DZ 4411:2026

New Zealand Standard

Environmental standard for drilling of soil and rock

Superseding NZS 4411:2001

Public Consultation Draft

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Referenced documents

Reference is made in this document to the following:

New Zealand standards

NZS/BS 21:1985 Specification for *pipe threads for tubes and fittings where pressure-tight joints are made on the threads* (metric dimensions)

NZS/BS 1387:1985 Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads

NZS 2403:2015 Code of practice for deep geothermal wells

NZS 3107:1978 Specification for precast concrete drainage and pressure pipes

NZS 3122:1995 Specification for Portland and blended cements (General and special purpose)

NZS 3122:2009 Specification for Portland and blended cements (General and special purpose)

NZS/BS 3601:1987 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

Joint Australian/New Zealand standards

AS/NZS 1477:2017 PVC pipes and fittings for pressure applications

AS/NZS 1554:- - - - Structural steel welding

Part 1:2000 Welding of steel structures

AS/NZS 1579 Arc-welded steel pipes and fittings for pressure applications AS 2634 Chemical plant equipment made from glass-fibre reinforced plastics (GRP) based on thermosetting resins

AS/NZS 3518:2013 Acrylonitrile butadine styrene (ABS) compounds, pipes and fittings for pressure applications

AS/NZS 3879:2011 Solvent cements and priming fluids for PVC (PVC-U and PVC-M) and ABS and ASA pipes and fittings

AS/NZS 4058:2007 Precast concrete pipes (pressure and non-pressure)

AS/NZS 4765:2017 Modified PVC (PVC-M) pipes for pressure applications

American standards

API 5L-B specification for carbon steel line pipe transporting oil, gas, and water

API 5CT:1988 specification for casing and tubing

API Q1 Quality Management System Requirements for Organizations Providing Products for the Petroleum and Natural Gas Industry

Australian standards

AS 1396:2000 Steel water bore casing

British standards

BS 7159 Code of practice for design and construction of glass-reinforced plastics (GRP) piping systems for individual plants or sites

International standards

ASTM A106-99E1 standard specification for seamless carbon steel pipe for high-temperature service

ASTM A312M standard specification for seamless, welded, and heavily cold worked austenitic Stainless steel pipes

ISO 9001 Quality management systems

Other publications

Brown, L J. *New Zealand Water Well Driller's Guide to Logging Water Wells*. New Zealand Geological Survey Report 145. 1990.

Government Inquiry into Havelock North Drinking Water. *Report of the Havelock North Drinking Water Inquiry: Stage 2*. Auckland: Government Inquiry into Havelock North Drinking Water, 2017.

Mining Inspection Group, Ministry of Commerce. *Health and Safety Guidelines for Shallow Geothermal Wells*. Wellington: Ministry of Commerce, 1996.

National Uniform Drillers Licensing Committee. *Minimum construction requirements for water bores in Australia*. 4th ed. 2020.

New Zealand Geotechnical Society. *Guidelines for the Field Classification of Soil and Rock for Engineering Purposes*. Wellington: New Zealand Geotechnical Society, 2005.

New Zealand Geotechnical Society. *NZ Ground Investigation Specification* volume 1. Wellington: New Zealand Geotechnical Society, 2022.

New Zealand legislation

Hazardous Substances and New Organisms Act 1996

Resource Management Act 1991

Water Services Act 2021

Websites

www.legislation.govt.nz

www.nems.org.nz

Review of standards

Suggestions for improvement of this standard will be welcomed. They should be sent to the National Manager, Standards New Zealand, PO Box 1473, Wellington 6140.

Foreword

This version of this standard was updated in 2025 and 2026 in order to align the minimum national environmental requirements for drilling of soil and rock with updated national and international best practice.

This version supersedes the previous version of the standard, NZS 4411:2001 Environmental standard for drilling of soil and rock.

The 2017 *Report of the Havelock North Drinking Water Inquiry* recommended the revision of this standard to 'update it to current international best practice and to extend its scope to cover all life cycle aspects of bores and casings relevant to drinking water'.

1 General

1.1 Introduction

The objective of NZS 4411 is to protect groundwater resources and preserve water quality, thereby safeguarding groundwater from potential contamination associated with drilling activities.

The standard aims to provide:

(a) A comprehensive framework for ensuring drilling activities are conducted in a manner that minimises risk to groundwater resources; and
(b) Information to bore owners, drilling contractors, regulatory authorities, and any others who may be involved in the drilling, construction, maintenance, and decommissioning of bores.

The standard sets the minimum environmental requirements and applies to all activities involving the drilling of soil and rock, except those identified as out of scope. To address the inherent natural variability of lithology and hydrogeology across New Zealand, the standard is performance-based to provide a degree of flexibility as to how the minimum requirements can be met. This includes identifying how these requirements may be applied to drilling activities that are short term (temporary) and long term (permanent) in application.

It is expected that the minimum requirements may be used by regulatory authorities as rules in regional and district plans, or as conditions to resource consents. It is also expected that regulatory authorities may have local requirements that would be considered additional to the minimum requirements. It is recommended that people relying on this standard check local plans and rules related to bore drilling before commencing any work.

Informative content has been included to give guidance and recommended best practices to help users understand and implement the minimum requirements.

The standard requires that both drillers and bore owners familiarise themselves with all sections of this document and with all applicable regulations or requirements of the relevant local and regional authorities prior to commencing drilling.

NOTE –

(1) Temporary bore installations are limited to the duration of the physical drilling activity/task (for example, exploration, investigation, in-situ testing) – no installations remain post-drilling, the bore is decommissioned on completion, and the sealing characteristics of the lithology are suitably reinstated.

(2) Permanent bore installations extend beyond the duration of the physical drilling activity/task (for example, seismic conduits, monitoring bores, water bores) – installations remain post-drilling and are suitably completed/constructed/protected to ensure the environmental protection of New Zealand's groundwater resource.

