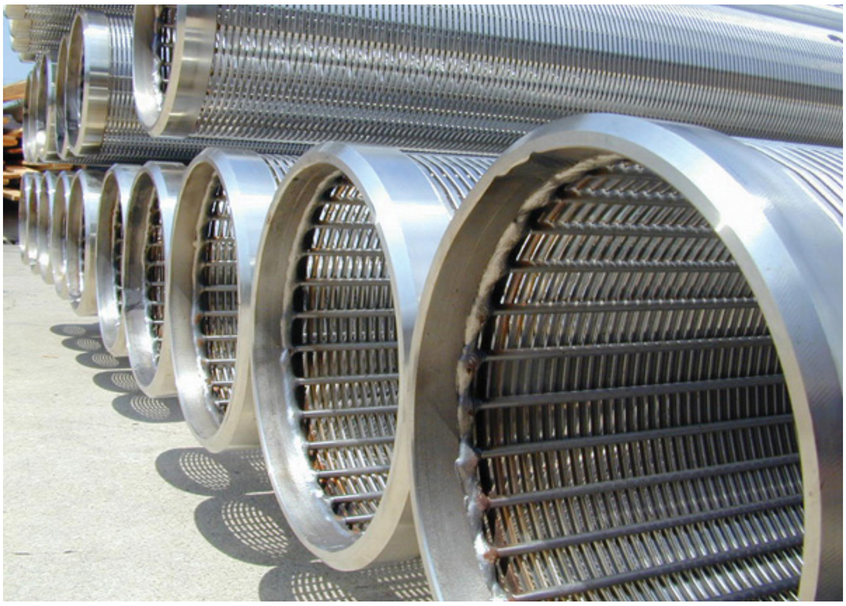
NAME: SIGNATURE: DATE:

Figure 10.4 Example of a sieve analysis report

The apertures in stacked sieve sets typically conform to the American Society for Testing and Materials (ASTM) international standards.

During the sieving process the stack is shaken and each sieve filters out a particular grain size. Each grain size can then be expressed as a percentage of the entire sample, with the finest material collecting in the bottom pan. A plot is then made of the percentage (by weight) of each sample to the whole to provide an indication of the physical make-up of the sample.

An example of a grain distribution plot is shown in Figure 10.4.



Stainless steel wire wrapped screen.

Photo courtesy of Aqseptence Group

Gravel Packing

A gravel pack is recommended where the water-bearing formation is so fine, silty, or layered that the aperture of a screen would be so fine that it would severely affect the flow of water into the bore, or where additional support for the aquifer zone and strata is needed.

The grain size and gradation of the filter are selected to stabilise the aquifer material and to permit only the fine fractions to move into the bore during development. After proper development, a correctly filtered bore should be sand-free, and near well permeability improved. *(See Chapter 12 for more details about bore development).*

The gravel pack should consist of washed, well-rounded gravel of selected grain size and gradation. It should be uniformly placed in the annular space between the screen and the wall of the borehole.

An alternative to manually installing a gravel pack is to use a pre-packed screen assembly. A pre-packed screen may allow for a smaller hole diameter, and provide certainty on the placement and composition of filter pack material.

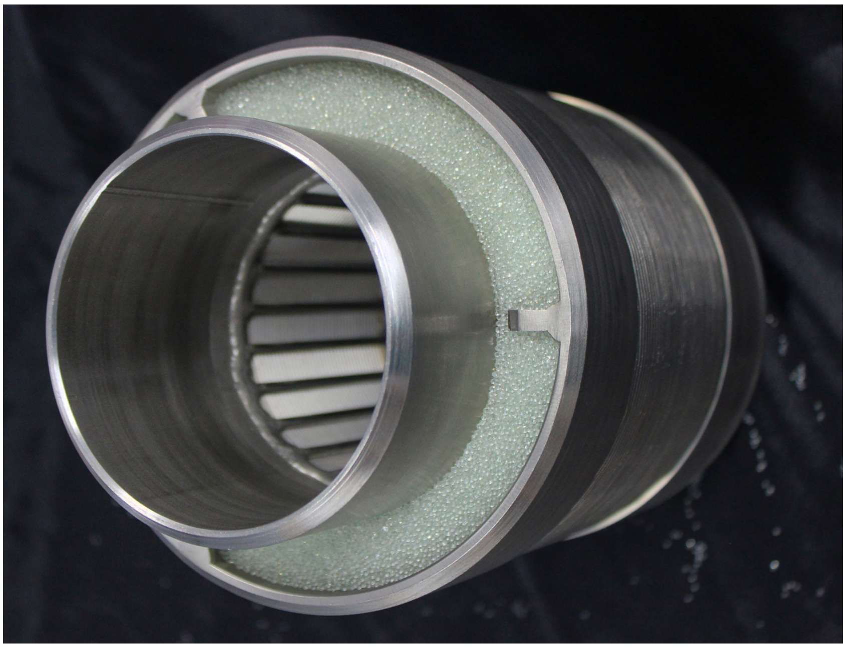
Based on the sieve analysis results, the gravel pack material should be five times the diameter of the modal size.

Ideally, the aperture of the screen selected should be 20 per cent smaller than the gravel pack size. If this is not possible because of the formation grain size, head loss may result from reduced entrance velocity (refer to 10.14).

The gravel pack has a considerably higher permeability than the formation, and this increases the efficiency and specific capacity of a bore.

Pre-packed screen assembly.

Photo courtesty of Aqseptence Group



Mandatory Requirements

10.1 The water entry intervals of bores shall only be constructed across one aquifer.

Good Industry Practice

General

10.2 Maximise bore efficiency by selecting the appropriate completion method. Factors to be considered include:

- the aperture and area of the screen or slotted or perforated casing
- the size of the gravel pack
- characteristics of the formation material
- consideration of the desired bore yield
- open hole bores should be cased to the depth of the required pump setting.

Slotted Casing

10.3 The casing should be slotted to minimise the loss of strength in the original casing material. This can be achieved by:

- numerous short narrow slots in a regular pattern rather than long, wide, randomly placed slots
- using short horizontal slots or small round perforations for unreinforced plastic-type casing.

NOTE: Care should be taken to ensure that vertical slots are not deformed by external pressure.

10.4 Slots should be positioned across the full circumference of the bore to suit the likely yield. The total open area of the slots should be at least twice the cross-sectional open area of the casing to limit water entrance velocity through the slots.

10.5 To reduce the risk of silting, slotted casing should not be placed against any non-aquifer material.

Screens

10.6 Screens should be designed to maintain their integrity during installation, development, and use.

10.7 Pre-packed screen assemblies should be designed to suit the bore characteristics and requirements.

Gravel Pack

10.8 The gravel pack should consist of washed, well-rounded gravel of selected grain size and gradation. Crushed stone or rock is not recommended. Furthermore:

- for maximum efficiency of the gravel pack, thin, flat, or elongated pieces should not be used
- no more than 5 per cent of the gravel should be soluble in hydrochloric acid
- the material should be washed and free of shale, mica, clay, dirt, loam, and organic impurities of any kind.

10.9 Gravel packs should be 30–80 mm annular thickness with 50 mm recommended for proper placement of the gravel pack material.

It is recommended that:

- the gravel pack material should be five times larger than the modal grain size of the formation material
- the pack shall be much more permeable than the formation material
- at the same time, it shall be fine enough to control the sand
- it shall support the formation without sand movement at the maximum pumping rate.

The gravel pack shall be developed after installation. (See Chapter 12 for more information about bore development.)

10.10 As gravel packs are generally used against uniformly graded fine sands, the grain size of the packing material should also be uniform. There should not be much material either smaller or larger than nominal gravel pack size (i.e. the size should be consistent).

The screen to be run in a gravel-packed bore shall have an aperture designed to retain 80–100 per cent of the pack material.

10.11 The gravel pack material should be placed in the annular space slightly below and adjacent to the bore screens and should extend above the screen to allow for settlement during development. The height of the gravel pack should be checked regularly to confirm correct placement.

A gravel pack top-up pipe may be incorporated into the annulus, and capped at the surface.

10.12 Centralisers should be used on the screen assembly and be constructed of inert material or the same material as the screen. They should be placed at the top and bottom of the screen and at no greater than 6-metre intervals for long lengths, to reasonably ensure the screened area is covered by a uniform thickness of gravel pack.

10.13 Gravel should be placed with care to ensure continuity of the gravel pack and to avoid bridging, voids, or segregation. It should be depth tagged to confirm placement is correct.

10.14 The table below presents examples of screen and filter pack sizes corresponding to formation modal size

Modal size (mm)	Filter pack size (mm)	Screen aperture (mm)
0.5	2.5	2
1	5	4
2	10	8
3	15	12

Downhole images of screens and gravel packs.

Photos courtesty of Age Developments Pty Ltd

11 Bore Sealing

Principle

Bores are sealed to:

- **protect the groundwater resource from contamination**
- **maintain aquifer pressures and groundwater quality**
- **isolate the targeted production zone from other formations.**

A range of methods and materials are used to seal bores. These include:

- cement grout — (cement powder, water, and additives)
- concrete — (cement and aggregate mix)
- bentonite — (chips and pellets).

The purpose of sealing is to:

- seal the annular space between the casing and the borehole, maintain aquifer pressures and prevent the transfer of water between zones
- seal off aquifers containing poor-quality water
- protect the integrity of the casing from corrosive soils and waters
- prevent surface water run-off or shallow subsoil contamination or pollution from reaching the aquifers
- prevent uncontrolled flow at the surface in artesian wells
- isolate the targeted production zone from other formations.

Some water authorities have maps that delineate known areas of strata and water that are corrosive to steel casing. In these areas the authority may request as a construction requirement or bore permit condition the use of plastic type casing or the grouting of steel casing.

In areas of high sulphate groundwater consideration should be given to using sulphate resistant cement.

Supervision of Cementing

State and territory regulatory authorities may require notification for on-site monitoring or supervision of all cementing operations by an authorised officer. This requirement may be stated in the bore permit.

Effective Sealing

To be effective, a seal must provide a continuous dense lining that completely surrounds the casing. To achieve this:

- The hole must have been drilled large enough to provide adequate clearance between the borehole wall and casing.
- The hole should be conditioned before cementing to ensure:
  - free circulation
  - low circulation pressures
  - full return of circulation
  - hole formation stability.

- The casing should be centred in the hole by means of mechanical centralisers. In corrosive water areas, centralisers should be of inert material, or material of a similar grade to the casing to which they are attached.
- For pressure cementing, unrestricted circulation down the casing and up the annulus must be obtained.
- The hole and casing volume must be calculated, and allowance should be made for washouts and formation losses.
- In cases where there is a risk of lost circulation during grouting, consideration should be given to adding lost circulation aids (eg fibreglass) to the grout mix.
- Direct contact between the cement grout and drill fluid should be avoided. Common drilling practice is to pump a volume of clean water ahead of the grout to provide a spacer between the cement grout and the drilling fluid, or to use a neat-fitting, drillable bottom plug.
- The specific gravity of the cements and drill fluids should be as close as possible to minimise channeling.
- Grout should be pumped into place as quickly as possible.

For all bores where the grout is to be placed under the fluid level, positive placement of grout by a tremie pipe or pressure cementing is to be used. Positive placement of grout from the bottom of the hole upward will usually ensure a complete seal of the annulus space behind the casing.

Potable or good quality water should be used wherever possible. Water should not contain any visible traces of oils, fats, detergents, suspended plant materials, or odour. Poor quality water should be avoided because it may result in grout or sealing failure.

High levels of chlorine in the mix water can retard the setting of the grout. Adding soda ash or lime to the mix water can raise a low pH to the desired level.

Adding acid to the mix water can lower a high pH to the desired level.

Grout should be allowed at least 24 hours curing time before any further downhole drilling activities are carried out.

Some accelerating or retarding admixtures, such as calcium chloride, can cause corrosion of steel and should not be added to the grout. In most cases the use of chlorides is not permitted. Advice should be sought before using accelerators, retarders, or other admixtures.

Recommended cement–water and cement–bentonite–water mixes are listed in Tables 11.1 and 11.2. Portland cement is commonly marked as G.P. or General Purpose cement. Blended cement is marked as G.B. or Builders cement.

Table 11.1a Recommended cement–water mixes

Basic mix using Portland (GP) cement

Number of 20 kg bags of cement	Litres of mixing water (i)	Litres of grout	Specific Gravity (SG)
1	15	21.30	1.64
1	12.5	18.83	1.72 (ii)
1	10	16.33	1.83 (ii)

NOTES

i. Cement will settle out of the grout if a mix ratio greater than 17.5 litres of water per 20 kg of cement is used in a basic mix of cement and water only (i.e. without other additives).

ii. Plasticiser cement additive can be used to improve and extend the workability of the mix and reduce friction while pumping high SG grouts.

Table 11.1b Recommended cement–water mixes

Basic mix using Builders cement (25% Fly Ash)

Number of 20 kg bags of cement	Litres of mixing water	Litres of grout	Specific Gravity (SG)
1	15	21.84	1.60
1	13.75	20.59	1.64
1	12.5	19.34	1.68

Table 11.2a Recommended cement–bentonite–water mixes using Portland (GP) cement

Cement 20 kg bags	Bentonite in mix (i) (%)	Mass of bentonite (kg)	Volume of water (litres) (ii)	Yield (litres)	Specific Gravity (SG)	Firmness
1	1	0.2	17.5	23.90	1.57	Hard
1	2	0.4	20	26.49	1.52	
1	2.5	0.5	21.25	27.78	1.50	
1	3	0.6	22.5	29.07	1.48	V Firm
1	4	0.8	25	31.65	1.45	
1	5	1.0	27.5	34.23	1.42	

NOTES

Mixing instructions — mix bentonite into water first, and then add cement.

Bentonite mixes should have 50 seconds minimum viscosity. Add more bentonite to increase viscosity.

i. A 10% or greater bentonite mix is not recommended for normal cementing operations. The percentage recommended is based on bentonite not being hydrated before mixing with cement.

ii. Bentonite volumes are only a guide — mixes can be affected by water quality.

iii. Bentonite used in the mixes should API grade.

Table 11.2b Recommended cement–bentonite–water mixes using Builders cement (25% Fly Ash)

Cement 20 kg bags	Bentonite in mix (i) (%)	Mass of bentonite (kg)	Volume of water (litres) (ii)	Yield (litres)	Specific Gravity (SG)	Firmness
1	1	0.2	17.5	24.34	1.55	Hard
1	2	0.4	20	26.84	1.51	
1	2.5	0.5	21.25	28.09	1.49	
1	3	0.6	22.5	29.34	1.47	V Firm
1	4	0.8	25	31.84	1.44	
1	5	1.0	27.5	34.34	1.41	

NOTES

Mixing instructions — mix bentonite into water first, and then add cement.

Add more bentonite to increase viscosity.

i. A 10% or greater bentonite mix is not recommended for normal cementing operations. The percentage recommended is based on bentonite not being hydrated before mixing with cement.

ii. Bentonite mixes can be affected by the quality of water used.

Cementing tank

Decreasing the Specific Gravity

Bentonite

Bentonite is a naturally occurring clay material that is added to a cement mix to decrease its specific gravity. Bentonite has the ability to absorb many times its own weight of water and to swell to many times its original volume.

As an admixture to cement, common bentonite allows the use of much more mixing water in the slurry before water separation occurs. It provides a lower specific gravity, an increase in slurry yield per bag of cement, a smooth grout, and reduced shrinkage in the cement as it sets in the bore.

Bentonite also gives the grout better sealing properties in porous formations, but it also decreases the strength. However, this should not greatly affect the final result when it is used only as a seal.

Bentonite used in the above tables is based on API grade bentonite. High yield bentonite containing polymer is not API grade and can adversely affect a cement grout mix.

Hollow spheres

Hollow spheres (eg E-spheres) are manufactured, free-flowing, hollow ceramic or glass spheres that are used as an additive in cementing to reduce the grout density. They look like uniform fine sands.

Recommended light cement mixes incorporating bentonite and hollow spheres to decrease the specific gravity are shown in Table 11.3.

Reducing Setting Time

Accelerators are used to reduce the time taken for the cement grout to set. These admixtures should be used at the dosage rates recommended by the supplier. (These rates should not be exceeded as excess quantities can sometimes have a retarding effect).

Table 11.3 Recommended light cement mixes using hollow spheres

Cement 20 kg bags	Water (litres)	Hollow spheres (kg)	Bentonite (kg) [(i)]	Yield (litres)	Specific Gravity (SG)
1	21.15	6.5	0.55	37.0	1.30
1	21.15	4.5	0.55	34.1	1.35

NOTES

Mixing instructions — mix bentonite into water first, then add hollow spheres, then add cement. More or less bentonite may be required, as the mix must be viscous enough to keep cement and cells in suspension — minimum recommended viscosity is 50 seconds.

i. The quantity of bentonite recommended in the table is based on bentonite not being hydrated before mixing with cement.

Calcium chloride is one such accelerator. It is corrosive to steel and should not be used as an accelerator when steel bore casing is used. Most cement additive supply companies have chloride-free admixtures for accelerating the setting time of cement.

Increasing Setting Time

When cementing deep bores with higher pressures and temperatures there is always a danger that the grout will take an initial set (gelling) before being pumped into its final position. Chemical admixtures can be used to retard or increase the setting time of the grout to allow placement over a longer time or to retard setting in higher temperature formations.

Great Artesian Basin

Bores constructed in the Great Artesian Basin must be constructed in accordance with the requirements of the local state and territory licensing authorities, which may be more stringent in some requirements than these Minimum Construction Requirements. Unless authorised by a bore permit, the supply from artesian bores shall be drawn from one primary formation only.

All aquifers and permeable zones, other than the intended production zone, must be grouted off to prevent interconnection.

The outer surface or control casing shall be placed to a minimum depth to allow control of the bore during drilling, seated 10 metres into competent impermeable strata, and cemented from the shoe to the surface. The inner production casing shall be cemented as stated in the bore permit so that the supply of water can be drawn from one primary formation only. All other aquifers and permeable zones shall be cemented off.

In some states or territories the minimum depth of any intercasing cementing requirements will be specified on the bore permit, as may the requirement for on-site monitoring and/or supervision of cementing operations.

Injection Bores

Injection bores, whether single or multiple aquifer, must be fully grouted from the top of the production zone back to the surface in accordance with the principles outlined in this chapter.

Mandatory Requirements

11.1 All bores shall be sealed to protect the production zone against contamination. This also includes the annular space between the casings and the borehole. Sealing, including any required top-up cement, shall be completed before the drilling rig leaves a work site.

In multiple aquifer bores there shall also be a seal between the aquifers and permeable zones to prevent intermixing, flow, and contamination.

11.2 All bores shall:

- be sealed from the surface to not less than 5 metres deep. In cases where the 'production zone' is less than 5 metres below ground level, the sealing shall be from 1 metre above the production zone to the surface
- have a minimum thickness of 20 mm grout seal around the outside of the surface casing
- have a minimum thickness of 15 mm of grout seal around the outside of the production casing.

11.3 When sealing the surface control casing in artesian bores, the casing shall be:

- seated at least 10 metres into competent impermeable strata, and grouted from the shoe to the surface
- sealed with cement grout having a minimum annular thickness of 20 mm above the maximum diameter of the casing (e.g. a coupling or shoe). This can be obtained using centralisers.
- Unrestricted circulation shall be obtained down the casing and up the annulus prior to pressure grouting

11.4 The production casing shall be:

- grouted so that the supply of water can be drawn from one water-bearing formation only
- for non-flowing multiple aquifer bores: grouted from the top of the production zone for a minimum of 10 metres, to seal off any aquifers above the production zone
- for flowing bores: grouted from no more than 30 metres above the production zone to the surface, and sealed with grout of minimum thickness of 15mm around the outside diameter of the casing.
- Unrestricted circulation shall be obtained down the casing and up the annulus prior to pressure grouting.

11.5 Bores drilled to provide access to aquifers for the injection of water shall be sealed with cement grout from the top of the production zone to the surface.

11.6 Multi-port monitoring bores intersecting more than one aquifer shall be cased and sealed with cement grout from the top of the lowest aquifer system back to the surface.

11.7 The sealing material shall be one of the following:

- cement grout
- cement/bentonite grout
- bentonite pellets/chips (below water level only)
- concrete.

Cement used for grouting shall conform to Australian Standard AS 3972 for Portland and Blended Cement. Bentonite used shall conform to API grade bentonite.

11.8 When placing the sealing material below the fluid level in the hole, the seal shall be placed from the bottom upward by methods to avoid segregation or dilution of material.

11.9 Bentonite pellets/chips shall not be used above the fluid level as part of the mandatory annular seal.

11.10 Minimum values of specific gravity for cement grout are:

- 1.6 for cement grout mix
- 1.39 for cement/bentonite grout mix
- 1.3 for cement/bentonite/hollow spheres grout mix.

11.11 When cementing:

- surface casings of artesian bores
- all production casings

a minimum of 24 hours' curing time shall elapse after placing the cement grout before commencing any downhole drilling activity.

11.12 Water for:

- cementing shall have a pH between 6 and 8
- cement/bentonite mix shall be conditioned to have a pH between 7 and 9
- grouting of steel casing shall be less than 3000 EC
- grouting of inert casing shall be less than 15000 EC.

11.13 Additives that are corrosive to the casing material shall not be included in grout sealing mixtures.

11.14 Some states and territories (e.g. New South Wales, Northern Territory, Queensland, and South Australia) have specific requirements regarding the bores constructed in the Great Artesian Basin. These requirements shall be complied with, where applicable.

Good Industry Practice

11.15 Material Safety Data Sheets (MSDS) and manufacturer's recommendations should be available on the drill site for all drilling products used. These should list instructions for handling, recipes, use, potential hazards, and any disposal requirements for the product or container.

11.16 All aquifers and permeable zones, other than the intended production zone, should be adequately cemented off to prevent interconnection or wastage between zones of differing pressure or water quality. Cementing should be from bottom upwards in a continuous process.

11.17 The salinity of the mix water can affect the strength and set time of grout mixes and may be corrosive to non-inert casing. Higher salinity decreases the strength and increase setting times.

11.18 Recommended cement - water and cement - bentonite - water mixes are listed in tables 11.1, 11.2 and 11.3.

11.19 Centralisers should be used to ensure a uniform and sufficient cement seal thickness. Centralisers are recommended to be spaced no more than 12 m apart.

Centralisers and casing connections should have sufficient strength to withstand construction and grouting. It is recommended centralisers should have a contact area with the hole wall of no less than 10 cm^2.

11.20 All cement mixes should be checked to ensure that they meet on-site specifications and are free from foreign material (eg sand, aggregate).

Cementing the bore

12 Bore Development

Principle

Bores are developed to:

- **remove introduced products**
- **improve near well permeability**
- **reduce entry losses**
- **reduce entry of suspended solids**
- **increase well efficiency.**

Bore development is performed to bring a bore to its maximum production capacity by optimising the bore efficiency, specific capacity, stabilisation of aquifer material, and control of suspended solids.

The development usually involves the use of various chemical and/or mechanical agitation methods, the selection of which will depend on the type of equipment available, the construction of the bore, and the aquifer type.

A number of techniques are used to remove fines and stabilise aquifer material. These include:

- air lifting and jetting
- surging
- pumping
- bailing
- adding dispersants and detergents.

Figure 12.1a Improving bore permeability through development

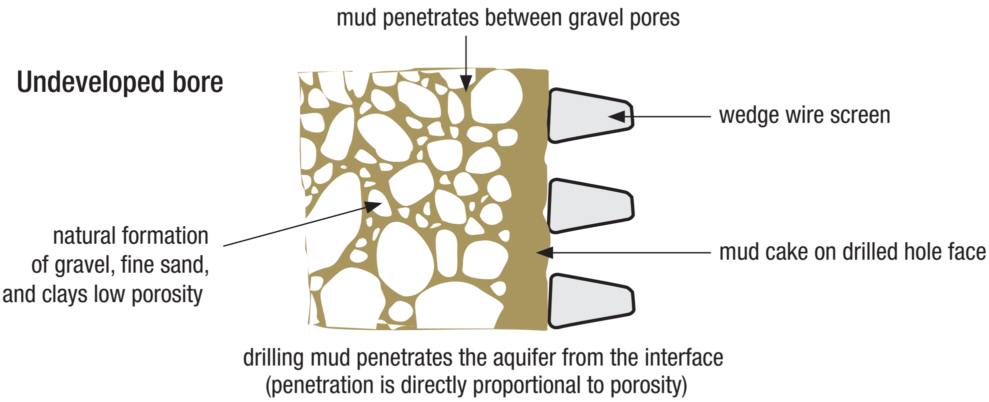
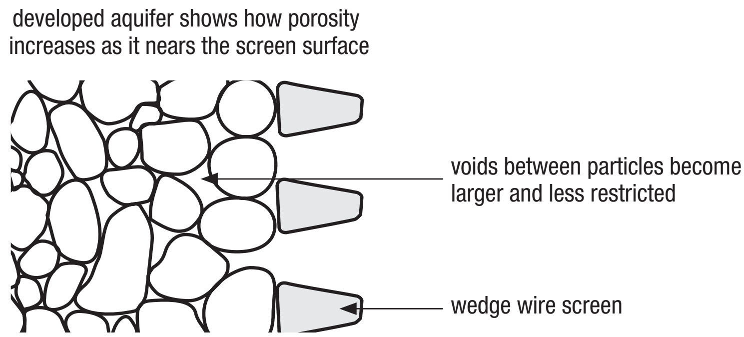


Figure 12.1b Improving bore permeability through development



Use of Chemicals

Chemical methods include the use of dispersants and detergents to wet, break down, and allow clayey materials and fines to be removed from the formation. Final development is usually by mechanical means.

Use of Mechanical Methods

Whatever mechanical method is used, the aim is to remove from the annulus, between the screen and hole wall, clays or compacted material resulting from the drilling operations, as well as the fine material from the water-bearing formation itself.

This results in a rearrangement of the remaining water-bearing formation. The bore development process is illustrated in Figure 12.2.

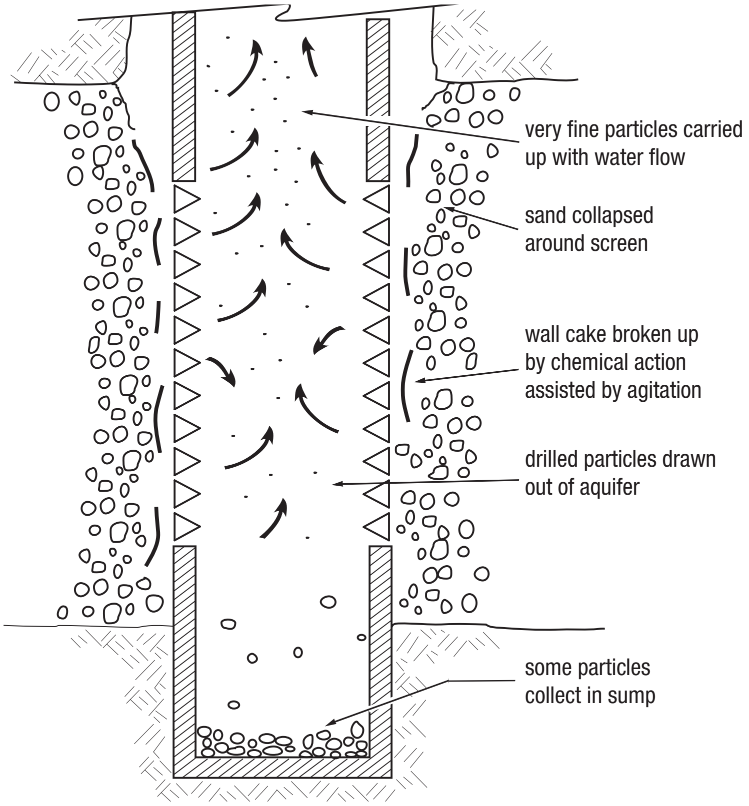


Figure 12.2 The bore development process

During development the fines drawn through the screen are periodically removed from the screen assembly. A small increase in permeability in the vicinity of the screen can result in considerably less drawdown in the bore for the same pumping rate.

The development process should involve techniques that progress from gentle to vigorous agitation.

Rapid de-watering of the bore should be avoided in the early stages of development as it may collapse the screen or casing or, in the case of a telescopic screen, relocate the screen to a higher and undesirable location inside the casing.

As well as increasing the production capacity of a bore, development also stabilises the formation that acts as a filter to prevent the pumping of sand that would otherwise result in serious damage to pumps and fittings.

Sand Content

In most formations the application of appropriate development techniques will result in a virtually sand-free or silt-free bore. Where the aquifer material is very fine, a compromise may have to be reached to achieve an acceptable flow rate and a relatively sand-free supply.

Good Industry Practice

12.1 The bore development process should employ techniques that progress from gentle to vigorous agitation.

12.2 The development technique should complement the screen design to maximise efficiency.

12.3 Rapid de-watering of the bore should be avoided in the early stages of development as it may collapse the screen or casing, or move a telescopic screen.

12.4 Too harsh a technique in the early stages of development can result in reduced yield, or erosion of the screen or slots.

12.5 During bore development, records should be kept of all observations. (See Chapter 15 for more information about recording and reporting data).

12.6 The development of a water bore should not be concluded before a continuous clean, silt-free and sand-free supply of water is obtainable at the full flow capability of the bore.

A sand-free supply can be regarded as having a sand content of no more than 5g/1000 litres.

After development, the bore shall be left clean and free of any other obstructions for the full depth.

12.7 A pump can be used for final development of the bore. (See Chapter 13 for more information about bore yield testing).

12.8 Development can be considered satisfactory when the following have been achieved.

- The bore produces no sand or silt for 1 hour.
- The bore is completely clean of particles from the top to the base, and the water is relatively clear and free of fines.
- There is no further increase in specific capacity of the bore with continued development.

Bore yield testing

Mobile pump test
unit (small flow)

13 Bore Yield Testing

Principle

All water supply bores should be tested to establish their indicative yield.

At the completion of bore construction the bore should be tested to provide the client with an indicative yield. During the test procedures it is important that accurate, regular water quantity and quality data is collected. This information is required to enable the client to decide whether to equip the bore and, if so, it will aid in pump selection.

Two types of yield tests are commonly performed:

- tests done by drillers at the completion of bore construction
- formal pumping tests.

Testing by drillers is usually conducted using the drilling equipment available. Measurements involve removing a known volume of water over a known period of time.

A value of yield derived from this type of test is, at best, an estimate. To gain a better understanding of safe yield or long-term supply a proper pumping test should be carried out. Results from a properly conducted pumping test can vary by as much as 50% from the original driller estimations.

Pumping tests involve more complex equipment and the measurement of flows, water quality, water level drawdown, and recovery over time.

Various types and durations of pumping tests are listed in Table 13.1.

Table 13.1 Type and duration of pumping test

Purpose of bore	Type of test	Duration of pumping (hours)	Duration of recovery (hours)
Low usage facility (e.g. general stock watering or household)	Constant discharge or variable discharge	4 - 6 [i]	2
Medium or high usage (capital intensive support, e.g. intense stock watering, mining, irrigation, industrial, municipal supply)	Step and constant discharge	24 - 100 [i,ii,iii]	8
Aquifer investigation	Constant discharge (other tests may be appropriate)	Depends on nature of investigation	Depends on nature of investigation

NOTES

i. Recovery duration is until a trend is definitely established, or to at least 80% of full recovery.

ii. The reliability of the prediction of well performance will increase with the duration of the test.

iii. A test duration nearer the upper limit is recommended if the consequences of failure to perform as predicted are severe.

Specifically, pumping tests:

- assess the hydraulic behaviour of a bore to determine its usefulness as a source of water
- predict performance under different pumping regimes, and enable determination of the most suitable pump and optimum intake depth
- determine the hydraulic properties of the groundwater system penetrated by the bore. This includes transmissivity, storativity, and the presence, type, and distance of any hydraulic boundaries.

Bore owners are encouraged to allocate sufficient funds for a comprehensive pumping test that can be used as a reliable basis for predicting future performance. It is also essential for pump selection in high-yielding bores.

No more information about pumping tests will be presented in this book as more detailed information is readily available from other hydrogeological references and texts.

Bore Testing by Drillers

On completion of any production bore, the driller should carry out adequate testing to provide the client with a reasonable indication of the capacity of the bore. This test will also demonstrate to the client if the bore has been constructed properly and is therefore capable of producing clean water. (See Chapter 12 for more information about bore development).

Air testing

This method is generally used in conjunction with rotary or air drilling and can be performed during drilling on a partly completed open hole. However, the final test must be on the completed, cased, slotted, or screened production bore.

The results of most air tests give an indication only of the available supply. Many physical aspects of the method can vary the results. These variables include:

- hole and drill pipe or airline annulus size
- air volume and pressure available
- depth of drill pipe or airline submergence.

Air lift pumping without sufficient submergence may not be efficient, therefore air testing may not always produce the full supply available in the bore. Test results to be recorded include:

- standing water level before testing
- depth of bottom of drill pipe or airline
- air pressure to lift water
- air pressure during pumping after initial lift
- duration of test
- discharge rate measured as accurately as possible at regular intervals throughout the test, particularly at the end
- water sample collected when water becomes clean and clear (the minimum volume required is one litre)
- final depth within the bore after air testing.

The water discharged should be confined in an earth drain or similar, and measured over a weir board of suitable dimensions to determine the discharge rate. If the flow can be diverted through a pipe or fluming, a measuring tank or bucket and stopwatch can be used.

Weir board

Bail testing

Bail testing is more commonly used with cable tool drilling. It involves lowering a 'bailer' of a known volume into the water, allowing it to fill, then withdrawing and emptying it at the surface. The procedure is repeated for the duration of the test. The resultant pump rate is then calculated by multiplying the number of bailers removed in one hour by the volume of the bailer. By dividing the bail rate by the metres of drawdown the yield of the bore can be calculated.

Test results to be recorded include:

- standing water level before testing
- bail rate
- water level during bailing
- final drawdown
- test duration
- final depth after bailing.

A bailer of known volume with no valve leaks should be used for bailer testing.

The duration of the test may vary, depending on the type of bore, bore depth, available supply, and intended use, but should be long enough to prove that the bore is producing clear, clean, silt-free water.

The water level should be monitored after any testing to ensure the level in the bore is recovering and the aquifer has not been de-watered.

Test pumping an irrigation bore

Good Industry Practice

13.1 On completion of any production bore, testing should be carried out to provide the client with a reasonable indication of the capacity of the bore.

13.2 Testing should continue until either 60 minutes have elapsed or the field water quality measurements have stabilised.

13.3 Regular flow readings should be made using a measuring device and recorded in L/sec.

13.4 Field measurements should be taken to determine EC and pH.

13.5 Water samples for laboratory analysis should be collected at regular intervals during the testing process.

14 Disinfecting Water Bores

Principle

Drilling equipment that has been used should be disinfected to prevent the transfer of microbiological organisms (bacteria) between sites.

After completing drilling, the bore should be free of any introduced microbiological organisms.

Generally, aquifers contain very limited numbers of microbiological organisms. However, various bacterial sources can be introduced into a bore through the normal use of drilling fluids placed into the bore. In most instances these are naturally occurring bacteria, such as iron bacteria. When introduced in a bore these bacteria can flourish and cause clogging of the screens and water delivery equipment.

The best drilling approach is to limit the introduction of any foreign material to the bore or aquifer, thus minimising exposure of the completed bore to any other contamination pathway for organic organisms. This can be achieved by disinfecting the drilling rig and equipment before drilling the bore.

Disinfecting the bore after construction is good practice, and should be carried out with the aim of inactivating organisms such as bacteria.

Drillers and landholders should make enquiries to determine whether an area in which they propose to work has, or is suspected to have, an iron bacteria problem.