1.2 Scope

The scope of this standard includes any drilling activity that presents a direct or indirect risk of contamination to groundwater sources.

The following types of drilling activities are included in this standard:

(a) Exploration drilling;
(b) Geotechnical drilling;
(c) Environmental investigative drilling;
(d) Penetrometer testing (for example, electric friction cone penetrometers, flat plate dilatometers, dynamic cone penetrometers);
(e) Drilling for the installation of instrumentation (including vibrating wire piezometers, inclinometers, extensometers, standpipes, monitoring bores);
(f) Drilling for the installation of groundwater supply bores (including permanent dewatering bores);
(g) Drilling for the installation of injection bores;
(h) Repurposing of existing drilled bores for another purpose and remaining in scope (for example, irrigation bore to become a drinking water supply bore); and
(i) Any other activity similar to that described above.

The following types of drilling activities are excluded in this standard:

(a) Drilling of blast holes, seismic shot holes, or similar where the hole will be destroyed on completion;
(b) Drilling for the installation of oil and gas bores;
(c) Drilling for the installation of landfill gas/leachate extraction bores;
(d) Drilling for the installation of geothermal bores with a temperature > 70°C;
(e) Drilling for the installation of piles/foundations;
(f) Drilling for soakage holes and offal holes; and
(g) Any other activity similar to that described above and dissimilar to that identified as in scope.

Notwithstanding the above activities that are outside the scope of this standard, the minimum requirements would still be considered appropriate where adverse effects on groundwater resources and/or quality may be had.

1.3 Interpretation

For the purposes of this standard, the word 'shall' refers to requirements that are essential for compliance with the standard, whereas the word 'should' refers to practices that are advised or recommended.

Specifically:

‘Shall’ indicates a requirement (normative);

‘Should’ indicates a recommendation (informative);

‘May’ indicates a permission (informative);

‘Can’ indicates a possibility or a capability (informative).

1.4 Definitions

For the purposes of this standard the following definitions shall apply.

Annulus	The space between the casing and the wall of the hole, or outer casing
Aquifer	Saturated rock or soil material capable of transmitting and yielding water in quantities sufficient for abstraction
Artesian bore	Groundwater confined under pressure in an aquifer so that the water in a bore intersecting the aquifer will rise above the top of the aquifer
Artesian flowing bore	A bore deriving its water from a confined aquifer in which the water level is above the land surface
Bore	Any hole regardless of the method of formation that has been constructed to provide access to the ground (for example, for the monitoring of ground or groundwater conditions, or extraction of groundwater)
Bore owner	Owner or operator of a bore or purchaser of drilling service(s); includes an agent or technical representative of the bore owner
Casing	A tube used as a temporary or permanent lining for a bore
Decommission	To permanently abandon a bore by backfilling and sealing
Development	The removal of rock and soil materials from within the bore and the aquifer immediately surrounding a bore, to remove drilling

	cuttings/fluids, to minimise the migration of soil materials during groundwater abstraction, and/or to increase bore efficiency
Driller	Company or person engaged by the bore owner to undertake a service(s) related to this standard.; includes the bore testing technician, engineer, or pump supplier
Drilling	Method of boring a hole into the ground, predominantly by rotating, percussive, or washing action; excludes excavation of pits by digging, blasting, or other forms of excavation, driven posts or driven solid piles
Drilling fluid	Water or air-based fluid (liquid or gas) used in the drilling process; includes additives
Drilling project	Overall scope of drilling required by the bore owner or representative (for example, geotechnical investigation, water bore construction)
Low environmental impact	Pertaining to any product or substance that does not leave a residual toxicity
Geotechnical	Pertaining to the investigation of soil/rock for engineering purposes
Geothermal water	Water heated by the earth to temperatures in excess of 30°C; includes water, steam and water vapour, and geothermal energy
Gravel pack	Material designed to provide a transitional zone in the annulus between a bore screen and the surrounding lithology to retain the soil materials and enable pore fluids (that is, groundwater) to pass freely
Groundwater	Water found in soil and rock
Grout	A fluid mixture of cement and/or bentonite and water used to provide a watertight seal in a bore annulus or hole
Headworks	All materials used at the ground surface to complete the bore; includes pipework, valves, gauges and access points, concrete pads, and/or chambers
Hole	Any hole that is created by drilling
Investigation	Drilling of a temporary nature to investigate subsurface conditions
Lithology	The character of soil or rock formations; the ‘layering’ of soil and rock formations where each layer has a particular set of characteristics that differentiates it from those above and below
Local authority	A council with statutory responsibility for resource management; includes regional councils, unitary authorities, district councils, and city councils
Permanent bore	Bore installations that extend beyond the duration of the physical drilling activity/task (for example, seismic conduits, monitoring bores, water bores), suitably completed/constructed/protected to ensure

	the environmental protection of New Zealand's groundwater resource
Production (inner) casing	An innermost continuous string of pipe (casing) that is inserted into or immediately above the chosen aquifer and extends back to the surface, through which water is extracted or injected
Rising main/column	A pipe used to convey water from within the bore to the ground surface when using a submersible pump and/or a surface pump
Screen	Slotted or perforated material used to retain the aquifer lithology and/or gravel pack while allowing groundwater to pass easily into the bore
Surface (outer) casing	The outermost pipe initially inserted into the hole
Temporary bore	An installation limited to the duration of the physical drilling activity/task (for example, exploration, investigation, in-situ testing, construction-related dewatering), after which no installations remain, the bore is decommissioned, and the lithology is suitably reinstated in a timely fashion
Toxic	Capable of causing ill-health in, or injury to, human beings and/or ill-health, injury, or death to any living organism
Tremie	A watertight tube used to place grout or backfill
Well	See 'bore'
Wellhead	See 'headworks'

1.5 Abbreviations

Abbreviations have the following meanings:

FRE	Fibreglass reinforced epoxy
FRP	Fibreglass reinforced plastic
GRE	Glass reinforced epoxy
PN	Pressure nominal
uPVC	Unplasticised polyvinyl chloride

2 Preliminary and general

2.1 Administrative

2.2.1 *Principle*

To ensure that drilling contractors and bore owners recognise and understand the standard's administrative requirements and adhere to the administrative requirements of regulatory authorities.