If an area is discovered to have an iron bacteria problem, bore and drilling equipment disinfection is an important part of the overall management strategy to stop the transfer of bacteria between regions.

However, disinfection cannot be regarded as the complete solution to treat bores that have become fouled with iron bacteria. Disinfectants such as chlorine can be effective only after the film that shields the bacteria has been broken down.

Specific treatments of bores fouled by iron bacteria are best tailored to the groundwater chemistry, hydrogeology, and pumping regimes.

In areas of known iron bacterial infestation, specific instructions regarding bore and equipment disinfection exist. In these instances the disinfection is focused on minimising the introduction of nutrient sources into bores and on the spread of bacteria from bore to bore.

A number of chemicals in the marketplace have been produced specifically for bore disinfection.

The major benefits claimed for these chemicals over chlorine are that they are:

- non-corrosive
- safe to handle
- environmentally friendly

Manufacturers can help drillers by providing technical information about their bore disinfection products.

Good Industry Practice

14.1 The driller should ensure that drilling tools are cleaned and disinfected before working on a new site.

14.2 In an area where iron bacteria is known or suspected to exist, equipment should be chlorine washed or steam cleaned after being used.

14.3 All water supply bores should be disinfected.

14.4 Reference should be made to the relevant local authority regarding the use of industry-approved chemicals before commencing any treatment of bores.

14.5 Care should be taken with any waste disposal of disinfection agents from the bore after completing drilling.

14.6 The driller should ensure that after completing drilling a bore is left so that it is not harmful to users, pumps, or the bore itself from chemicals used to disinfect the bore.

15 Recording and Reporting Data

Principle

Accurate information on the drilling, construction, reconditioning, and decommissioning is recorded to be available for the use of drillers, landholders, and regulators.

In a continent as dry as Australia it is vital that water resources are used effectively and sustainably. By the nature of their location, groundwater resources are costly to explore and develop.

It is most important therefore that when bores are drilled an accurate and complete record is made of the drilling, construction, reconditioning, and decommissioning processes. These records must be submitted to the relevant state or territory water authority to be added to other data to aid in the development of knowledge about:

- the nature and extent of the groundwater resource
- potential impacts from regional and localised pumping
- the impact of future developments and land use change on regional and localised drawdowns
- the development of groundwater management plans and future groundwater allocations and restrictions
- assisting future drilling operations.

The driller should keep a record of drilling observations in a field book while drilling progresses. These observations should include:

- the accurate location of the bore site
- start and finish dates
- the bore identification number (i.e. a unique identification of the bore site by number or name)
- drill string inventory
- bit types and sizes
- strata details
- details of the aquifer, yield, and water quality
- casing lengths, sizes, and types
- the penetration log
- the drilling method over any particular zone
- the decommissioning method used
- cement grouting details
- hole behaviour
- observed drilling fluid changes and depth.

Where accurate and comprehensive records are provided, this information is of value to the client, landholders, other stakeholders, and state or territory water authorities responsible for the development and management of the resource.

Most state and territory water authorities have a bore completion report (or drill log or specific form) they can supply to drillers to detail the information required.

As the information required to be submitted may vary between authorities, drillers should ensure they satisfy the requirements of the particular state or territory in which they are working (Bore completion report templates are usually available from relevant departments).

There are some states that now have on-line bore completion forms available for drillers to use. The relevant on-line reporting web sites are listed in Appendix B.

Mandatory Requirements

15.1 A bore completion report shall be supplied as required by the state or territory water licensing authority. (See Chapters 17 and 18 for more information about bore completion).

Good Industry Practice

15.2 During the drilling and construction of a bore the driller should keep accurate records. These details should include:

- the bore identification or licence number
- start and finish dates
- the name and address of the client
- the name of the driller
- the type of drilling method used
- the diameters and depth of hole drilled
- complete strata details
- details of any water supplies cut
- casing type and diameter (OD), class of pipe and/or wall thickness, position within the hole, and how it is secured and sealed
- cement grouting details
- water entry to the bore, for example, length of slotted sections and locations, screen type, dimensions and location, gravel pack material and size
- bore development procedure and record
- GPS coordinates including datum and/or location sketch of the bore site showing a north point, distances from two adjacent property boundaries or other topographical features, and the real property description
- bore disinfection procedures used.

An example of a bore completion report is included in Figure 15.1.

Guidelines for soil and rock classifications and descriptions are in Tables 15.1 and 15.2.

15.3 A detailed report, including a diagram of the bore, should be prepared by the driller on the decommissioning of any bore or test hole.

15.4 The driller should provide details of the bore construction report and any other relevant information to the client and should also retain a copy. Other relevant information could include:

- results of any pump tests
- a description of the water quality
- any geophysical logs/parameters that were run.

Water bore drilling log

EXAMPLE

Queensland Government

Authorisation details

Registered number .... Development permit number .... Works reference number ....

SECTION A—LOCATION DETAILS

Name of landholder **Joe Bloggs** Phone No. **(07) 4034 92122**

Postal address **PO Box 19 Atherton** Postcode **4883**

Real property address **1859 Hastie Road, Atherton** Postcode **4883**

Real property description Lot **123** Plan **RP4567** or Bore location GPS. Latitude **-17.28405** Longitude **145.49389** Datum **GDA'94**

Easting **338808** Northing **8088770** Zone **55**

SECTION B—BORE COMPLETION DETAILS

Date commenced 23/06/2019

Date completed 25/06/2019

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other ....

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
250	0	12
240	12	36

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	140	7.65	0	36

SECTION F—CENTRALISERS

Type	Location (metres) From	To
Kwik-zip	0	36

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
Slots	140	1.5	27	33

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement grout	250	140	0	12
Drill Cuttings	240	140	12	25
Bentonite seal	200	140	25	26
Gravel pack 2mm	200	140	26	36

SECTION I—BORE PURPOSE

☐ Domestic ☒ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial Other (please specify) ....

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	2	Top Soil, Red	
2	10	Basalt, Decomposed	
10	16	Basalt, Fresh, Hard	
16	21	Clay, Stiff, Red	
21	27	Basalt, Hard	
27	29	Basalt, Honeycomb	*
29	31	Basalt, Hard	
31	33	Basalt, Fractured	*
33	35	Clay, Grey	
35	36	Granite, Hard	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
27	16	1/2	Potable
31	16	2 1/2	Potable

Conductivity (μS/cm) 111 pH 7.1

SECTION L—SUB ARTESIAN BORE ON COMPLETION

Depth to standing water level from ground level 16 (metres)

Depth to pump suction or bottom of drill stem 28 (metres)

Type of test used ✓ Air ☐ Bail ☐ Pump

Estimated supply 3 (litres/second) Duration of test 3 (hours) Drawdown level from surface 28 (metres)

SECTION M—ARTESIAN BORE ON COMPLETION

Shut-in pressure (kPa) Free flow (litres/second) Temperature (°C)

SECTION N—REMARKS

Surface casing installed to 12m while drilling.
Pull surface casing before cementing to 12m via tremmie pipe.

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller D.Rigg Driller's licence no. 1234

Trainee driller R Mud Driller's licence no. 5678

Signature of driller **D Rigg** Date 25/06/2019

Contractor The Big Aussie Drill

Department of Natural Resources Mines and Energy

White — forward to the Department of Natural Resources, Mines and Energy Pink — provide to landholder Blue — Driller to retai

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 983L of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002 (Qld)* and may be stored in a departmental database. For more information on the department's privacy

Figure 15.1 Example of a bore completion report/drill log

Rock Types

Geologists classify rock types in three major groups:

- Igneous rocks — those which have cooled and solidified from an originally molten mass
- Sedimentary rocks — those resulting from the deposition of sediments by water, wind, or chemical precipitation and later consolidation
- Metamorphic rocks — those from either of the first two groups which have been altered by heat, pressure, solution, or other means.

Rocks are further classified according to particle size. Igneous rocks include coarse-grained types such as granite and gabbro, and the fine- grained types such as rhyolite and basalt. The coarse-grained types have cooled and become solid at great depths under the earth's surface whereas the fine-grained rocks have cooled at or near the surface (such as lava flows). In rocks such as granite, water is found in joints or fractures in the rock and occasionally in the upper weathered zone of the rock. Normally only a small amount of water can be obtained from bores drilled in such rocks. Some lava flow type of igneous rocks, however, may be quite porous and bores penetrating those porous zones may yield a considerable quantity of water.

Sedimentary rocks include shale, sandstone, conglomerate, limestone, dolomite, etc. These rocks are the result of compaction and consolidation of loose sediments such as clay, sand fossil shells, etc., and chemical precipitates or evaporation product such as salt and gypsum.

The terms clay, silt, sand, and gravel properly refer only to the size of the particles that compose the sediment.

Water is often found in abundance between the particles of medium and coarse-grained unconsolidated sediments such as sand and gravel. Fine- grained sediments, such as clay, may contain much moisture but due to the small size of the clay particles and the pore space between these particles it is difficult to obtain water from such sediments.

When the sediments become consolidated to form a sedimentary rock, the proper rock name is applied – clay becoming shale, sand becoming sandstone, gravel becoming conglomerate, etc. Water occurs in these rocks just as in the original unconsolidated sediments, but due to compaction and sedimentation the porosity of the rock is usually less than that of the original loose material.

Limestone is a sedimentary rock composed chiefly of calcium carbonate (lime), which was formed by precipitation of a fine-grained limey mud, by the accumulation of many animal shells in oceans or lakes, or by other means. Dolomite is another rock similar in most respects to limestone but containing calcium and magnesium carbonates. Dolomite does not effervesce or 'fizz' as rapidly to dilute hydrochloric acid in the way that limestone does. Since limestone and dolomite are somewhat soluble in water, solution openings and cavities up to the size of large caves may be formed.

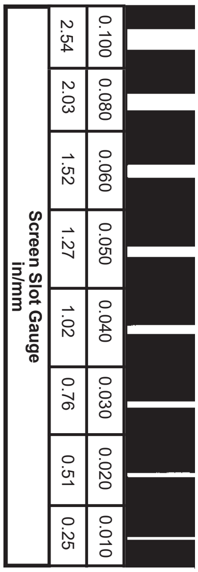
Groundwater may be obtained from small pores of limestone or dolomite, just as in sandstone, but most water is obtained from cracks, crevices, and larger solution openings.

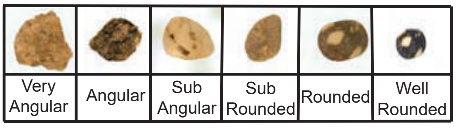
Metamorphic rocks include slate, quartzite, marble, schist, gneiss, etc. They are the result of long action of heat, pressure, and solutions upon igneous and sedimentary rocks. With the exception of marble, which is a metamorphosed limestone, most rocks in this group are dense and only small quantities of water can be obtained from cracks or joints. Marble may contain larger solution openings, similar to those found in limestone, from which abundant supplies of water can be obtained.

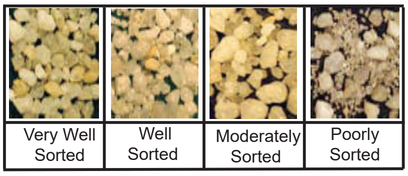
Geologists group certain rock units which can be mapped and traced by the study of bore cutting and field mapping over a large areas into 'formations'. Each formation is given a name, usually referring to some geographical place where the formation is well exposed at the surface.

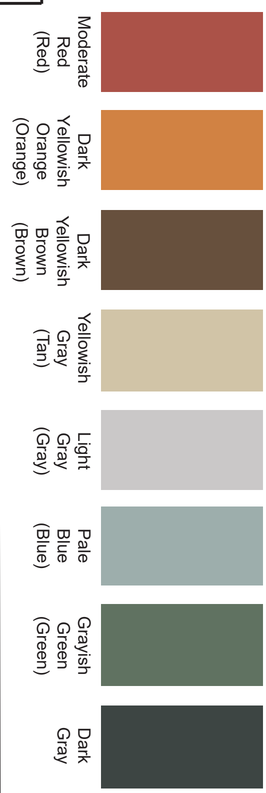
Classification of Granular Materials and Approximate Slot Size for Naturally Developed Wells					
Name	Millimeters	Inches	Sieve Size	Slot Size (inches)	Slot Size (mm)
Boulders	>300	>11.8	>12"	>0.100	>2.5
Cobbles	300 - 75	11.8 - 2.9	12"- 3"	>0.100	>2.5
Gravel - coarse	75 -19	2.90 - 0.75	3" - 3/4"	>0.100	>2.5
Gravel - fine	19 - 4.8	0.75 - 0.19	3/4" - 4	>0.100	>2.5
Sand - coarse	4.8 - 2.0	0.19 - 0.08	4 - 10	0.100	2.5
Sand - coarse to medium	3.3 - 1.8	0.13 - 0.07	6 - 12	0.090	2.3
Sand - medium	2.2 - 1.3	0.09 - 0.05	8 - 16	0.070	1.8
Sand - medium	1.8 - 1.0	0.07 - 0.04	12 - 20	0.050	1.3
Sand - medium	1.3 - 0.5	0.05 - 0.02	16 - 30	0.030	0.8
Sand - fine	0.5 - 0.2	0.02 - 0.008	30 - 70	0.015	0.4
Sand - fine	0.2 - 0.08	0.008 - 0.003	30 - 200	0.007	0.2
Slits and Clays	<0.08	<0.003	<200	NA	NA

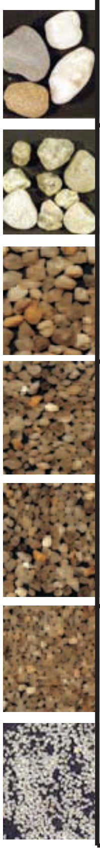
Grain size classification is based on USCS and slot selection is based on well construction using natural development and average grain sizes.











Sand / Slot Size Gauge						
Gauge	Name	Natural Development Slot		Filter Pack	Filter Pack Slot	
		inches	mm	sieve	inches	mm
	Gravel	0.125	3.2	3/8" - 3/4"	0.250	6.4
	Sand - Coarse	0.100	2.5	4 - 3/8"	0.160	4.1
	Sand - Coarse	0.080	2.0	3 - 6	0.120	3.0
	Sand - Medium	0.060	1.5	4 - 8	0.090	2.3
	Sand - Medium	0.040	1.0	6 - 12	0.070	1.8
	Sand - Fine	0.020	0.5	10 - 20	0.040	1.0
	Sand - Fine	0.007	0.2	20 - 40	0.018	0.5

Range of Hydraulic Conductivities

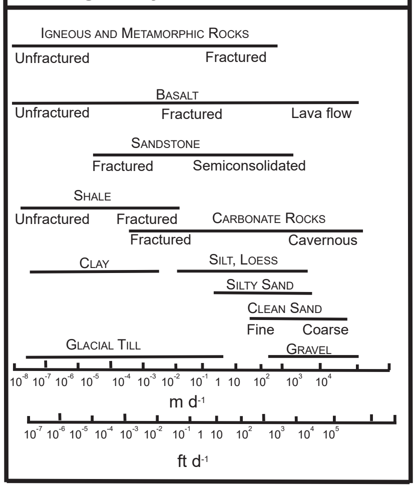


Table 15.1 Guidelines for rock classification and description

16 Bore Completion, Headworks, and Site Restoration

Principle

Headworks shall control the flow of water.

The protruding casing should be completed so that it:

- **is protected from damage**
- **prevents surface run-off or potentially contaminated fluids from entering the bore.**
- **After completion of the job the site should be restored as close as possible to its original condition.**

Headworks

After a bore has been drilled and tested it is important to secure the bore and protect it from damage and from the entry of any contaminants. These works may include:

- installing headworks
- sealing and capping to protect the aquifer.

It is also important to:

- protect the bore from environmental conditions such as flooding, sunlight, vandalism, fauna, insects, and fire
- dispose of any waste or potentially hazardous materials
- restore the site.

If the bore has to be located in an area of potential flooding, the casing should be raised above flood level or, if this is not feasible, completely sealed to prevent the entry of floodwater.

Tongue type valves (gate valves) should be used on artesian bores and headworks to assist in reducing water hammer that can result from rapid closing of other valve types.

Figure 16.1 shows an example of headworks design for a flowing bore.

Heavy duty bore head protection

Restoring the Drilling Site and Waste Disposal

It is important for health, safety, regulatory requirements, and environmental protection that any unwanted materials and waste products are disposed of responsibly.

The driller has a responsibility to restore the drill site. The site should be returned, as close as reasonably practicable, to its pre-drilling condition.

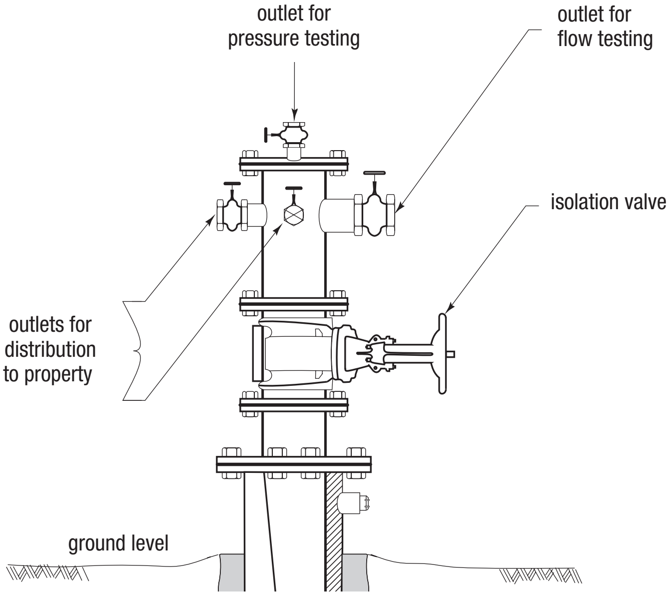


Figure 16.1 Example of a headworks design for a flowing bore

Left: Water supply under control

Right: Water supply out of control

Mandatory Requirements

16.1 The driller shall ensure the bore casing is capped with a fit for purpose threaded, flanged, or welded cap, or a compression seal.

16.2 All flowing bores shall be fitted with headworks in such a way as to control the flow of water. NOTE: The design may be specified by state and territory regulators.

16.3 When the water temperature exceeds 50°C, or the flow exceeds 15 litres per second, the following requirements apply:

- A main isolating valve of equivalent diameter to the inner casing shall be installed below the headworks distribution outlets.
- The headworks for flowing artesian bores shall be made to enable testing of pressure and flow, without having to interfere with reticulation or pumping systems.
- The flow measurement valve shall comply with the following minimum sizes:

Flow rate (litres per second)	Minimum valve diameter (mm)
0 - 10	50
10 - 30	75
30	100

- When constructing headworks for flowing bores the materials used shall conform to the following Australian standards:

Flanges

- for headworks shall conform to AS 2129
- up to and including 150 mm diameter shall use Table D (with M16 galvanised bolts)
- for headworks above 150 mm diameter shall use Table E (with M20 galvanised bolts)

Valves fitted to the headworks shall comply with either:

- AS 1628 Water Supply — Metallic Gate, Globe and Non-return Valves
- AS 2638 Gate Valves for Waterworks Purposes

Gaskets

- all gaskets must be new and be manufactured of fibrous material, be no less than 2mm thick, and be fit for purpose for the pressure of the water bore

Stainless steel pipes and valves shall comply with:

- ASTM A312 Stainless Steel Pipe (American standard)
- API 603 Stainless Steel Flanged Gate Valves. (No standard applies to stainless steel screwed gate valves.)

Good Industry Practice

16.4 Flowing wells should be fitted with a full diameter main isolating valve to assist future bore maintenance and rehabilitation. (See Chapter 17 for more information about bore maintenance and rehabilitation).

16.5 At all times the driller should ensure precautions are taken to prevent foreign material or surface water from entering the bore.

16.6 All plastic bore casing should be protected:

- If above ground this can be achieved with a steel cover pipe from the top of the bore casing and cemented to a depth not less than 0.5 m.
- If below ground this can be achieved with a cover that provides a complete seal to prevent the entry of any fluids.

16.7 All bores should be positioned so that the headworks can be protected from frequent flooding and surface water drainage.

If the bore is located in an area of potential flooding, the casing should be raised above flood level. If this is not feasible, it should be completely sealed to prevent the entry of floodwater.

16.8 All containers or bags for chemicals, cement, drilling fluids, and additives should be disposed of in such a way to cause minimum impact on the environment. This shall be done in accordance with the requirements of the respective state, territory, or local authorities, and the client

16.9 Any well development and disinfecting chemicals should be neutralised or otherwise disposed of in a safe manner.

16.10 The use of mud tanks and mud cleaning systems are often required by customers to minimise environmental impacts and reduce restoration costs.

16.11 Mud pits, if used, should be drained and filled in, or arrangements made for the work to be carried out.

16.12 Drilling camps should be adequately decommissioned, and all waste should be disposed of in an appropriate manner.

17 Bore Maintenance and Rehabilitation

Principle

Bore maintenance is intended to preserve performance of the bore and its component parts in good repair.

Rehabilitation is intended to repair a bore that has failed.

Bores, like any constructed asset, can deteriorate with age. This can lead to the bore owner experiencing issues with bore performance and ultimately water supply problems.

The severity of these problems can range from the bore becoming unsuitable for its intended purpose to less significant issues such as encrustation or scaling.

No matter the complexity or size of the problem, each will cause some level of inconvenience to, and have some financial impact on, the bore owner.

Some causes of reduced bore performance are:

- bio-fouling or clogging
- silt/clay infiltration
- chemical encrustation
- reduction in water table
- well structural failure
- water entry problems.

Monitoring

Many bores and pumps fail because they are either not maintained properly or because gradual changes go unnoticed.

Knowing the physical condition of the bore is rarely enough to be able to select the most appropriate curative or preventative action. However, long- term monitoring of bore performance can assist in the early identification of any decline in performance.

Monitoring the:

- standing water level
- discharge volume
- power usage
- water quality

can help to identify the cause of the problem.

The structural integrity of the bore should be checked to identify any signs of bore component failure. Techniques may include:

- geophysical logging
- dye testing
- using a down-hole camera.

It is essential that the casing condition be thoroughly examined and any deterioration, damage, or holes be accurately located and assessed.

Local knowledge is also valuable to assist with problem-solving, as other bores may have experienced similar issues.

With this information the bore owner is able to better understand if the bore requires maintenance or rehabilitation.

Maintenance tasks will not result in changes to the physical structure of the bore.

Rehabilitation may change the structure of the bore. As a result, bore rehabilitation should be performed only by a licensed driller, and a bore permit is required to undertake this work.

Bore Maintenance

As water bores are drilled in different types of formations and to different depths, some bores will require more maintenance than others.

In certain groundwater environments, encrustations or blockages of various types can occur on bore casings, screens, in gravel packs, and in pumps. These blockages must be removed to return the bore to optimum performance.

A number of common physical and chemical repair methods are available and provide effective solutions for common bore performance problems.

These methods include:

- airlifting, jetting, and surging
- bailing, surging, and swabbing
- brushing
- ultrasonic treatment
- chemical treatment
- use of detergents.

Chemicals are generally used in conjunction with mechanical actions to break up or dissolve any encrustation or blockages.

Table 17.1 shows various chemicals used in the treatment of bores and the types of problems they target. A number of proprietary products have been developed specifically to treat bores. They often contain one or more of the listed chemicals, although the particular formulation is often not published.

Table 17.1 Chemicals used in the treatment of bores

Chemical	Use
Chlorine (derived from calcium hypochlorite or sodium hypochlorite) Hydrogen peroxide Copper sulphate Potassium permanganate	Disinfectant
Acid (hydrochloric, phosphoric, sulphamic)	Scale/encrustation removal
Polyphosphates Sodium hexametaphosphate (Calgon)	Dispersing agent for treating clay
Proprietary products [i] (usually acid-based with a disinfectant)	A number of products are available that target all of the above

NOTES

i. Proprietary products usually incorporate an inhibiting agent to lower corrosiveness and a wetting agent to assist infiltration of chemicals.

Rehabilitation

Structural mechanical repair methods for the rehabilitation of bores can present many more problems than drilling a replacement bore. In part, this is because of uncertainties about the condition of the existing casing and bore construction history, including cost and variations in materials used.

In many instances the loss of capability from the bore because of reduction in casing size is preferable to decommissioning the bore and drilling a replacement.

Rehabilitation of bores can include:

- relining the bore with a new casing
- in situ repairs
- repairing the screens
- removing and replacing the casing
- sealing a zone.

Relining is an option for structurally weak bores where large sections of casing or screen have failed.

In situ repairs are best attempted when isolated sections of the casing or screen require repair. This can be achieved by swaging a patch across the affected area. In situ repairs are less intrusive than other methods of mechanical repair of casing, such as relining, and generally do not have a major effect on the overall diameter of the casing.

Retrieve and replace techniques are generally not used because of the risk of borehole collapse after retrieval, or the casing parting on removal.

Particular care is required when grout sealing rehabilitated bores. Sealing pressures can exert additional pressure on old casing, causing further problems.

Mandatory Requirements

17.1 The rehabilitation of any bore shall be carried out in accordance with state or territory requirements.

17.2 The standards set down for constructing new water bores also apply to the rehabilitation of existing water bores.

Good Industry Practice

17.3 Before any work is done, a thorough check for any historical information about the bore should be carried out. Details of all known related bores should also be researched.

Every effort should be made to identify the problem, because much time and money can be wasted on work that does not target the actual cause.

17.4 If the presence of iron bacteria is suspected (but not obvious), a water analysis should be carried out to determine the level of infestation.

Before chemically treating a bore, it is wise to determine the nature and cause of the problem in the first place, as this will allow the specific problem to be targeted and the appropriate treatment to be carried out.

17.5 It is good practice to measure the pH and conductivity of the water before any treatment is commenced. When treatment is complete, the quality of the discharge water should be tested and should be similar to that tested before treatment.

The pH should be within 0.5 units and conductivity within 10 per cent of pretreatment readings before the supply is reconnected to the reticulation system. This will ensure that there is little or no residual chemical remaining in the bore on completion of the work.

17.6 During treatment, the supply should be disconnected from the reticulation system to ensure that water is not available for consumption.
Remember, treating a bore with the incorrect chemical is a waste of time and money. For example, using a disinfecting agent to treat an encrustation will not result in any improvement in the bore's performance.

17.7 During any maintenance work, the driller should ensure that the appropriate safety precautions are taken. Chemicals should be used only by experienced personnel, particularly where no directions are provided for use in water bores.

17.8 All discharged waste water should be disposed of in a manner that will not affect the environment or existing users.

17.9 The structural integrity of the casing and the condition of the production interval should be monitored regularly to ensure that any early warning signs of problems that may affect bore performance are detected.

17.10 Accurate costing of structural mechanical repairs is very difficult as there can be a number of unpredictable and unplanned factors to take into consideration.
Landholders should always be aware of this fact from the outset, and if work proceeds should be advised about any problems arising and additional costs.

17.11 The owner of the bore should keep records of its performance during its life. This will provide an ongoing record for future reference and will be helpful if rehabilitation is ever required.

17.12 When rehabilitating bores it is also acceptable to have a minimum 10 mm thickness of cement grout sheathing the pump housing casing where the pump housing casing is constructed of inert material such as plastic. Such pump wells are to be limited to a maximum depth of 60 metres below either:

- the calculated static head at the time of rehabilitation for an artesian bore or
- the standing water level at the time of rehabilitation in a sub-artesian bore.

17.13 The production casing below the pump housing casing should have a minimum 15 mm thickness of cement grout sheathing it.

18 Bore Decommissioning

Principle

Failed or unwanted bores should be decommissioned to restore, as far as possible, the aquifer isolation that existed before the bore was drilled and constructed.

All bores and test holes that are to be decommissioned must be permanently sealed to prevent:

- the entry of any surface fluids and contaminants
- the intermixing of fluids and pressures between aquifers
- injury and harm to people and animals.

Reasons for decommissioning a bore include:

- they are no longer required
- they are no longer suitable for clients' needs
- the casing has deteriorated, leading to poor casing integrity
- they are unsealed abandoned test holes
- there is uncontrolled flow.

Failed bores constitute a potential hazard to public health and safety, and to the preservation of the quantity and quality of the groundwater resource.

The following matters should be considered when decommissioning a bore:

- the construction of the bore
- geological formations encountered
- hydrogeological conditions
- regulatory requirements.

To decommission a water bore, several requirements must be met. These include:

- eliminating any physical hazard (e.g. filling in open holes)
- preventing groundwater contamination
- conserving yield and maintaining hydrostatic head of aquifers
- preventing waters intermixing.

Decommissioning by fully grouting from the bottom of the bore to the surface is the preferred method for all bores. The original construction of the bore should be considered and the need to seal the annular space via perforating the casing and grouting.

Figures 18.1, 18.2, 18.3, and 18.4 show the arrangements that should be used to decommission the most common types of bores and/or holes.

Figure 18.1 Decommissioning a single aquifer bore by fully grouting (preferred method for all bores)

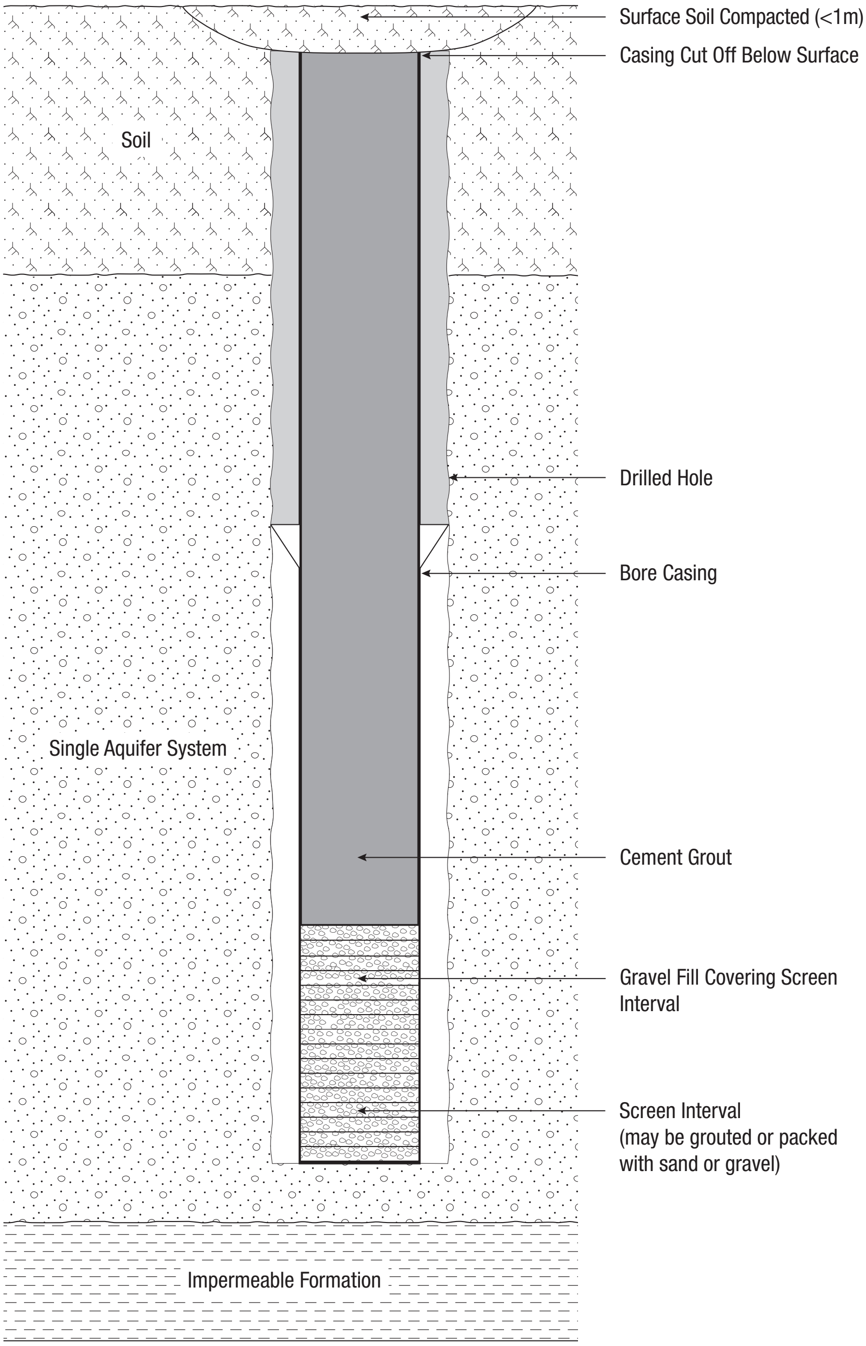


Figure 18.2 Decommissioning a multiple aquifer bore by fully grouting (preferred method for all bores)