Additional local administrative requirements may apply in addition to the administrative requirements of the regional regulatory authorities.

2.2.2 *Minimum requirements*

The drilling contractor or bore owner shall enquire with both the local and regional regulatory authority to understand how drilling activities are classified for regulatory purposes; including, specifically, whether a resource consent is required under the current resource management legislation. If it is required, the driller or bore owner shall apply for and obtain the necessary resource approvals prior to undertaking the physical drilling activity/task. In all situations the drilling contractor and bore owner shall ensure that the minimum requirements and local/regional regulatory authority conditions are satisfied.

Where required by the local/regional authority, each bore shall be assigned a unique identifier by the regulatory authority. The driller shall reference the identifier on all documentation/records produced from the drilling activity/task (for example, bore logs, construction reports, aquifer test data, water quality reports).

Upon completion of the physical drilling activity/task, a report containing the minimum reporting information shall be prepared by the drilling contractor for the bore owner and if required submitted to the regulatory authority (see 2.2).

2.2 Record keeping

2.2.1 *Principle*

To provide accurate and informative information about the drilling activity/task to facilitate reporting to bore owners, drilling contractors, and/or regulatory authorities, or any other appropriate person or organisation.

2.2.2 *Minimum requirements*

Information shall include:

(a) The geographical location of the bore (address, area, map coordinates);
(b) The resource consent/permit reference (issued by a regulatory authority) or permitted activity status;
(c) The unique bore identification number (issued by a regulatory authority or alternative);
(d) The date(s) of when work was undertaken (start and finish);
(e) The purpose of the work (new bore, maintenance, refurbishment, testing, decommissioning, investigation);
(f) The adopted drilling method(s);
(g) A description of the lithology encountered as applicable (soil and rock description): see 3.3;
(h) A description of the hydrogeology as applicable (depth(s) where groundwater was encountered, measured yields and drawdowns, water quality);
(i) Details of permanent materials and equipment used in the completed bore as applicable (dimensions, materials, depths and types of screens, casings, backfill/seal materials and instrumentation and the method of installation and protection where applicable);
(j) The dimensional measurements of the completed bore (drilled depth, diameter(s)); and
(k) An as-built record of bore construction, including surface seal(s), headworks.

2.2.3 *Good industry practice*

Information can include:

(a) The name and address of the driller;
(b) The names of personnel on site;
(c) The name of the person preparing the drilling log;
(d) The name of the bore owner;
(e) Elevation and orientation of the hole, if not vertical;
(f) The timings and depths at which drillers encounter groundwater and drilling breaks;
(g) Records of losses or gains in drilling fluid;
(h) The depth, a description and the results of any in-situ testing and sampling undertaken; and
(i) The aquifer test and water quality results undertaken on completion, if applicable.

Here is an example of a bore logging driller's report: https://www.ecan.govt.nz/document/download?uri=3150003.

2.3 Experience and training

2.3.1 *Principle*

To ensure that drilling activities/tasks are carried out by people who are appropriately qualified and have relevant experience in accordance with industry best practice.

2.3.2 *Good industry practice*

Bore owners should select competent drilling contractors and practitioners with appropriate training, qualification, experience, and valid affiliation/membership/registration with recognised industry groups relative to the activity/task to be undertaken.

Recognised industry groups include:

(a) The New Zealand Drillers Federation;
(b) The Australian Drilling Industry Association; and
(c) Any other recognised industry groups.

Recognised qualifications include:

(d) New Zealand Certificate in Drilling (Levels 3–4);
(e) New Zealand Drillers Federation Drillers Registration (Drillers Assistant, Driller, and Senior Driller); and
(f) Any other relevant qualifications.

3 Bore construction

3.1 Siting/positioning

3.1.1 *Principle*

To ensure bore owners and drilling contractors consider relevant and practical factors when selecting bore sites, such as proximity to contamination and differing risk profiles for temporary versus permanent use.

3.1.2 *Minimum requirements*

Bore owners and drilling contractors shall take account of:

(a) Landowner permission requirements;
(b) Conditions regarding location specified in the bore permit and local authority requirements;
(c) Flood hazard risk, including ponding areas and overland flow paths;
(d) Below-ground conditions as applicable (for example, artesian pressures, geothermal activity, land fill, gases, contamination);
(e) Land usage (current/historic/future) and risk of the bore to and from surrounding activities (animals, stock, cultivation, earthworks, construction, landfill, traffic, industrial activities);
(f) Proximity to structures, underground/overhead services, and the ability to maintain/preserve space and access during bore construction and for future bore maintenance or decommissioning as relevant;
(g) Any nearby archaeological sites, to prevent any activity which may modify, damage, or destroy pre-1900 archaeological sites; and
(h) Sites that are on culturally sensitive land and may require consultation with local iwi.

Bores shall be positioned a suitable distance from known possible sources of contamination or, if this is not possible, designed and constructed to prevent all sources of contamination degrading the installation and/or otherwise entering the bore.

3.1.3 *Good industry practice*

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

Noting any relevant (local and national) regulations, and the purpose of the bore, bores should be positioned:

(a) A suitable distance away from legal boundaries;
(b) Away from the influence of possible sources of contamination; for example, a septic tank, effluent discharges, refuse dumps, herbicide/pesticide use, or preparation areas. Local or regional councils manage land use registers, which list properties that have been or are currently used for activities that may contaminate soil, water, or groundwater;
(c) A suitable distance from human drinking water bores/areas, to the satisfaction of the owner of the existing supply bore(s)/area;
(d) A sufficient distance from coastlines, streams, rivers, or lakes such that surface water is prevented from migrating into the bore (unless the bore is specifically intended and designed to intercept surface water); and
(e) A suitable distance away from geothermal features.