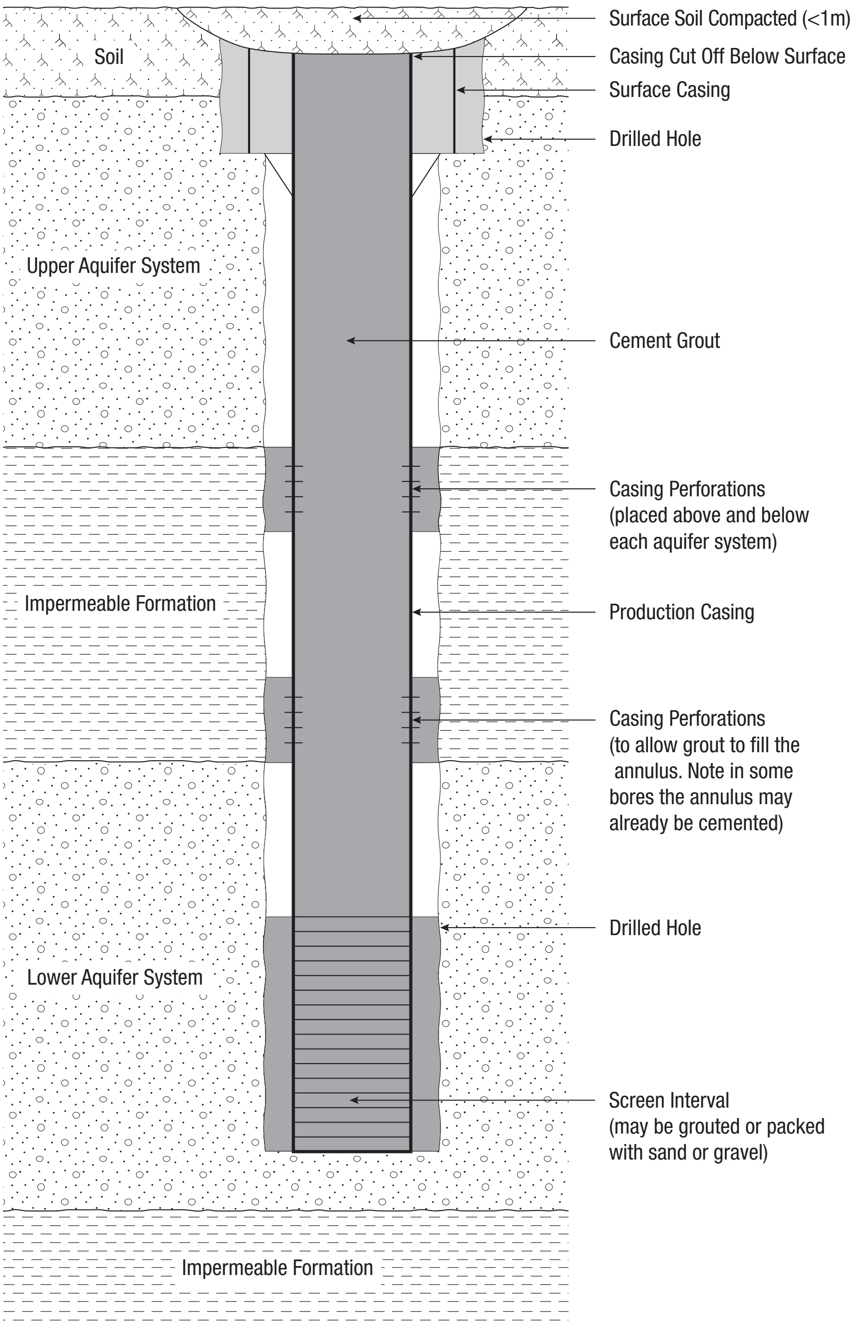


Figure 18.3
Decommissioning a multiple aquifer bore by cement grout bridges

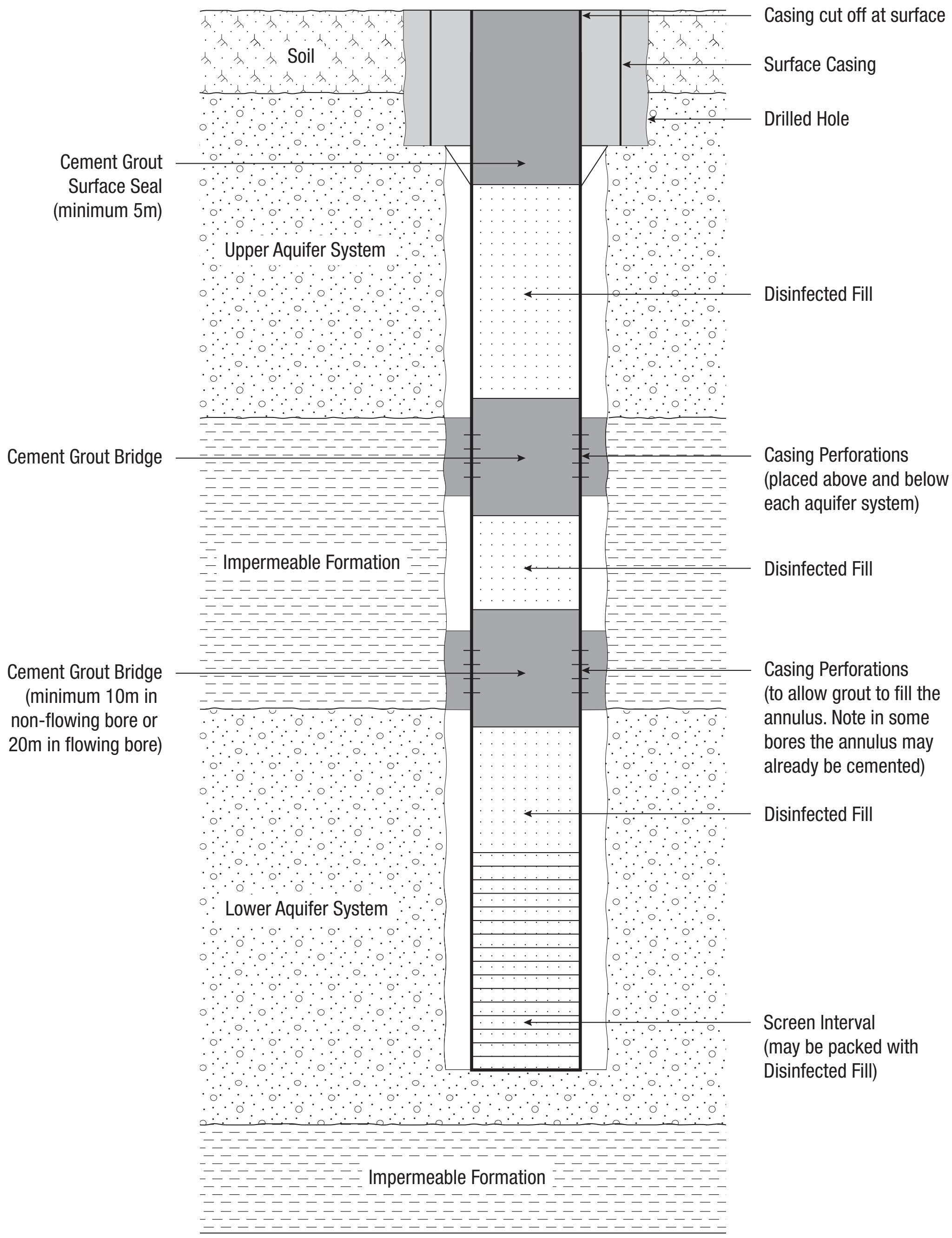
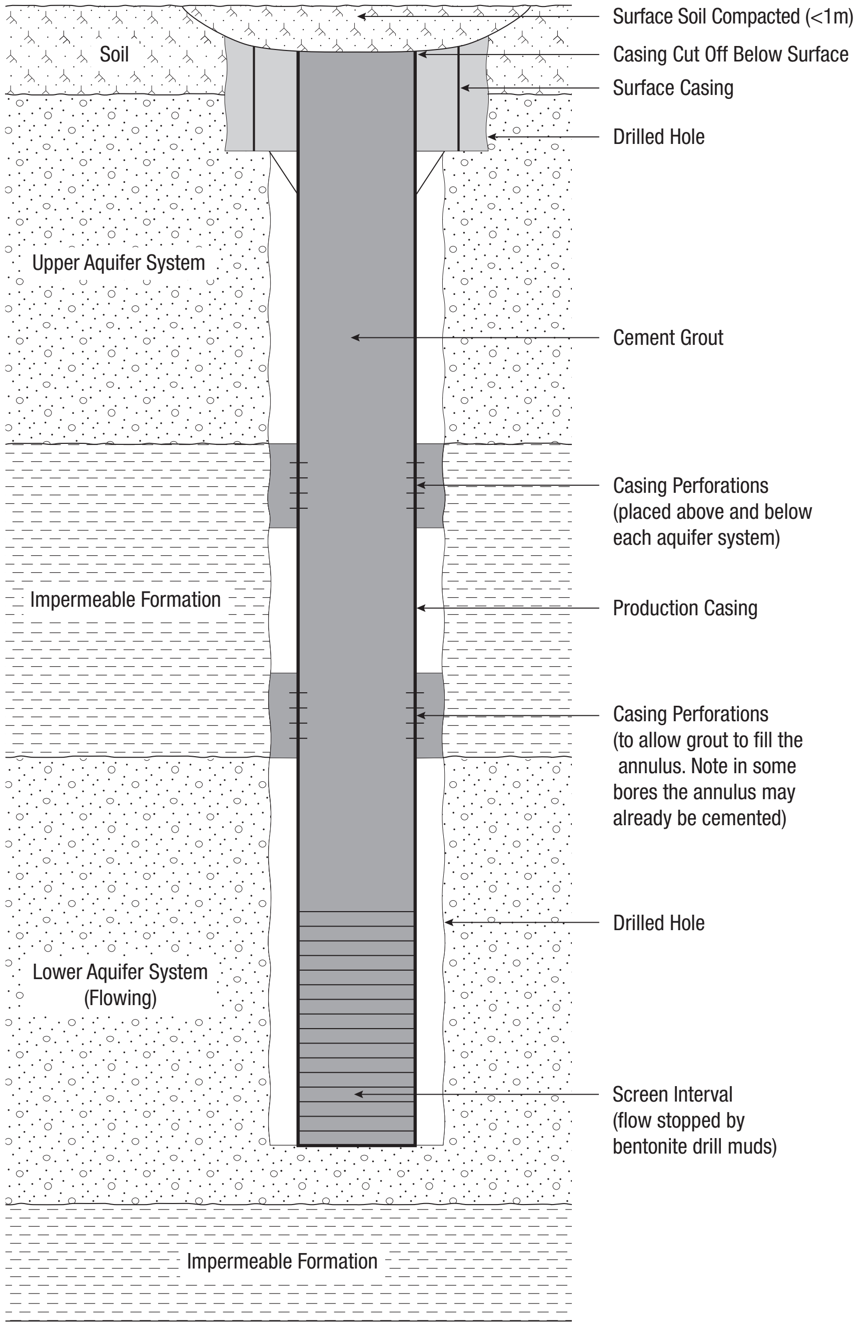


Figure 18.4 Decommissioning a flowing bore by fully grouting



NOTES

Surface casings may be cut off below ground level if required.

Flow to be stopped by pumping a column of dense barites – bentonite mud – or cement grout into bore.

Any possible flow inside or outside the casings between water-bearing formations of different quality or pressure must be prevented.

Mandatory Requirements

18.1 Any bore or hole that is to be permanently decommissioned shall be sealed to prevent vertical movement of water in the bore, including water in the annular space surrounding the casing.

The water shall be permanently confined to the specific zone in which it originally occurred.

To ensure all penetrated aquifers are protected, all test holes, decommissioned water bores, and wells shall be sealed.

All test holes and test bores shall:

- Be decommissioned by grout sealing (including any required top-up cement) as soon as possible, but no longer than 10 days from commencement of drilling.

OR

- Be constructed and completed to comply with the mandatory construction requirements for water bores (refer to 11.1).

Supervision of this work by the relevant water authority may be required in some areas.

18.2 The sealing material shall consist of one or more of the following:

- Cement grout
- bentonite cement grout
- concrete.

Sealing materials shall be placed to avoid segregation or dilution of material and unnecessary contamination of the aquifer zone.
The sealing material shall not pose any potential health risk.

18.3 Fill material shall consist of uncontaminated sand, coarse stone, clay, or drill cuttings.

18.4 When using the internal grout bridges method, the seals shall be set in impermeable strata immediately above and below each aquifer formation in the bore.

When using the internal grout bridges method, for non-flowing bores, a minimum of 10 metres of grout plug shall be set for a seal

18.5 When using the internal grout bridges method, for flowing bores the length of grout seal shall be:

- sufficient to overcome the pressure and stop the discharge of groundwater
- not less than 20 metres unless the flow originates from less than 20 metres below the surface.
- the seal must be at the top of the production zone.

18.6 Complete and accurate records shall be kept of the entire decommissioning procedure and supplied to the state or territory water authority. (See Chapter 15 for more information about recording and reporting data)

18.7 Regardless of the decommissioning method used, a concrete or grout surface seal to a minimum depth of 5 metres shall be installed in all decommissioned bores and/or holes.

Where a native soil topping is required, the surface seal shall be installed to at least 1.0m below the surface, and the soil topping compacted and finished to prevent ponding of surface water above the decommissioned bore.

18.8 For multi-port monitoring bores aquifer isolation must be maintained at all times during operation.

Decommissioning must take place within 7 working days of the removal of the isolation packers.

Good Industry Practice

18.9 It is preferable to fully grout bores, however bridges may be used in bores where complete grouting is not practicable.

It is often cheaper to completely grout a seal in a hole than to construct bridges within the hole.

18.10 When installing more than one cement plug, care should be taken that existing previously placed cement plugs do not move.

Grout plugs and backfill material should be tagged after installation to ensure they are placed correctly. A sample can be taken to check that previous plugs have taken an initial set.

18.11 In multi-aquifer and flowing bores where the casing has not been grout sealed between aquifers, casing perforation should be completed. This is to seal the bore annulus with grout to prevent inter aquifer flow. Casing perforations should be of sufficient size and number to allow flow of cement grout into the bore annulus.

18.12 Water bores and monitoring bores are covered by the Minimum Construction Requirements for Water Bores in Australia.

All other holes, irrespective of their purpose, should be decommissioned in accordance with this document. This should occur as soon as practicable when the purpose of the hole is complete in order to protect the groundwater resource.

This is designed to prevent the intermixing or contamination of groundwater.

Appendix A: Acronyms and Definitions

The following definitions may be useful in understanding this book.

Alignment The horizontal deviation between the actual bore centre line and a straight line representing the ideal centre line.

Annular space (Annulus) The ring-like space between the bore casing and the outer bore casing or borehole.

Aquifer A geological formation, group of formations, or part of a formation, capable of transmitting and yielding quantities of water.

Aquitard aquiclude see *Confined groundwater*.

Artesian bore A bore in an aquifer where the groundwater is confined under pressure, so that the water level in the bore will rise above the top of the aquifer and ground level (a flowing bore).

Bailer A tube made from pipe with a valve in the bottom, used to remove cuttings or sediments from the hole. A bailer can also be used as a device to extract water from a bore.

Bore (well) A hole sunk into the ground and completed for the abstraction of water or for water observation purposes.

Bore completion report The report required to be submitted by state and territory regulatory authorities on completion of bore construction. (Also known, for example, as Drill Log, Form A.)

Bore construction permit (Bore permit) An authority issued by a state or territory regulator to construct a bore on a specified location.

This document that lists state or territory legislative requirements, authorises construction, and outlines conditions for bore construction, alterations, and decommissioning.

Casing A tube used as a temporary or permanent lining for a bore.

Casing – surface casing The outer most pipe initially inserted into the hole.

Casing – production casing An inner-most continuous string of pipe (casing) that is inserted into or immediately above the chosen aquifer (see Production zone) and back to the surface, through which water is extracted or injected.

Cement grout A fluid mixture of Portland cement and water of a consistency that can be forced through a pipe and placed as required.

Cementing The process of placing a grout into an annular space to provide a permanent seal.

In this book this process is referred to as 'grouting'.

Centraliser A device used to centre the casing in the hole.

Client The party entering into a contract or agreement for the purchase of any materials or work to be performed in accordance with the provisions of this publication. A client may or may not be the owner.

Conditioning The process of removing cuttings and stabilising the formation within a drilled hole.

Confined groundwater A completely saturated aquifer in which the upper and lower boundaries are relatively impermeable layers (aquitards or aquicludes). The groundwater is contained under sufficient pressure to cause it to rise above the aquifer if the top of the impermeable layer is breached.

Confining bed A layer of relatively impermeable material underlying, overlying, or adjacent to, one or more aquifers.

Consolidated formation Competent rock-material strata of sedimentary- igneous, or a metamorphic-type rock, which can be porous and permeable to provide an aquifer.

Construction The entire process of creating a bore, from initial drilling and inserting the surface casing through to insertion of a screen and developing the aquifer prior to installing a pump.

Contractor The party that enters into a contract or agreement with the client to furnish the work and materials according to the provisions of this publication.

Decommissioned bore A bore, that has been permanently sealed to prevent contamination of aquifers and remove a potential surface hazard.

Development The removal of sand and other fines (including drilling mud) from the aquifer immediately surrounding the bore in order to optimize bore efficiency, remove impurities, and limit fine sediment from entering the bore.

DHH Down hole hammer.

Discharge The volume of water pumped or flowing from a bore per unit of time, expressed in litres per second.

Drawdown The difference between the observed water level during pumping and the water level before pumping commenced.

Drill log see *Bore completion report*.

Driller A licensed water bore driller who is ultimately responsible for the work being carried out.

Drilling fluid (Drilling mud) A medium used to stabilise the formation, control groundwater, and remove the drill cuttings from the hole as drilling takes place.

Drilling operations The drilling, construction, development, maintenance, rehabilitation and decommissioning of a bore.

Fill Material consisting of uncontaminated sand, coarse stone, clay, or drill cuttings.

Filter pack see *Gravel pack*.

Flowing bore A bore from which groundwater is discharged at the ground surface without the aid of pumping.

Formation A bed or deposit composed throughout of substantially the same kind of rock; a lithologic unit. Each different formation is given a name.

Formation pressure (Head, Hydrostatic Pressure) The confined groundwater pressure within a formation. The pressure can be converted to a virtual water level which is referred to as ‘head’.

FRE/GRE Fibreglass-reinforced epoxy casing.

FRP Fibreglass-reinforced plastic casing.

GAB Great Artesian Basin.

Good Industry Practice The preferred methods that are commonly used to achieve acceptable results. They are used extensively by the majority of drilling contractors.

Gravel pack Granular material introduced into the annulus between the borehole and a casing or perforated lining to prevent or control the movement of finer particles from the aquifer into the bore.

Grout A fluid mixture of cement and water of a consistency that can be pumped through a pipe, to which other additives (e.g. bentonite) may be added to enhance its properties.

Sometimes called 'cement grout' or 'cement slurry'.

Grouting The operation of placing or pumping a grout into an annular space or cavity.

Head see *Formation pressure*.

Headworks The above ground bore construction designed to protect the bore from contamination or damage, and to contain flow in artesian bores.

Hydrogeological properties The properties of formations that control the movement and storage of groundwater (e.g. hydraulic conductivity, storativity, transmissivity and permeability).

Licensed A requirement that drillers shall possess a certain class of license in order to construct the bore.

Liner A telescoped section of casing, screen inserted into a larger casing, screen, or open hole as a means of sealing off undesirable material or maintaining the structural integrity of the well.

Maintenance Restoring a bore by a variety of chemical or mechanical means that do not involve replacing or modifying any of the original materials used to construct the bore.

Mandatory Requirements Enforceable by regulators (through legislation) designed to protect groundwater resources. Mandatory Requirements shall be adhered to during all phases of constructing a bore.

Modal Size The sieve size that retains the highest mass of sample in a sieve analysis.

Monitoring bore A bore constructed solely to obtain hydrological or water-quality data.

MPa Megapascal.

Nominal diameter An approximate diameter (internal or external) of the tube, usually used for simple identification purposes. For example, a 100 mm diameter tube may vary within a manufacturing range of 99.5 mm and 100.5 mm.

On site A rule that requires a licensed driller to be physically present and in control during all the various phases throughout the construction of a bore.

Perched water Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone and supported by an aquitard or aquiclude.

Perforations A series of openings in a bore casing.

Permeability The capacity of a porous medium for transmitting water.

Permit see *Bore permit*.

pH Index of acidity or alkalinity of water.

Piezometer A pipe in which the elevation of the water level or potentiometric surface can be determined. The pipe is sealed along its length and open to water flow at the bottom.

PN (pipe nominal) The nominal pressure rating of the pipe.

Plumbness The horizontal deviation (drift) of the bore centre line from true vertical.

Production zone The zone within the target formation that produces the water supply requirements for the bore.

Pumping level The water level in the bore when pumping is in progress.