The construction and drilling methodology should always consider and mitigate the associated risks for that bore, such as corrosion resistance, groundwater contamination, and access requirements for future use and maintenance of the bore. Where sites have a known contamination source, a suitable bore design (for example leachate extraction or environmental monitoring bores) should be adopted so as not to exacerbate contamination migration.

3.2 Drilling method(s)

3.2.1 *Principle*

To ensure drilling contractors and bore owners consider whether drilling method(s) are appropriate for the site lithology/hydrogeology and the purpose of the bore.

To ensure drilling method(s) protect the groundwater resource and prevent contamination of an aquifer, cross-contamination between multiple aquifers, and/or uncontrolled artesian flow.

3.2.2 *Minimum requirements*

Where flowing artesian conditions may be encountered, the drilling method(s) selected shall include pressure control capability.

Where a bore construction may include drilling through multiple aquifers, the drilling method(s) selected shall prevent cross-contamination.

An appropriate drilling method(s) shall be selected which prevents contamination of an aquifer and/or uncontrolled artesian flow.

3.2.3 *Good industry practice*

Drilling contractors and bore owners should choose drilling methods that are suitable for the anticipated lithology/hydrogeology to:

(a) Enable the advancement of a bore to the desired target depth;
(b) Ensure the completed bore is appropriate to its desired purpose and intended duration of use;
(c) Establish and maintain down-hole conditions to support effective lithological sampling to recover representative samples (soils and pore fluids) as required to describe and identify the lithology in a fit-for-purpose manner; and
(d) Support the suitable construction of a temporary/permanent bore installation or reinstatement of the same.

Table 1 sets out common drilling methods.

Table 1 – Common drilling methods, suitability, and applications

Principle of operation	Suitable ground conditions	Advantages	Disadvantages
Sonic drilling			
Uses high-frequency, resonant vibratory energy transferred to the drill string and bit. This causes the ground particles at the bit face to fluidise, allowing for rapid advancement.	Unconsolidated lithologies, sand, gravel, glacial till, cobbles, boulders. Can also penetrate softer rock.	High penetration rates, excellent core recovery in unconsolidated lithologies, minimal fluid use, can often drill without casing in unstable ground.	Specialised and expensive equipment, less effective in very hard rock.
Rotary mud drilling			
A rotating drill bit cuts through the ground, and drilling fluid (mud) is circulated down the drill pipe to cool the bit, lubricate the hole, and carry cuttings to the surface. Many variations in methodology fall under this category.	Wide range of soil conditions, including fine particles, soft rock, sand, gravel, and bedrock.	Fast and efficient for deep wells, provides borehole stability in loose lithologies. Can be configured for obtaining undisturbed samples. Allows for larger diameter holes.	Requires significant water supply, generates drilling mud waste that needs disposal, slower than air rotary in some conditions, can contaminate samples if mud is not properly formulated.
Rotary air drilling			
Similar to rotary mud, but compressed air (sometimes with water or foam) is used as the circulating medium to remove cuttings.	Hard rock lithologies, competent soils, lithologies where water is scarce.	Fast penetration rates in hard rock, cleaner process than mud rotary (less waste), good for identifying water-bearing zones, cost-effective in suitable conditions.	Not effective in unconsolidated or wet lithologies (borehole collapse risk), can be noisy, can create dust if not managed properly.
Cable tool drilling			
A heavy drill bit is repeatedly raised and dropped by a cable, using a percussive action to break and crush the ground. Cuttings are periodically removed with a bailer.	Soft to medium-hard rock lithologies, unconsolidated materials, shallow to moderate depths.	Simple, rugged, low equipment cost, versatile for various well types (water wells).	Slow penetration rates, limited depth capabilities, difficult to obtain continuous samples, borehole instability in loose lithologies (no constant fluid support).
High-pressure rotary air with down-hole hammer			
Combines rotary action with a percussive hammer located at the bottom of the drill string, powered by high-pressure compressed air. The air also flushes cuttings.	Very hard rock lithologies, fractured ground, abrasive conditions.	Extremely efficient in hard rock, high penetration rates, good for straight holes, clean boreholes due to air flushing.	Requires powerful air compressors, not suitable for soft or unconsolidated ground, can have higher operational costs.

Principle of operation	**Suitable ground conditions**	**Advantages**	**Disadvantages**
Rotary core drilling			
Utilises a rotating, annular (ring-shaped) drill bit (often diamond-impregnated) to cut and retrieve a cylindrical core sample of the subsurface material.	Soils with cohesion and all rock types, especially where continuous geological samples are required.	Provides high-quality core samples for geological and geotechnical analysis, excellent for understanding rock structure and composition.	Slower and more expensive than open-hole drilling, specialised bits are costly, requires careful handling of core samples.
Auger drilling			
A helical screw (auger) is rotated and advanced into the ground, bringing excavated material to the surface along its flights. Can be solid or hollow stem.	Soft, unconsolidated soils (clays, silts, sands), above the water table.	Simple, relatively inexpensive, quick for shallow depths, provides continuous (with hollow stem) soil samples, minimal drilling fluids.	Limited depth, not suitable for hard rock or consolidated materials, can be difficult in very wet or caving conditions, samples can be highly disturbed with solid flight augers.

Table 2 is a broad guide to common drilling methods and their applications. Drilling contractors may employ a mix of drilling methods to successfully construct a bore. It is important to recognise that hydrogeological conditions associated with these lithologies may not support the application.

Table 2 – Drilling methods and their applications

Type of lithology	Auger	Cable tool drill	Rotary mud	Rotary air	Sonic	Rotary air with down-hole hammer
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
Loose coarse gravels and boulders	Not suitable	Suitable (if casing driven)	Difficult–slow, sometimes impossible	Not suitable	Suitable	Not suitable
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 gneiss	Not suitable	Not suitable	Slow	Slow	Not suitable	Suitable
Fractured ignimbrites	Not suitable	Not suitable	Slow	Slow	Not suitable	Suitable
Granite	Not suitable	Not suitable	Suitable	Suitable	Not Suitable	Suitable

3.3 Lithological sampling and logging

3.3.1 *Principle*

To ensure that a comprehensive and representative record or 'log' of lithologies and lithological changes encountered during bore drilling is produced and recorded by the driller.

3.3.3 *Minimum requirements*

Reliable information on specific lithology and aquifer conditions at the bore location is required to establish the best design for the various elements of a bore. The driller shall record this information in the bore completion report.

The bore completion report shall be supplied as required by the local authority and a copy provided to the bore owner.

3.3.4 *Good industry practice*

Good industry practice for lithological sampling and logging is as follows:

(a) Representative lithological samples should be taken to determine the nature and type of strata encountered;
(b) Sampling methods should be suitable to provide a representative sample of the soil and/or rock for the purpose of visual classification; and
(c) Classification of lithology should be in accordance with recognised standards such as the 2005 New Zealand Geotechnical Society *Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes* and Brown, L J *New Zealand Water Well Driller's Guide to Logging Water Wells*.

Further classification should be in accordance with the New Zealand Geotechnical Society's *NZ Ground Investigation Specification* volume 1.

The driller should describe and identify the lithology in a fit-for-purpose manner to inform the application of environmental requirements and the associated decision-making process for bore construction and decommissioning. For example, identifying soils of low and/or high permeability would enable an understanding of where seals would be required to prevent the potential vertical movement of water between aquifers, to inform the design of any proposed installations or the decommissioning of the bore on completion.

Samples should be collected:

(a) As soon as possible;
(b) At regular intervals and whenever there is a change in the lithology encountered;
(c) Laid out in a chronological order so that depth intervals can be identified; and
(d) Drained of excess moisture.

To support the receipt of representative lithology samples during the drilling process, the drilling method should maintain optimal up-hole velocity throughout the drilling of the bore (see Table 3).

Table 3 – Recommended (optimum) up-hole velocities

Fluid type	Up-hole velocity (m/sec)	Up-hole velocity (m/min)
Air or mist	15–25	900–1500
Water	0.6	36
Mud	0.4	24
Thick mud	0.3	18
Foam	0.2	12

3.4 Drilling fluids

3.4.1 *Principle*

To ensure that drilling fluids have a low environmental impact and minimise contamination of the lithology and/or groundwater. Examples of drilling fluids are down-hole lubricants, drilling muds, and additives.

3.4.2 *Minimum requirements*

The drilling fluids selected shall be:

(a) Inert, with a low environmental impact;
(b) Not a hazardous substance in terms of the Hazardous Substances and New Organisms Act 1996; and
(c) Supported by published material safety sheets and used in accordance with manufacturers' guidelines.

The use of substances (products) for drilling fluids that appear not to meet minimum requirements shall be at the discretion of the local or regional authority.

3.4.3 *Good industry practice*

All base water used for, and in preparation of, a drilling fluid should be obtained from a known source and sufficiently clean to avoid contamination of the groundwater. Where practical, water should be clean and uncontaminated.

Drilling additives should be carefully selected with the intended purpose of the bore in mind and able to be adequately neutralised, removed, and/or disposed of if needed (for example, chlorides should not be used if steel casing is used; sulphides should not be used if cement is to be used).

Chemicals and other drilling fluid additives that could pose an unacceptable risk to the environment based on their persistence, bio-accumulative potential, and toxicity should not be added to any drilling fluids and cement slurries.

Drilling fluids should be selected and managed to:

(a) Facilitate the drilling process;
(b) Ensure the removal of cuttings from the borehole; and
(c) Minimise damage to the lithology.

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

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

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

The equipment for testing drilling fluid includes:

(a) Mud balance for fluid density;
(b) Marsh funnel for viscosity;
(c) Filter press for filtration and wall cake; and
(d) Sand content set for sand content.

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

- Water-based drilling fluids; and
- 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.

To maintain the cleanliness of the hole, drilling fluid circulation viscosity should be as shown in Table 4.

Table 4 – Suggested Marsh funnel viscosities for unconsolidated materials

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

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.

3.5 Drilling waste/discharge

3.5.1 *Principle*

To ensure that drilling related waste is controlled, captured, and disposed of in an appropriate manner.

Examples of drilling-related waste include spoil, cuttings, arisings, drilling muds, and development water.

3.5.2 *Minimum requirements*

Minimum requirements are as follows:

(a) All drilling-related waste shall be captured and disposed of in an appropriate manner onsite or offsite and in accordance with any regional authority regulations (for example, erosion and sediment control rules);
(b) Any contaminated soils or hazardous waste shall be disposed of at a licensed facility;
(c) Suitable storage capacity for waste generation and/or facilities to treat waste before moving offsite shall be provided within site boundaries; and
(d) Disposal of drilling fluids shall avoid discharge to surface waters or any other sensitive receiving environment.

3.5.3 *Good industry practice*

Granular, cohesionless, and clean (free of fines) cuttings produced from drilling can be considered as a suitable material for bore reinstatement or annular backfill to minimise offsite disposal.

Inground pits, settlement tanks, solids control units, filtration cells, and flocculation dosing equipment are considered to be proactive measures to manage drilling waste and discharge.

Figures 1 and 2 show solids control units.

Figure 1 – A solids control unit

Figure 2 – Solids control units

3.6 Cleaning/disinfection

3.6.1 *Principle*

To minimise the exposure of groundwater and the completed bore to any new contamination pathways.