PVC-U Unplasticised polyvinyl chloride.

Reconditioning Restoring a bore by a variety of chemical or mechanical means that do not involve replacing or modifying any of the original materials used to construct the bore.

Recovery The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.

Regulator A state or territory water licensing authority.

Rehabilitation The restoration of a bore to its most efficient condition using a variety of techniques, which may include replacing or re-lining the production casing and/or screens.

A driller shall be licensed in order to carry out rehabilitation of a bore.

Screen A specially manufactured filter-like section of bore casing that allows groundwater to enter a bore. A screen has apertures of set sizes to allow water to enter the bore efficiently while blocking out sands and gravel as required.

Shoe An extension fitted to the end of the casing, commonly a drive shoe (for advancing the casing) or a float shoe (used for grouting).

Slotted Casing modified to allow water to enter the bore through openings.

Sonic Drilling A continuous core drilling method that uses vibrosonic energy to pulverise drilled material and push it outwards from the borehole. This permits the hole to be advanced without requiring a drilling fluid to remove cuttings back to the surface.

Commonly used for environmental investigation.

Sorted (well/poorly) A measure of the uniformity of grain sizes.

Spear point A shallow bore installed by jetting or driving casing into unconsolidated sediments for groundwater extraction.

Specific capacity The ratio of the discharge to the drawdown it produces, measured inside the bore (L/min/m of drawdown).

Specific gravity The weight of a given volume of material compared to the weight of an equal volume of water at a reference temperature under standard conditions.

Standing water level The level of groundwater standing in a bore uninfluenced by pumping in that bore.

Static head The height, relative to an arbitrary reference level, of a column of water that can be supported by the static pressure of the aquifer at a given point.

Target formation The intended geological formation.

Telescoping A method of fitting or placing one casing inside another or introducing a screen through a casing diameter larger than the diameter of the screen.

Test bore Completed bore for pumping to obtain information on capacity, groundwater quality, geological and hydrological conditions, and related information.

Test hole/investigation hole An uncased hole used only to obtain information on groundwater quality and/or geological and hydrological conditions.

TDS (Total dissolved solids) The quantity of dissolved inorganic and organic substances in a sample of water, expressed as mg/L.

Transmissivity An aquifer hydraulic property that relates to the ease with which water passes through a formation, expressed in square metres per day.

NOTE: Transmissivity is equal to the hydraulic conductivity multiplied by the thickness of the aquifer.

Tremie pipe A device or small-diameter pipe that carries materials to a designated depth in the hole.

Unconfined aquifer An aquifer in which the water level first encountered during drilling is equal to the actual formation water level.

Unconsolidated formation Loose, soft rock-material strata of sedimentary, igneous, or metamorphic-type rock, which includes sand, gravel, and mixtures of sand and gravel.

These formations are widely distributed and can possess good storage and water transmissivity characteristics.

Wall cake A low permeability film that is deposited on the porous face of the borehole by the drilling fluid to prevent fluid loss (the ability to deposit this film is a principal requirement of the drilling fluid).

Water-bearing formation A formation capable of storing and transporting water.

Water table The depth to the groundwater surface in an unconfined aquifer.

Well see *Bore*.

Appendix B: Resources

Relevant sections of this book should be read with reference to the following **Australian Standards**:

AS 1396 *Steel Water Bore Casing*

AS/NZS 1477 *Unplasticised PVC (PVC-U) Pipes and Fittings for Pressure Applications*

AS 1579 *Arc Welded Steel Pipes and Fittings for Water and Wastewater*

AS/NZS 3879 *Solvent Cements and Priming Fluids for Use with Unplasticised PVC (PVC-U) Pipes and Fittings*

AS 3972 *Portland and Blended Cements*

API Q1 *Quality management system for manufacturing. Developed by American Petroleum Institute*

AS 1289.3.6.1 – *Soil classification test - determination of particle size distribution by sieving*

AS 1628 *Water supplies metallic gate values*

AS 2129 *Australian standard for flanges*

AS2634 *Chemical plant equipment made from glass-fibre reinforced plastics (GRP) based on thermosetting resins*

ASTM A312M *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

BS7159 *Design and Construction of Glass Reinforced Plastics (GRP) Piping Systems for Individual Plants or Sites*

Training courses to develop skills for

- screening and gravel packing bores
- drilling fluid techniques and testing
- cement grouting

are conducted on a regular basis across Australia by

Australian Drilling Industry Association

5 Profit Pass
Wangara WA 6065
Phone: (08) 6305 0466
www.adia.com.au

More information on drilling methods and applications, and on the design and construction of water bores, is in the following industry publications.

Drilling – The Manual of Methods, Applications and Management

Available from:

Australian Drilling Industry Association
5 Profit Pass
Wangara WA 6065
Phone: (08) 6305 0466
www.adia.com.au

Johnson's Groundwater and Wells

Available from:

Australian Drilling Industry Association
5 Profit Pass
Wangara WA 6065
Phone: (08) 6305 0466
www.adia.com.au

Aqseptence Group (Johnson Screens)
88 Brickyard Road
Geebung Qld 4034
www.aqseptence.com

Useful Websites

GROUNDWATER INFORMATION AND DATA

Australia Wide - Bureau Of Meteorology

http://www.bom.gov.au/water/groundwater/explorer
http://www.bom.gov.au/water/groundwater/insight

Victoria

http://www.water.vic.gov.au/groundwater/groundwater-resource-reports
http://www.vvg.org.au
http://data.water.vic.gov.au

South Australia

http://www.waterconnect.sa.gov.au/Systems/GD
http://www.environment.sa.gov.au/licences-and-permits/water-licence-and-permit-forms/statewide

Queensland

http://www.business.qld.gov.au/industries/mining-energy-water/water/bores-and-groundwater
http://qldglobe.information.qld.gov.au/?topic=water-bores

Northern Territory

https://nt.gov.au/environment/water

Western Australia

http://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx
https://online.water.wa.gov.au

New South Wales

http://realtimedata.waternsw.com.au/water.stm

Tasmania

http://wrt.tas.gov.au/groundwater-info

ACT

https://actmapi-actgov.opendata.arcgis.com/datasets/act-government-groundwater-monitoring-bores

ON-LINE BORE CONSTRUCTION REPORTING

Victoria

http://mywater.waterregister.vic.gov.au

South Australia

http://forms.business.gov.au/smartforms/sa-dfw/well-construction-permit-html

Appendix C: Sample Contract Documentation

Explanatory Memorandum – Model Water Bore Agreement

The model Water Bore Agreement ("Agreement") can be used across a range of water drill contracts in Australia. ADIA Members are encouraged to use particular clauses or the Agreement in its entirety to the extent it mirrors arrangements agreed and as contained in the tender documentation. This Explanatory Memorandum provides a brief explanation of each of the clauses as follows below.

The Agreement Particulars

The Agreement needs to be particularised because each and every contractual arrangement differs according to project requirements. You can identify particulars required by the square brackets ([ ]) in the document. If any of the particulars are not applicable to your agreement you can remove the square bracketed text where it appears in the agreement.

Schedule 1 - Project Scope

The Services are those to be provided by the contractor. The term of Agreement applies for the drilling work before profits can be recovered through the inclusion of the existing contractual relationship for that period.

Schedule 2 – Rigs and Equipment

The schedule is to contain the rig and equipment specifications and requirements and the information indicated by the by the square brackets ([ ]) can be completed via the tender documents.

Schedule 3 – Rates & Fee

The fee and pricing schedule and rates need to be included in schedule 3. Examples have been provided for the purpose of demonstrating the information required. Payment of the fee and rates are a major component of costs for the Company. It is a critical component of the development equation for the Contractor.

Definitions

The definition section is important in setting up the complete legal relationship by defining the scope of the agreement formed through the contractual relationship.

Parties

The parties include the Contractor and the Company.

Term

The Agreement may be used by ADIA members on smaller jobs as well as more complex jobs lasting several months or more with respect to covering the deeper level of work and time required.

Insurance

There is a requirement that some forms of insurance for the project be purchased and maintained by the company.

Company Obligations

The Company and its officers and directors are subject of the Company obligations in accordance with applicable law, permits and other requirements required for the project.

Representations and Warranties

Representations and warranties are promises given about the important aspects involved with the drilling arrangement. For example, the inclusion of best industry practices, applicable skill and relevant qualifications are warranties required to be given by the Contractor.

Confidentiality

Confidential information includes information which is defined in the commencement clause of the Agreement. It is a wide definition inclusive of trade secrets, ideas, know-how, concepts amongst other components of information.

Default and Termination

The Contractor may terminate the Agreement if the Company causes a significant breach or otherwise invoke the provisions of the agreement. In such circumstances the Contractor can be compensated and/or entitled to payment for services.

Arbitration

The agreement allows for any dispute that is not remedied to be referred to arbitration in accordance with the agreement requirements. This is to avoid litigation if at all possible whilst maintaining an amicable relationship given the breach circumstances involved.

General Clauses

The so-called 'General Clauses' include rights and obligations with respect to assignment and subcontracting, alterations, notices, waiver, time of the essence, governing law and jurisdiction amongst the other requirements set out in the Agreement.

[**INSERT NAME OF COMPANY**]

ACN: *** *** ***

ADDRESS (INCLUDE AREA, STATE, POSTCODE)

(‘Company’)

And

[**INSERT NAME OF CONTRACTOR**]

ACN: *** *** ***

ADDRESS (INCLUDE AREA, STATE, POSTCODE)

(‘Contractor’)

TABLE OF CONTENTS

THIS AGREEMENT is made on the **[XXth]** day of **[month]**, **2017**

BETWEEN:

[INSERT NAME OF COMPANY] (ACN ** * *** ***)** having its registered office at [Insert ADDRESS]

(hereinafter called the **"Company"**);

AND

[INSERT NAME OF CONTRACTOR] (ACN ** * *** ***)** having its registered office at [Insert ADDRESS]

(hereinafter called the **"Contractor"**)

RECITALS

A. The Contractor agrees to furnish all labour, Services, Materials, Equipment, and all other things necessary for the timely and proper completion in accordance with this Agreement.

B. The Company agrees to engage the services of the Contractor for the purpose of the Contractor providing the Services and Materials for the benefit of the Company. In consideration the Company agrees to pay the Fee to the Contractor in accordance with this Agreement.

C. The Company and the Contractor agree to the rights, obligations, covenants and promises contained herein and as consideration to one another.

THE PARTIES AGREE

1. Definitions

In this Agreement the defined terms set out in this clause shall, unless the context otherwise requires, have the following meanings:

Affected Party means the party whose performance obligations under this Agreement is affected due to commission and/or omission of actions, of the opposite party and/or Force Majeure.

Agreement means this Agreement and any schedules and annexures to it.

Approvals means and include all licenses, permits, consents and permission necessary under Applicable Law in respect of this Agreement for the performance of any obligation or exercise of any right by a Party herein.

Business Day means Monday to Friday excluding public holidays in Victoria.

Claim means a claim, action, proceeding or demand however it arises and whether it is present or future, fixed or unascertained, actual or contingent and includes a claim for any Loss or any legal liability.

Commencement Date means the date this Parties obligations are due for performance obligations to commence under this Agreement.

Company means [INSERT NAME OF COMPANY] (ACN ** *** *** ***) having its registered office at [Insert ADDRESS]

Company Representative means the person nominated by Contractor to be its representative in accordance with this Agreement.

Completion means the performance on the Completion Date by the parties of their respective obligations under this Agreement.

Completion Date means [Insert Date] or such other date as agreed between the Parties in writing.

Confidential Information: means all trade secrets, ideas, know-how, concepts, information, customer lists, supplier lists and Intellectual Property whether or not in writing or owned or used by the Contractor.

Contractor means the Party responsible for providing the Services in accordance with this Agreement [INSERT NAME OF COMPANY] (ACN ** *** *** ***) having its registered office at [Insert ADDRESS] and shall include its legal representatives, successors.

Effective Date means the date when this agreement is signed by the Parties.

End Date means the date for completion of the parties' obligations under this Agreement.

Equipment means the equipment owned or by the Contractor or otherwise used in connection with the Services.

Fee means the amount payable to the Contractor for the provision of the Services and the Materials and other costs payable in accordance with this Agreement.

Force Majeure means an act, event, circumstance or cause, that adversely and directly renders the performance of obligations under the Agreement impossible in whole or in part and could not have been prevented including, but not be limited to, act of God, earthquake, volcanic, eruption, landslide, flood, cyclone, typhoon, tornado, war embargo, or exceptionally adverse weather conditions and any act of war.

Government means a government or governmental, semigovernmental, administrative, fiscal or judicial body, department, commission, authority, tribunal, agency or entity whether foreign, federal, state, territorial or local.

GST Act means has the same meaning given to that term in A New Tax System (Goods and Services Tax) Act 1999 (Cth).

Intellectual Property means all intellectual property at any time protected or capable of being protected by statute or common law including copyright, trade marks, patents, registered designs and rights in and to designs and any application or right to apply for registration of any intellectual property rights including or in connection or owned by the Contractor.

Loss means any loss, damage, cost, interest, expense, fee, penalty, fine forfeiture, assessment, demand, action, suit, Claim, and proceeding, cause of action, liability or damage.

Materials means the materials set out in this Agreement for which the Contractor is paid a Fee (in whole or in part) by operation of this Agreement.

Material Breach means substantial failure in the performance of the obligations, terms and conditions of this Agreement by one Party, significant enough to have an adverse effect on the business, condition (financial or otherwise), liabilities, assets, operations (or the result of operations) or prospects of the other Party.

Notice means a notice given in accordance with the notice clauses of this Agreement.

Party means a party to this Agreement.

PPSA means the **Personal Property Securities Act (Cth).**

Schedule means a schedule to this Agreement.

Security Interest: means:

(a) a security interest under the Personal Property Securities Act 2009 (Cth);

(b) any other mortgage, pledge, lien or charge in relation to any property (whether or not it is personal property);

(c) any other interest or arrangement of any kind that in substance secures the payment of money or the performance of an obligation, or that gives a creditor priority over unsecured creditors in relation to any property (whether or not it is personal property);

(d) an easement, restrictive covenant, caveat or similar restriction over property (except an easement or covenant whose burden is noted on the certificate of title to the land concerned);

(e) a trust or other third party interest; and

(f) an agreement to create any of the above or to allow any of them to exist.

Services means all activities, work, tasks and things described under this Agreement by the Contractor as specified in the Schedule.

Tax means a tax, levy, charge, impost, fee, deduction, withholding or duty of any nature, including, without limitation, stamp and transaction duty or any goods and services tax (including GST), value added tax or consumption tax, which is imposed or collected by a Government agency, except where the context requires otherwise. This includes, but is not limited to, any interest, fine, penalty, charge, fee or other amount imposed in addition to those amounts.

Tax Act means the *Income Tax Assessment Act 1936 (Cth)*, the *Income Tax Assessment Act 1997 (Cth)*, the *Taxation Administration Act 1953 (Cth)*, or other law, regulation or rule of a Government Agency imposing obligations in respect to taxation, as applicable.

Term means the period between the Commencement Date and the End Date.

Warranties means the warranties set out in this Agreement.

1.1 Interpretation.

In this agreement unless the context otherwise requires:

(a) the headings are for convenience of reference only and shall not be used in and shall not affect the construction or interpretation of this Agreement;

(b) words in the singular include the plural and words in the plural include the singular, according to the requirements of the context;

(c) words importing a gender include every gender;

(d) a reference to "include", "includes" or "including" means "includes but is not limited to;

(e) where a word or phrase is defined, its other grammatical forms have a corresponding meaning;

(f) a reference to any legislation or provision of legislation or a policy includes all amendments, consolidations or replacements and all regulations or instruments issued under it;

(g) a reference to Party to a document includes that Party's permitted successors, assignees, administrators and substitutes;

(h) where a day on or by which any thing is to be done is not a Business Day, that thing must be done on or by the next Business Day;

(i) a reference to a notice form, consent or approval of a Party and agreement between the Parties, means a written notice, consent, approval or agreement;

(j) a "Recital", a "Clause", a "Section", a "Schedule", an "Attachment", an "Annexure", a "Paragraph" shall be construed to be a reference to a recital, a Clause, a section, a schedule, an attachment, an annexure and a paragraph respectively of this Agreement; and

(k) a reference to any person includes any natural person, corporation, business trust, joint venture, association, company, partnership or government, or any agency, or political subdivision thereof.

2. Term of Agreement

This Agreement, unless terminated earlier in accordance with terms hereof shall continue to remain in force throughout the life of the Project starting on the Commencement Date and ending on the End Date.

3. Provision of Services

3.1 The Contractor has agreed to provide the services described in the Schedule (the "Services") to the Company for the period (the "Period") described the Schedule.

3.2 Subject to this Agreement, the Contractor will use all reasonable endeavours to commence providing the Services at the Site on or about the Commencement Date (as defined in the Schedule) and complete the Services by the End Date (as defined the Schedule).

3.3 The Contractor will not be held liable for and will not be in breach of this Agreement, for failure to commence the Services on the Commencement Date (as defined the Schedule) or complete the Services by the End Date (as defined the Schedule) due to circumstances beyond its reasonable control.

4. Contractor's Fee

4.1 In consideration of the Contractor providing the Services, the Company will pay the Contractor the Fee calculated at the rates described the Schedule.

4.2 The Contractor shall invoice the Company for work completed on a fortnightly basis or at the completion of the job if the Period is less than a fortnight.

4.3 The Company will make payments to the Contractor within fourteen (14) days following the date of the invoices from the Contractor.

4.4 If any invoice submitted by the Contractor is disputed by the Company, the Company may withhold payment of the disputed portion pending determination of such dispute, provided that the Company shall pay the portion not in dispute and the Contractor shall continue to perform the Services.

4.5 If the Company does not dispute an invoice within 10 days after receipt of the invoice, then the Company cannot later dispute or refuse to pay any the invoice, except where a manifest error has occurred.