3.6.2 *Minimum requirements*

All equipment used in the drilling of soil and rock and any associated activity/task of bore construction, testing, maintenance, and decommissioning shall be cleaned/decontaminated after use and between respective boreholes.

3.6.3 *Good industry practice*

Soil should be removed from equipment and tools by washing, water blasting, and/or steam cleaning followed by disinfection.

Drillers and land/bore owners 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 has an iron bacteria problem, bore and drilling equipment should be thoroughly disinfected at the completion of drilling (of each separate bore, in the case of a bore field) as this is a critical component of the overall management strategy to stop the transfer of bacteria between bores and locations.

In areas where iron bacteria could be an issue, equipment should be washed with a chlorine solution. Disinfection protocols include using 0.02–0.1% (200–1,000 mg/L) active chlorine solutions and application by thorough surface spraying and/or full immersion. Full immersion and enough time for the compound to react is most effective.

All potable water supply bores should be disinfected on completion.

See relevant local authority guidelines regarding use of potential bore treatment chemicals.

3.7 Construction materials

3.7.1 *Principle*

To ensure that materials used for the construction of bores are suitable for the application.

3.7.2 *Explanatory*

Materials used for the construction of bores should have sufficient strength, composition, and durability to withstand operations during the physical construction and subsequent work, and take account of environmental considerations below and above ground.

3.7.3 *Minimum requirements*

Casing materials shall demonstrate:

(a) The strength required to support lithology pressures and minimise the potential for external collapse;
(b) Resilience to weakening from external factors such as sunlight (UV), corrosion by soils/water, electrolysis, cold/heat, and impact;
(c) Compatibility with fluids used during drilling, construction materials such as cement grout, and/or other chemicals/substances considered for potential maintenance, decommissioning, or similar tasks/activities; and
(d) The capability to accommodate instrumentation, sampling equipment, submersible pumps, and associated influences such as changes in water level, flow rates, vibration, and so on.

Casing joints shall be watertight and achieve the same minimum standards as the casing itself.

The use of casing shall comply with the manufacturer's recommendations according to Table 5.

Table 5 – Casing materials minimum standards

Casing material	Minimum standard
Steel	API 5L-B (American Petroleum Institute's specification for carbon steel line pipe transporting oil, gas, and water) or AS/NZS 1396 Steel water bore casing or AS/NZS 1579 Arc-welded steel pipes and fittings for pressure applications
uPVC	AS/NZS 1477 PVC pipes and fittings for pressure applications PN6 pressure pipe has insufficient strength and must **not** be used as bore casing.
FRP	AS 2634 Chemical plant equipment made from glass-fibre reinforced plastics (GRP) based on thermosetting resins or BS 7159 Code of practice for design and construction of glass-reinforced plastics (GRP) piping systems for individual plants or sites and ISO 9001 Quality management systems equivalent
GRE	API Q1 Quality Management System Requirements for Organizations Providing Products for the Petroleum and Natural Gas Industry
Stainless Steel	ASTM A312M Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

NOTE – uPVC is unplasticised polyvinyl chloride.

The minimum acceptable casing wall thickness shall be according to Table 6 below.

Table 6 – Casing minimum wall thickness

Steel

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

Stainless steel

Nominal diameter (mm)	Minimum wall thickness (mm)	
	Schedule 10	Schedule 40
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

Fibreglass

Nominal diameter (mm)	Minimal wall thickness (mm)	Operating collapsible pressure (kPa)	Maximum 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	16 530
250	11	1590	4540	29 290
300	12.5	1410	4360	39 820
350	15.5	1630	4580	59 200
400	17	1470	4420	74 180
450	18.5	1450	4390	88 940

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.

uPVC

Pressure nominal (PN)	Unconsolidated lithology (metres head)	Consolidated lithology (metres head)
9	26	60
12	56	110
15	100	200
18	200	300

NOTE –

(1) uPVC should be de-rated in pressure when temperature exceeds 20°C.

(2) 'Metres head' refers to the maximum difference between external and internal water levels (includes fully grouted and gravel packed casing).

(3) The tables for minimum wall thickness for stainless steel, FRP. and FRE are based on their having similar collapse pressure to steel casing of the same diameter (see Table 7 below).

(4) In the 'Stainless steel' section of this table, 'Schedule' refers to the American Petroleum Institute specifications, which state: 'Schedule 10 pipes are thin-walled, lightweight piping often used in low-pressure, corrosion-resistant, or structural applications, adhering to ASME B36.10M/B36.19M and API 5L specifications'.

3.7.4 *Good industry practice*

Common types of casing used in bores are:

(a) Steel;
(b) uPVC;
(c) Fibreglass (FRP and GRE); and
(d) Stainless steel.

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

3.7.3.1 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:

(a) It is often stronger;
(b) It can be pressure-cemented to greater depths because of its higher collapse strength;
(c) It can withstand high temperatures;
(d) It is available in large diameters; and
(e) It can withstand rougher treatment.

Steel casing is available in different wall strength classes: Schedule 10, 20, and 40 the most commonly available classes. Schedule 40 has the higher strength and is suitable for critical assets, deep bores, and larger diameter bores, while Schedule 10 and 20 are generally only used in less critical assets or shallow bores. A disadvantage of steel is that its life can be reduced in a corrosive environment; for example, where there are corrosive soils, water, or galvanic action arising from the use of dissimilar materials in the bore.

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

3.7.3.2 uPVC (unplasticised polyvinyl chloride)

uPVC pipe 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 uPVC pipe suitable for use as bore casing is pressure-rated pipe manufactured to conform to NZS/AS 1477 PVC pipes and fittings for pressure applications. This New Zealand and Australian standard is for pipe that is rated for potable water supply.

uPVC pipe that conforms to AS 1477 uses a pressure nominal (PN) rating, which indicates the pressure rating of the pipe. This provides a guide to the external collapse pressure.

PN6 pressure pipe has insufficient strength and must **not** be used as bore casing. PN12+ pipe is the recommended casing for most bore construction applications.

Internal diameter needs to be taken into consideration for pump selection and installation.

uPVC has certain advantages over other types of materials. It is:

(a) Non-corrosive;
(b) Readily available in some sizes, particularly small diameters;
(c) Light and easy to handle and join; and
(d) Inert.

uPVC 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.

uPVC 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.

(a) uPVC casing requires care in handling, storage, and installation to prevent breakage and/or distorting its shape;
(b) Plastic parts installed above the ground must be protected from damage (for example, moving vehicles, contact with drilling tools, fire);
(c) the impact strength of uPVC casing may be reduced significantly over time from extended exposure to UV rays;
(d) Occasionally uPVC casing will float in a bore during installation, thus creating special handling problems;
(e) The short-term strength of uPVC casing is much higher than its strength over time; therefore the driller should consider the long-term forces of the lithology on the casing;
(f) Changes to differential pressure and temperature ratings may result from cementing;

(g) Volatile organic chemicals may permeate the casing and enter the bore if they are in contact with uPVC casing; and
(h) Care is needed during backfilling or gravel packing, as any voids in the backfill or gravel pack may lead to a sudden collapse of lithology materials against the casing, causing the casing to collapse.

3.7.3.3 Fibreglass

'Fibreglass' is a generic term 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). The different types of fibreglass casing can vary in the manufacturing process used and the type of resin systems applied.

GRE is manufactured by manufacturing facilities with an API Q1 licence; this guarantees its conformance and quality. It is generally the highest grade of fibreglass casing available; it has a higher tensile strength, higher external collapse pressure, and higher collapse strength to weight ratio than steel. It has been used to depths up to 3000 m.

FRP is not necessarily constructed to meet the API Q1 standards. It can be custom engineered to meet different requirements; for this reason, 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. When using FRP, casing specifications should be checked prior to use.

The minimum casing wall thickness required for 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 fibreglass casing may vary, all fibreglass has a high level of corrosion resistance and resistance to extreme temperatures.

All forms of fibreglass casing are constructed with swelled joints, and therefore additional annular space may be required. Other forms of casing may have flat joints.

3.7.3.4 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 commonly available in New Zealand and 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; Schedule 10 and Schedule 40 are the most commonly available classes. Schedule 40 has the higher strength and is suitable for deep bores and larger diameter bores; Schedule 10 is generally only used in shallow bores.

3.7.3.5 Collapse resistance for pipes or casings

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 pressure at which the pipe wall will fail. Casing that is subjected to a high enough pressure externally (or differential pressure) will collapse.

For uPVC, the maximum appropriate differential pressures 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 lithologies at which 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.

A comparison of the typical strengths of casing materials is shown in Table 7.

Table 7 – Comparative strengths of bore casing materials

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

NOTE –

(1) Higher temperature ratings may be achieved for FRP using special resins.

(2) The impact strength of steel and stainless steel is so high relative to uPVC and to the demands during construction that it is generally not a design consideration

Differential pressures can arise as a result of lithology pressures, cementing, development, and pumping. The expected differential pressure in plastic casing will determine the wall thickness.

Table 8 specifies maximum potential pressure differentials for uPVC bore casing. PN 9 uPVC pressure pipe is the minimum class allowed for use as bore casing. PN 6 uPVC pipe and uPVC sewer, PVC-O, PVC-M, and drainage pipe shall not be used.

Table 8 sets out uPVC strength deratings by temperature.

Table 8 – uPVC strength de-rating by temperature

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

3.8 Screens

3.8.1 *Principle*

To ensure that screens are used to support the lithology while providing openings in the bore casing to enable water entry into the bore.

To ensure that the method of completion across the water entry zone of the bore allows efficient entry of water into the bore, stabilises the lithology, and prevents unacceptable ingress of materials from the lithology.

3.8.2 *Minimum requirements*

Screen materials with the following properties shall be selected:

(a) The strength required to support lithology pressures and minimise the potential for external collapse;
(b) Resilience to weakening from external factors such as corrosion by soils/water, electrolysis, cold/heat, and impact;
(c) Compatibility with drilling fluids used during drilling, backfill materials, and/or other chemicals/substances considered for potential maintenance, decommissioning; or similar tasks/activities; and
(d) Capability to accommodate instrumentation, sampling equipment, submersible pumps, and associated influences, such as changes in water level, flow rates, vibration, and so on.

Screens shall be selected to:

(e) Maximise the free passage of pore fluids/gases;
(f) Minimise the free passage or migration of existing lithology or backfill materials; and
(g) Minimise the potential for clogging.

Screen joints shall have the same structural integrity as the casing itself.

3.8.3 *Good industry practice*

Common types of screen used in bores are:

(a) Slotted uPVC;
(b) Slotted steel;
(c) Perforated steel; and
(d) Wrapped stainless steel wire (wedge wire).

Each of these screen types have different properties in relation to column, collapse, and tensile strengths; resistance to corrosion; reaction to ground and water chemistry; and temperature

Screens can be either 'telescopic', where the screen is of a smaller diameter than the casing, or 'in-line', where the casing and the screen are of the same diameter.

Screens can be selected with different aperture sizes to match finer or coarser layers in the surrounding lithology (see 4.2).

3.9 Annular backfill materials

3.9.1 *Principle*

To ensure that the materials used to backfill a bore are appropriate for the bore and have a low environmental impact.

3.9.2 *Minimum requirements*

Materials used to backfill a bore and/or backfill the annular space external to the casing, screen, or instrumentation shall be:

(a) Inert and with a low environmental impact;
(b) Free from chemicals or substances that have the potential to leave a residual toxicity;
(c) Free from material that may decay, derogate, or disintegrate during or after installation;
(d) Placed in a controlled manner to provide continuous lithology contact/support without bridging and void creation; and
(e) Supported by published material safety sheets and used in accordance with manufacturers' guidelines.