4.6 If the Contractor assesses that any drilling site contains any hazard or potential hazard to implementing the works, whether wholly or partly, then all costs which the Contractor believes necessary to eliminate or prevent such a hazard shall be an additional expense and shall be borne by the Company as per the Schedule of rates in this Agreement.

5. Contract for Services

5.1 The parties agree that this Agreement is a contract for services and nothing herein shall be interpreted so as to construe the Contractor as an employee, agent, joint venturer or partner of the Company.

5.2 The Contractor agrees to provide the Services in accordance with this Agreement.

6. Representatives

6.1 The Company shall appoint the Company Representative for the purposes of facilitation of communications and responsiveness on behalf of the Company for any queries and discussion within 30 days of the Commencement Date.

6.2 All directions on behalf of the Company to the Contractor shall be given by the Company Representative who, at all times, has the authority to act on behalf of and bind the Company.

6.3 The Company Representative must:

(a) Attend site meetings and any other meetings with the Contractor, as reasonably necessary for the provision of the Services in accordance with this Agreement or as otherwise required by the Contractor; and

(b) Provide the necessary information and assistance to the Contractor.

7. Contractor's Employees

The Contractor shall employ such employees as are necessary for the proper performance of the Services and who are skilled, licensed and experienced in their respective trades.

8. Contractor's Plant and Equipment

Unless otherwise agreed with the Company, the Contractor shall supply all plant, equipment and materials necessary for the performance of the Services including the equipment described in the Schedule. Subject to the terms of this Agreement, the cost of maintaining and replacing any plant and equipment shall be borne by the Contractor.

9. Insurance

9.1 At all times during the term of the Agreement, the Contractor must maintain the following insurance:

(a) Worker's compensation insurance in full compliance with applicable laws and regulations;

(b) Public liability insurance in respect of bodily injury (including death) and property damage howsoever caused with a limit of not less than ten million Australian dollars; and

(c) Insurance for Motor Vehicle Third Party Liability and Motor Vehicle Third Party Property Damage with a limit of not less than five million Australian dollars.

9.2 Unless copies have already been provided to the Company, the Contractor must provide The Company with copies of insurance certificates (and any updates) relating to the insurance policies maintained pursuant to this Agreement.

10. Tax, Superannuation and Government Charges

The Contractor shall be responsible for all compulsory superannuation, payroll tax, income tax, drilling licenses and any other associated Government levies and charges relating to its employees and incurred in connection with providing the Services.

11. Company Obligations

11.1 The Company shall be responsible for:

(a) clearly marking bore hole location with a stake, flag or other legally distinguishable method and to provide the Contractor with a map of the property identifying the position of the proposed bores;

(b) providing good and safe access to the property and to each drilling site;

(c) obtaining and complying with all municipal shire, State and Commonwealth government laws regulations, bylaws and bore permits or licences requirements at law, including any statutory obligations in relation to the works, except for those specified herein to be the responsibility of the Contractor;

(d) ensuring that all necessary firebreaks have been provided at near and/or in the vicinity of each site;

(e) will at all times be available and carry out all supervisory work required to effectively complete the works agreed to be undertaken in accordance with all government, statutory, and contractual requirements;

(f) providing all information necessary for the Contractor to assess any hazards, both actual and/or potential to performing the works which exist or may exist on, within or near each site; and

(g) Indemnifying the Contractor for any Losses or Claims made against the latter arising from or in connection with the works to the extent that any such claim exceeds the sum insured by the Contractor as provided for and specified in this Agreement.

11.2 Prior to the Commencement Date, the Company must:

(a) Provide to and check for the benefit of the Drilling Contractor all survey plans and other data relating to underground services at, near and/or in the vicinity of each site; and

(b) any relevant documentation relating to the Services, that is necessary to enable the Contractor to perform the Services.

The Contractor:

(a) without investigation of the documentation, will be able to rely on; and

(b) will not be liable for any costs, losses, damages, expenses or liabilities arising out of, suffered or incurred by the Company resulting from the Contractor relying on, using, reviewing or commenting on, any documentation provided by the Company to the Contractor under this clause.

11.3 The Company accepts the sole risk of all delays and all costs, losses, damages, expenses and liabilities arising out of, suffered or incurred by the Company or the Contractor in respect of the physical conditions (including the below ground conditions, geological structure and geological conditions) of the Site, its near surrounds and any access roads to the Site, excluding gazetted roads.

12. Contractor's Obligations

12.1 The Contractor, providing that the Company has fulfilled all his obligations described herein, shall be responsible for:

(a) commencing the work on the Commencement Date.

(b) keeping and maintain all necessary permits, licences and other approvals relating to the performance of the Services by the Contractor;

(c) for any material breach or non-observance by the Contractor of any permits, licences or approvals granted to the Contractor;

(d) using all reasonable endeavours to observe and ensure material compliance with the provisions of all relevant State water acts, occupational health and safety acts, heritage and environmental protection acts and any other applicable laws, statutes, rules or regulations relating to the performance of the Services as they relate to the Contractor and identified in in the Schedule ("Relevant Law");

(e) exercising due skill, care and diligence in the performance of the Services;

(f) drill at each site designated by the Company at a nominal diameter and to a maximum depth as per the Company's requirements in the Schedule; and

(g) provide and install casing and suitable slotted screen or other screen at a diameter and type as specified in the Schedule.

(h) carry out development and test each bore in accordance with relevant legislative and/or regulatory requirements and as per any special conditions of this Agreement as require by the Company.

(i) ensure correct alignment by ensuring that the casing shall be concentric, true to line and free of obstruction.

(j) that bore construction is carried out in conformity with all applicable legislation and/or regulations and if required by such law, under the supervision of a duly qualified holder of a drilling license.

(k) cleaning up and containing pollution or contamination which originates above the surface from the disposition of items wholly in the Contractor's possession and control and directly associated with the Contractor's Equipment.

12.2 The Contractor shall not be responsible for any error in relation to any bore's location which responsibility at all time vests with the Company.

13. The Company and the Drilling Contractor agree;

13.1 Guarantee of Water

The Contractor does not at the time or at any time prior to this agreement represent, warrant or promise to the Principal that water would be located and/or it would be of a certain quality. Further that all payments to the Drilling Contractor for or in connection with the works shall be made by the Principle whether or not water is found and/or irrespective of its quality.

13.2 Delay/Stoppages

The Contractor shall not be responsible for any stoppage or delay either in the commencement and/or completion of the works caused by strike, lockout, industrial disturbance, breakdown of plant and equipment (which will be remedied by the Drilling Contractor without undue delay) or any other cause beyond the Contractor's control. The Principle shall not be entitled to cancel or rescind this agreement or claim damages by reason of such stoppage or delay described herein.

13.3 Bore Specifications

The Contractor shall have the right to reduce the diameter of the bore if in the Contractor's sole discretion it is considered it would be impractical to continue to drilling without further reducing the diameter of the bore and further the Contractor shall not be required to drill into rock unless so specifically provided in this agreement.

13.4 Reports/Documents

The copyright subsisting in all drawings, reports, specifications, calculations and other documents provided by the Drilling Contractor is owned by the Drilling Contractor. The Company shall have a license to use the documents referred to above in connection with the works but shall not except as permitted by legislation and /or regulation use or make copies of the documents other than in connection with the works.

13.5 Licensed Driller

The initial Drilling License/Permit holder nominated by the Drilling Contractor is holder of License/Permit number [.........................]

14. Environment

14.1 The Contractor shall ensure that the impact on the environment during the course of the Services as a result of the actions of its employees, agents and invitees is kept to the minimum necessary, and that vehicular movement and travel is restricted to defined roads, tracks and the Site. These roads and tracks will be identified to the Contractor by the Company prior to commencing the Services.

14.2 The Contractor must handle and store all hydrocarbons in accordance with guidelines in Australian Standard AS 1940-2004.

14.3 The Contractor must supply and maintain spill kits at all times.

14.4 The Contractor must dispose of all waste in waste facilities licensed to accept each type of waste as generated by the Contractor's activities.

15. Loss

15.1 The Company acknowledges that the Contractor will not be liable to the Company for any delay in performance of the Services arising from any damage or loss of the Contractor's equipment referred to in this Agreement.

15.2 If a bore hole at the Site is lost or damaged due to other than the Contractor's default, the Principle is:

(a) solely responsible for the damage or loss to the hole, including the casing; and

(b) responsible for the costs of repairing the loss or damage, including payment to the Contractor of the applicable rate specified in this Agreement.

16. Representations and Warranties

16.1 The Contractor warrants to the Company that:

(a) It shall complete the Services in accordance with the terms of this Agreement using best industry practice and providing all appropriately qualified supervision at all time during the Term; and

(b) It has the required skill and expertise to carry out the Services and that the Contractor's employees, agents, consultants shall have all the relevant qualification and experience necessary to perform the Services.

16.2 The Company warrants to the Contractor that:

(a) It is a corporation duly incorporated, validly existing and in good standing under the applicable laws, with full corporate power and authority to own, lease and operate its business and properties and to carry on its business in the places and in the manner currently conducted or proposed to be conducted;

(b) The execution, delivery and performance of this Agreement (1) has been duly authorised by all requisite corporate actions; (2) to the best of its knowledge will not conflict with any provisions of Applicable Law; and (3) will not conflict with, result in the breach of, constitute a default under or accelerate performance required by any covenant, agreement, understanding, decree or order to which it is a party or by which it or any of its properties or assets is bound or affected;

(c) It holds all permits, certificates, licenses, clearances, approvals and other authorisations as are necessary for the conduct of its business and it is in compliance with the terms thereof and has not received any notice or claim pertaining to the failure to obtain, or the breach or violation of the terms of, any such authorisation;

(d) The Company is not insolvent and no liquidator, receiver or administrator has been appointed over any part of its assets and no such appointment has been threatened; and

(e) all information which has been given by or on behalf of the Company (or to any agent or adviser of the Company) with respect to the Agreement is true and accurate in all respects.

17. Indemnity Against Losses, Liabilities etc.

17.1 The Company indemnifies the Contractor against:

(a) loss of or damage to the Contractor's property and claims in respect of personal injury or death or loss of, or damage to, any other property arising out of or as a consequence of the Company or its consultants, agents or other contractors (not being employed by the Contractor) carrying out or failing to carry out the Company's obligations under this Agreement;

(b) any and all claims against the Contractor arising out of or in connection with the provision of the Services and which cause:

i. the destruction of, or loss or impairment of, any property or equipment or right in or to any resource or similar geothermal anomalies; or

ii. any loss or damage to any formation strata or geothermal anomaly beneath the surface; and

(c) any other cost, expense, loss, damage or other liability suffered or incurred by the Contractor, including any third party claim, caused by a breach of this Agreement by the Company.

but the indemnity will be reduced proportionally to the extent that any breach of this Agreement by the Contractor or any negligent act or negligent omission of the Contractor caused the injury, death, loss, damage, cost, expense or liability.

17.2 The total liability of the Contractor to the Company under this Agreement is limited to the total of the Contractor's Fee under this Agreement.

17.3 In addition to the Company's liability and obligations and the remedies provided elsewhere in this Agreement, the Company shall be solely responsible for any loss of or damage to the project, damage to environment, death or injury to person, and any other liabilities, damages, losses and reasonable cost and expenses (including legal costs) suffered by third parties in the following cases:-

(a) Resulting from any act, omission or negligence of the Company or any other person claiming through or under it, and their respective employee, agents and representatives;

(b) In connection with, arising out of, or resulting from any breach of warranty, material misrepresentation by the Company or any other person claiming through or under it, or non-performance of any term, condition, covenant or obligation to be performed by the Company under this Agreement.

17.4 The Company shall be liable for any loss or damage which occurs as a result of any act, event, omission, negligence or default (including property circumstances, quality of materials used, workmanship, structural, design or other defects, latent or patent, non- compliance with laws or regulatory requirements, specifications and standards or any other matter) for which the Company is liable or which is attributable to the Company.

17.5 The Company shall be responsible only to the extent the Company is responsible (in whole or in part) for the Loss to the Contractor's equipment, installations, materials, tools and supplies in the connection with the Services and the Company is liable for any damage, destruction, depreciation in value or theft of such equipment, installations, materials, tools and supplies.

18. Confidentiality

18.1 Subject to this clause the Contractor must only use the Confidential Information of the Company for the sole purpose of providing the Services and must not use, whether directly or indirectly, or turn to its advantage in any way or profit from the use of, the Company's Confidential Information or any part thereof, whether during the term of the Agreement or any time thereafter.

18.2 Subject to this clause, the Company must only use the Confidential Information of the Contractor for the sole purpose of fulfilling the Company's obligations under this Agreement and must not use, whether directly or indirectly, or turn to its advantage in any way or profit from the use of, the Contractor's Confidential Information or any part thereof, whether during the term of the Agreement or any time thereafter.

18.3 A party **(Recipient)** may reveal Confidential Information of another Party **(Provider)**:

(a) if required by law or by any stock exchange to disclose, in which case the Recipient must immediately notify the Provider of the requirement and must take lawful steps and permit the Provider to oppose or restrict the disclosure to preserve, as far as possible, the confidentiality of the Confidential Information;

(b) if the Confidential Information is in or enters the public domain for reasons other than a breach of this Agreement;

(c) if the Confidential Information is disclosed to the Recipient by a third party legally entitled to disclose that information and who is not under an obligation of confidentiality to the Provider; or

(d) to its professional advisers to obtain professional advice.

18.4 The Contractor will procure that its agents, employees and subcontractors abide by the provisions of this clause as if they were the Contractor.

18.5 The Company will procure that its agents, employees and subcontractors abide by the provisions of this clause as if they were the Company.

18.6 Each Party will immediately on demand deliver up to the other Party all copies of Confidential Information on any media that has been provided to it by the other Party.

18.7 Each Party will not, and will ensure that its employees, officers, contractors and agents do not, reverse engineer, decompile or disassemble any software or other products supplied to that Party by the other Party.

18.8 The Parties acknowledge that monetary damages may not be a sufficient remedy for any unauthorised disclosure of Confidential Information by a Party and that the other Party will be entitled, without waiving any other rights or remedies, to such injunctive or other equitable relief as may be deemed proper by a court of competent jurisdiction.

18.9 In this clause, "Confidential Information" means:

(a) in relation to both Parties, the valuable information, technical knowledge, intellectual property, financial data, rates, drilling program data, client contacts, databases and agreements, personnel contacts, data and employment records, research, development, business activities, services, processes or business or marketing plans, experience and data of a secret, commercially sensitive and confidential nature of each Party disclosed or provided in any form by any Party to any other Party in connection with the subject matter of this Agreement;

(b) in relation to the Contractor, the methods, machinery, plant, or any other information necessary or relevant to the drilling process or any other Intellectual Property Rights of the Contractor disclosed or provided in any form by the Contractor to the Principal in connection with the subject matter of this Agreement; and

(c) all information and documents generated by the Parties in connection with the provision of the Services or performance of either Party's obligations under this Agreement,

all of which are regarded as commercial assets of considerable value which if disclosed to a competitor or client or member of the public may have the potential to adversely affect the relevant Party's commercial operations and interests.

19. Loss

19.1 The Company is responsible at all times for:

(a) damage to or downgrading or destruction of the Contractor's equipment caused by:

i. a direction by the Company that the Contractor's equipment be operated at more than its rated capacity; or

ii. acts or omissions of the Company or any Company its employees, agents and invitees or the Company's contractors (other than the Company); and

(b) any damage to, no matter how caused, or loss of, the Contractor's drill string and down hole tools, provided this is not due to the negligence of the Contractor,

(c) and must reimburse the Contractor at the landed replacement or repair cost, having due consideration for the age and condition of such damaged or lost item(s) at Site, as evidenced by invoices or receipts provided by the Contractor.

19.2 The Company acknowledges that the Contractor will not be liable to the Company for any delay in performance of the Services arising from any damage or loss of the Contractor's equipment.

19.3 In addition to the Company's responsibilities set out in this Agreement, the Company will pay to the Contractor:

(a) the relevant standby with crew rate, specified in the Schedule, during the period of any repair or replacement of such damaged Contractor's equipment; and

(b) the relevant Services rate, specified in the Schedule, during any period in which attempts are made to recover any damaged or lost Contractor's equipment, including the drill string and down hole tools, provided that the Company may instruct the Contractor at any time in writing to cease attempts to recover any damaged or lost Contractor's equipment, provided this is not due to the negligence of the Contractor.

20. Default and Termination

20.1 If a Party:

(a) suffers an Insolvency Event; or

(b) breaches (in whole or in part) a material obligation under this Agreement and in the case of a breach capable of remedy has failed to remedy the breach within 14 days of receipt of notice from the non-defaulting Party requiring remedy of the breach,

it is a **"Defaulting Party"** and the non-defaulting Party may immediately terminate this Agreement by written notice to the Defaulting Party.

20.2 Termination of this Agreement is without prejudice to the accrued rights of either Party arising out of this Agreement prior to the date of termination and will not affect those clauses of this Agreement which are intended to survive the expiry or termination of this Agreement.

20.3 In this clause, "Insolvency Event" means:

(a) an administrator of the body corporate being appointed under the Corporations Act;

(b) the body corporate or a subsidiary executing a deed of company arrangement otherwise than for the purpose of an amalgamation or reconstruction;

(c) the entry by the body corporate into a scheme of arrangement or a composition with, or assignment for the benefit of, all or any class of its creditors, or a moratorium involving any of them, otherwise than for the purpose of an amalgamation or reconstruction;

(d) the body corporate being insolvent within the meaning of section 95A(2) of the Corporations Act;

(e) the appointment of a receiver or receiver and manager in respect of the body corporate or any part of its property;

(f) the making of a winding up order, or the passing of, or attempted passing of, a resolution for winding up, except for the purposes of reconstruction or amalgamation;

(g) an application being made (which is not dismissed within 10 days) for an order, a resolution being passed or proposed, a meeting being convened or any other action being taken to cause anything described above, other than for the purposes of an amalgamation or reconstruction; or

(h) anything analogous to or of a similar effect to anything described above under the law of any relevant jurisdiction.

20.4 If any event of default occurs which is set out in this Agreement the Contractor may by notice to the Company declare the Fee be immediately due and payable without further demand, notice or other legal formality of any kind. The Contractor may terminate this Agreement by delivering 3 months' prior written notice to the Company in case of the occurrence of the event of default as mentioned in this clause.

20.5 All obligations hereunder incurred prior to and which by their nature would continue beyond the cancellation, termination, or expiration of this Agreement shall survive such termination.

20.6 In the event of the termination of this Agreement under this clause, the Contractor shall remove from the machinery, goods and materials and be paid the Fee by the Company.

20.7 If a Party (the "Affected Party") by Force Majeure becomes unable to carry out an obligation under this Agreement strictly in accordance with this Agreement the Affected Party shall give notice to the other Party of such event of Force Majeure as soon as reasonably practicable, but not later than five(5) days after the date on which such Party knew or should reasonably have known of the commencement of the event of Force Majeure.

20.8 In the event of either Party giving a Force Majeure notice, the Parties must meet promptly or each party shall use reasonable endeavours to reach a mutually acceptable solution to alleviate any hardship or unfairness caused by either Party as a result of the circumstances constituting the Force Majeure.

20.9 If the Company fails to make payment due to the Contractor for a period of 14 days after the Contractor issues an invoice then the Contractor may terminate this Agreement upon 7 days' written notice to the Company, and recover from the Company payment for the Fee and for Materials, Equipment, tools, and machinery, including reasonable overhead, profit and all other consequential damages.

20.10 This Agreement shall be terminated by any one or more of the following events:

(a) At any time by written agreement between the parties;

(b) In the event the Company enters into liquidation whether compulsory or voluntary or otherwise then for the purpose of amalgamation or reconstruction or compromise with its creditors or having a receiver appointed over all or any part of its assets or taking or suffering any similar action in consequence of debt.

(c) By either party giving to the other party at least one [1] month's notice in writing of its intention to terminate this Agreement.

(d) If a party commits a breach or non observance of this agreement the other party may terminate this Agreement forthwith by giving notice in writing to the defaulting party.

20.11 Any such termination under this clause shall be without prejudice to the rights and obligations accrued under this Agreement prior to termination.

21. Entire Agreement

This Agreement constitutes the entire agreement between the Parties regarding the matters set out in it and supersedes any prior representations, understandings or arrangements made between the Parties, whether orally or in writing.

22. Assignment and Subcontracting

22.1 This Agreement is personal to each Party and neither Party may assign the rights or benefits of this Agreement to any person except:

(a) to a Related Entity; or

(b) to any other person,

with the prior consent of the other Party, which the other Party must not withhold if it is reasonably satisfied that the Related Entity or other person has sufficient assets, resources, expertise and the financial capability to perform all of the assigning Party's obligations under this Agreement.

22.2 In this clause, “Related Entity” means in respect of a Party, means each person:

(a) that is a Subsidiary of that Party;

(b) of which the Party is a Subsidiary; or

(c) that is a Subsidiary of a company of which the Party is also a Subsidiary.

22.3 In this clause, “Subsidiary” has the meaning given to it in the Corporations Act.

23. Alterations

This Agreement may be varied only by mutual consent given in writing.

24. Governing Law and Jurisdiction

This Agreement shall be governed by and construed according to the laws of the State or Territory in which the Services are undertaken and the Contractor hereby submits to the jurisdiction of the Courts of said State or Territory.

25. Waiver

A right created by this Agreement cannot be waived except in writing signed by the Party entitled to that right. Delay by a Party in exercising a right does not constitute a waiver of that right, nor will a waiver (either wholly or in part) by a Party of a right operate as a subsequent waiver of the same right or of any other right of that Party.

26. Legal expenses and Stamp Duty

26.1 Each Party must pay its own legal costs and disbursements in connection with the negotiation, preparation, execution and carrying into effect of this Agreement.

26.2 The Company must pay all stamp duty assessed on or in respect of this Agreement and any instrument or transaction required by or necessary to give effect to this Agreement.

27. Notices

27.1 A notice, consent or other communication under this document is only effective if it is in writing, signed and either left at the addressee’s address or sent to the addressee by mail, fax or email. If it is sent by mail, it is taken to have been received 3 Business Days after it is posted. If it is sent by fax or email, it is taken to have been received if no rejection has been received by the sender and:

(a) if it is transmitted by 5.00 pm (EST time) on a Business Day – on that Business Day; or

(b) if it is transmitted after 5.00 pm (EST time) on a Business Day, or on a day that is not a Business Day – on the next Business Day.

27.2 A person’s address and contact number are those set out below, or as the person notifies the sender:

The Company	**[INSERT]**
Address:	**[INSERT]**
Email Address:	**[INSERT]**
Tel Number:	**[INSERT]**
Attention:	**[INSERT]**
The Contractor	**[INSERT]**
Address:	**[INSERT]**
Email Address:	**[INSERT]**
Tel Number:	**[INSERT]**
Attention:	**[INSERT]**

28. GST

28.1 Words used in this Agreement that are defined in the GST Law have the meaning given in that legislation where used in this Agreement.

28.2 Unless otherwise specified, all amounts payable under this agreement are exclusive of GST and must be calculated without regard to GST.

28.3 If a supply made under this Agreement is a Taxable supply, the recipient of that Taxable supply (Recipient) must, in addition to any other consideration, pay to the party making the Taxable supply (Contractor) the amount of GST in respect of the supply.

28.4 The Recipient will only be required to pay an amount of GST to the Contractor if and when the Contractor provides a valid Tax invoice to the Recipient in respect of the Taxable supply.

28.5 If there is an adjustment to a Taxable supply made under this Agreement then the Contractor must provide an adjustment note to the Recipient.

28.6 The amount of a Party's entitlement under this Agreement to recovery or compensation for any of its costs, expenses, losses, damages or other liabilities is reduced by the input

28.7 Tax credits to which that Party is entitled in respect of those costs, expenses, losses, damages or other liabilities.

28.8 In this Agreement, "GST" means any form of goods and services Tax payable payable under the GST Law and "GST Law" means the A New Tax System (Goods and Services Tax) Act 1999 (Cth).

29. Exclusion of Warranties

29.1 Except for the express warranties set out in this Agreement and except to the extent that applicable law provides otherwise, the Contractor disclaims all warranties. To the maximum extent permitted by applicable law, all conditions and warranties that would be implied (by statute, general law, custom or otherwise) are expressly excluded.

29.2 If any condition or warranty is implied into this Agreement under the Competition and Consumer Act (Cth) or under any equivalent legislation, and cannot be excluded, the liability of the Contractor for breach of the condition or warranty is limited to one or more of the following, at the option of Contractor:

(a) in the case of goods:

i. the replacement of the goods or the supply of equivalent goods;

ii. the repair of the goods;

iii. the payment of the cost of replacing the goods or of acquiring equivalent goods; or

(b) the payment of the cost of having the goods repaired; or

(c) in the case of services:

i. the supplying of the services again; or

ii. the payment of the cost of having the services supplied again.

30. Arbitration

Disputes, which cannot be satisfactorily resolved by mutual negotiation between the Parties shall be adjudicated by arbitration in accordance with applicable legislation by a sole arbitrator acceptable to the Parties.

31. Time of the Essence

Time is of the essence as regards all dates, periods of time and times specified in this document.

32. Survival of Indemnities

Each indemnity in this document is a continuing obligation, separate and independent from the other obligations of the parties and survives termination of this document.

33. Enforcement of Indemnities

It is not necessary for a party to incur expense or make payment before enforcing a right of indemnity conferred by this document.

34. No Merger

The warranties, undertakings, agreements and continuing obligations in this document do not merge on Completion.

35. PPSA

35.1 Where the Contractor advises the Company that it requires security for the payment of its Contract fees, the Company agrees that this document:

(a) is a security agreement; and

(b) creates a security interest,

in any personal property offered by way of security by the Company for the purposes of the PPSA and will be construed so as to comply with the provisions of the PPSA and any other applicable laws.

35.2 The Company agrees that for the purpose of the PPSA, until the Contractor is paid in full, the Contractor has a security interest and the proceeds ("Proceeds") from any ("Proceeds") from any dealings with the Services (or part thereof) ("Security Interest").

35.3 The Company agrees that the Security Interest where possible, will enable but not oblige Us to register a Purchase Money Security Interest ("PMSI").

35.4 In this clause:

(a) PPSA means the Personal Property Securities Act 2009 (Cth);

(b) PPSR means the register established under section 147 of the PPSA; and

(c) The meaning of terms "security agreement" "security interest", "secured party", "perfected", "personal property", "possession", "collateral", "accession", "commingled" and "control" have the meanings given to them in the PPSA.

35.5 Whenever the Contractor requests that the Company does anything to ensure this Agreement and any security interest granted under it is fully effective, enforceable and perfected with the priority required by the Contractor, the Company must do it immediately at the Company's own cost. This may include:

(a) doing anything to make, procure or obtain any consent, authorisation, registration or approval in respect of anything, or to facilitate it;

(b) creating or executing (or procuring the creation or execution of) any document, including any form, notice, consent or agreement; and

(c) delivering documents or evidence of title or otherwise giving possession or control with respect to any personal property or other asset.

35.6 The Company shall:

(a) ensure that the Contractor's security interest is enforceable against third parties, perfected (within the meaning of the term 'perfect' under the PPSA) or otherwise effective;

(b) ensure that the security interest has the appropriate priority required by the Contractor (including where applicable as a 'purchase money security interest' under the PPSA);

(c) not register or permit to be registered any other security interest in respect of the personal property that comprises the collateral in respect of that security interest, other than one that has been consented to or granted by the Company;

(d) not give control of the collateral to a person other than the Contractor;

(e) not allow any collateral to become an accession to, or comingled with, any property that is not the collateral;

(f) not give or allow any person to have an interest in or security interest over the collateral; and

(g) not alter the collateral or do or omit to do anything else likely to diminish the value of the collateral.

35.7 To the extent this Agreement or the transactions contemplated by it create a security interest under the PPSA, the parties contract out of each provision of the PPSA which section 115 permits, other than sections 96, 117, 118, 120, 123, 126, 128, 129, 134(1) and 135, and any other provision of the PPSA notified by the Contractor to the Company.

35.8 Nothing in this clause or the provisions of the PPSA set out above shall derogate from the terms of this Agreement. Where relevant, the Contractor may determine whether it exercises a particular right or power under a provision of this Agreement or under the PPSA.

35.9 The Company waives its right to receive:

(a) each notice which section 144 or 157 permits it to waive and, to the extent capable of being waived, notice under any other provision of the PPSA; and

(b) (anything from the secured party under section 275 and the Company agrees not to make any request of the secured party under that section.

35.10 For the purposes of section 275 of the PPSA, the parties agree that neither the Contractor nor the Company may disclose any information of the kind referred to in section 275(1) of the PPSA.

35.11 The Contractor may disclose Confidential Information:

(a) for the purposes of enforcing this Agreement, in a proceeding arising out of or connected with this Agreement or to the extent that disclosure is regarded by the Contractor as necessary to protect its interests under this Contract;

(b) as required by any government agency or any procedure for discovery in any proceedings;

(c) as required under Law (except that this clause does not require or allow the Contractor to disclose any information of the kind referred to in section 275(1) of the PPSA); or

(d) to its legal advisers and consultants.

35.12 This clause survives the expiry or termination of this Agreement.

Counterparts

This Agreement may be executed in two counterparts. All counterparts when so executed shall be effective for the purpose of binding the Parties hereto, and both of which shall together constitute the same instrument.

EXECUTED as an Agreement on the Commencement Date.

Executed by **[Company]** [**ACN**] in accordance)
with Section 127 of the *Corporations Act 2001*)

Signature of Director	Signature of Director/Secretary
Name of Director	Name of Director/Secretary

Executed by **[Contractor]** [**ACN**] in accordance)
with Section 127 of the *Corporations Act 2001*)

Signature of Director	Signature of Director/Secretary
Name of Director	Name of Director/Secretary

SCHEDULE 1 – PROJECT SCOPE

Commencement Date	**[INSERT AS TENDERED]**
Period	**[INSERT AS TENDERED]**
End Date	**[INSERT AS TENDERED]**
Services	**[INSERT AS TENDERED]**
Company	**COMPANY NAME:** **ACN:** **REGISTERED ADDRESS:** **WEBSITE:**
Company Representative	**NAME:** **POSITION:** **EMAIL ADDRESS:** **POSTAL ADDRESS:** **TELEPHONE NUMBER:**
Project Scope	**[INSERT AS TENDERED]**
Project Specifications	**[INSERT AS TENDERED]** i. The type of well development and yield evaluation procedures to be used ii. The type of screen to be installed, where needed iii. The type of well cap or seal to be provided

SCHEDULE 2 – RIGS AND EQUIPMENT

Part 2 – Rigs and Equipment

2.1 Rig and Equipment (Availability / Timing)

[INSERT AS TENDERED]

2.2 Casing and Screens

Provide and install casing and suitable slotted screen or other screen at a diameter of;

[EXAMPLE ONLY BELOW]

2.2.1	Casing (nominal)	......................mm I/D
2.2.2	Screens	......................mm I/D
2.2.3	Special Screens	......................mm I/D

SCHEDULE 3 – SCHEDULE OF RATES OR LUMP SUM FEE

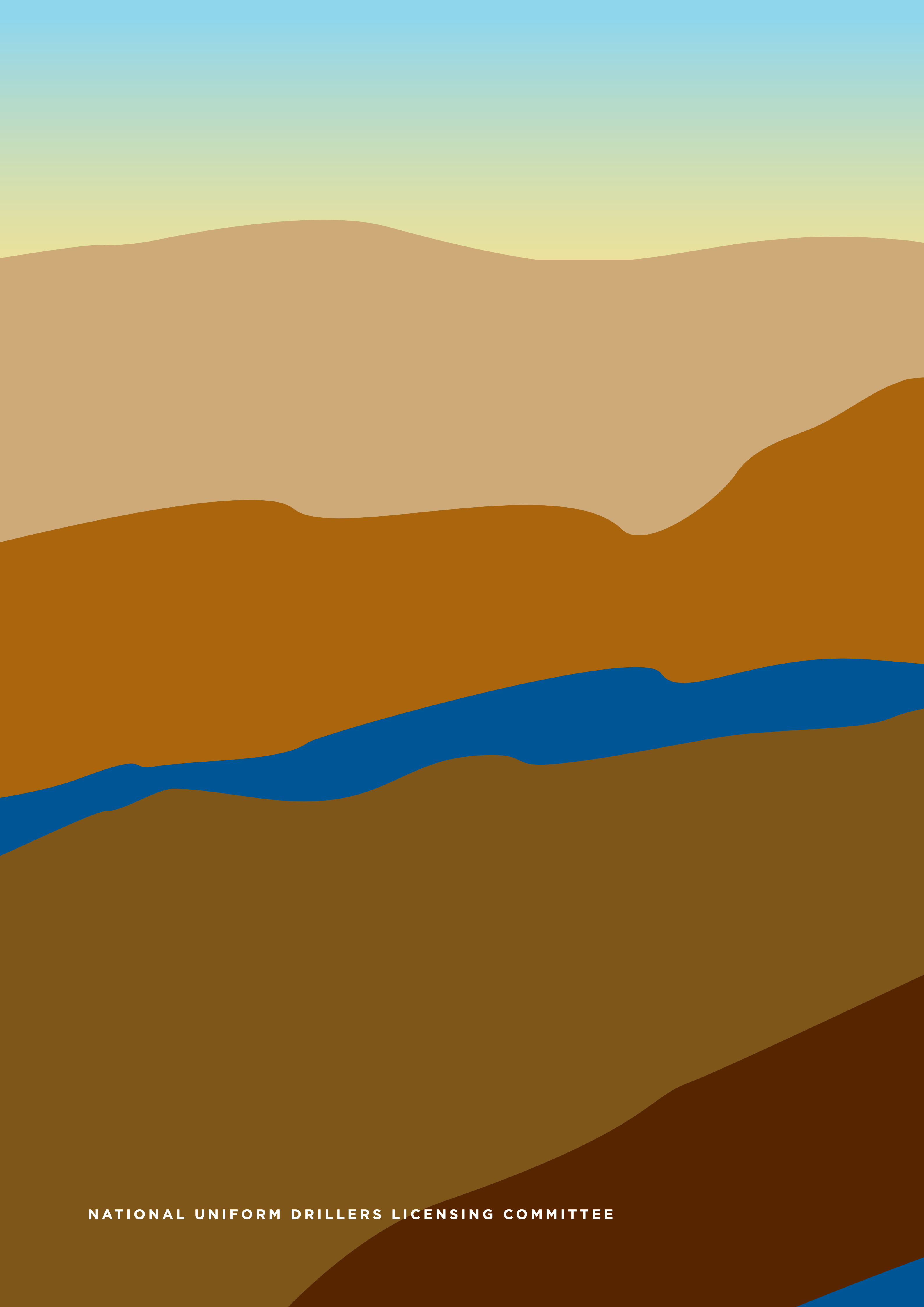
Schedule of Rates

Item	Description	Fee	
1.1	Mobilization to site	$	
1.2	Drilling of bore	$	per metre
1.3	Supply, delivery and installation of casing and accessories	$	nominal mm I/D at per metre
1.4	1. Supply and delivery of screens 2. Gravel pack (if required)	$	nominal mm I/D at per metre
1.5	Development including all development work on the bore, testing for alignment, removing casing, cementing and reinstatement	$	per hour
1.6	Drilling into rock	$	per metre
1.7	Standby rates where the rig and crew are idle due to the orders of the Principle or waiting on sieve analysis and/or water analysis	$	per hour
1.8	Testing of the bore, including establishment	$	per hour
1.9	All other materials, tools, equipment rates	$	

OR

Lump Sum Agreement

2.1	Make full payment to the Drilling Contractor on the completion of the works the sum of; …………………………………………………………	$



NATIONAL UNIFORM DRILLERS LICENSING COMMITTEE