3.9.3 *Good industry practice*

3.9.3.1 Gravel pack

The following guidelines apply to gravel pack.

(a) Gravel pack should consist of washed, well-rounded gravel of selected grain size and gradation. Angular crushed stone or rock is not recommended;
(b) Gravel pack material placed in the annular space slightly below and adjacent to bore screens should extend above the screen to allow for settlement during development;
(c) The height of the gravel pack should be checked regularly to confirm correct placement;
(d) To ensure the effective placement of granular backfill materials, the receiving borehole should provide a minimum of 25 mm external radial clearance for installations less than 100 mm diameter and 50 mm clearance for installations greater than 100 mm diameter;
(e) Pre-made ('prepack') gravel pack screens can be a useful option; and
(f) Wherever practicable, backfilling should match the properties of the natural lithology. Consideration should be given to material size, density, compaction, and porosity.

See section 4.

3.9.3.2 *Grout*

Where possible, grout mixes should be placed using a bottom-up displacement method (tremie). Grout mixes should consist of calculated quantities of ingredients and be prepared in a manner to provide consistency and support ease of placement. To ensure the effective placement of flowable backfill materials, the receiving borehole should provide a minimum of 25 mm external radial clearance for all installations. Table 9 sets out recommended cement–water mixes by number of bags of cement.

Table 9 – Recommended cement–water mixes

Number of 20 kg bags of cement	Litres of mixing water	Litres of grout	Specific gravity
1	15	21.30	1.64
1	12.5	18.83	1.72
1	10	16.33	1.83

NOTE –

(1) 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 (that is, without other additives).

(2) Plasticiser cement additive can be used to improve and extend the workability of the mix and reduce friction while pumping grouts of high specific gravity.

Table 10 sets out recommended cement–bentonite–water mixes.

Table 10 – Recommended cement–bentonite–water mixes using Portland (GP) cement

Number of 20 kg bags	Bentonite in mix (%)	Mass of bentonite (kg)	Volume of water (litres)	Yield (litres)	Specific gravity	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	
1	4	0.8	25	31.65	1.45	
1	5	1.0	27.5	34.23	1.42	Firm

NOTE –

(1) Mixing instructions: mix bentonite into water first, and then add cement

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

(3) 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.

(4) Bentonite volumes given here are only a guide: mixes can be affected by water quality.

(5) Bentonite used in the mixes should API grade

Table 11 provides sample quantities for grouting bore casing, to make 1 m³ of grout.

Table 11 – Cement/bentonite grout mix

Bentonite kg	Cement kg	Bentonite/cement ratio (%)	Litres of water	Specific gravity	Hardness
0	1226	0.0%	609	1.84	Very hard
11.4	984	1.2%	682	1.68	↕
15.2	903	1.7%	707	1.62	
22.8	741	3.1%	755	1.52	Very firm

30.3	580	5.2%	804	1.41	
34.1	499	6.8%	828	1.36	Firm
45.5	257	17.7%	901	1.20	Plastic

3.10 Bore sealing

3.10.1 *Principle*

To:

(a) Protect groundwater quality and preserve aquifer pressures;
(b) Isolate the targeted aquifer zone from other lithological zones to avoid cross-contamination; and
(c) Prevent surface water run-off, shallow subsoil contamination, or pollution reaching the aquifers.

3.10.2 *Minimum requirements*

The minimum requirements for bore sealing are as follows:

(a) All bores shall be sealed to protect the production zone against contamination;
(b) All bores shall be sealed from the surface to not less than 5 m deep. In cases where the ‘production zone’ is less than 5 m below ground level, the sealing shall be from 1 m above the production zone to the surface; and
(c) When sealing the casing in artesian conditions, the casing shall be seated into competent impermeable strata or to a suitable depth to achieve the equivalent control.

For water supply bores, see 4.2.2 for additional minimum requirements.

3.10.3 *Good industry practice*

All permanent and temporary bores should be sealed at surface and at depth (subsurface) to maintain, as closely as practicable, the sealing characteristics of the natural lithology.

Subsurface seals should extend to an appropriate depth below ground level or to a zone of low permeability lithology. Surface seals should be integrated into subsurface seals. In multiple aquifer bores, there should also be a seal between the aquifers to prevent intermixing.

Sealing should include the annular space between the casings and the bore. Sealing, including any required top-up cement, should be completed before the drilling rig leaves a work site.

Where grouted, bores should be sealed with cement grout having a minimum annular thickness of 20 mm above the maximum diameter of the casing. This can be obtained using centralisers.

When sealing the surface control casing, unrestricted circulation should be obtained down the casing and up the annulus prior to pressure grouting.

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

Consideration should be given to how to hydrate bentonite pellets or chips where used above the water table.

The bores should be protected during/throughout construction to avoid contaminants entering the bore.

Injection bores should be fully grouted from the top of the production zone back to the surface (for more information, see 5.2).

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

Centralisers should be used to ensure a uniform and sufficient cement seal thickness. Centralisers should be spaced at a suitable interval to maintain alignment and be of sufficient strength to withstand construction and grouting processes.

3.11 Headworks

3.11.1 *Principle*

To ensure that bores are sealed and protected at the surface and can support operational functionality.

3.11.2 *Minimum requirements*

Minimum requirements for headworks are as follows.

(a) All headworks shall satisfy the requirements and conditions of regulatory authority permits/consent;
(b) All permanent bores shall be equipped with a durable, secure, lockable, water- and vermin-proof cap, together with headworks, air vents, and any other apertures;
(c) All bores with equipment installed and cables/conduits (or similar) passing through the bore cap shall meet the water- and vermin-proof requirement;
(d) All bores that provide a direct pathway to groundwater shall be completely sealed to prevent the entry of contaminants in the event of headworks inundation (including provision for backflow protection through cables/conduits);
(e) All permanent bores shall have impermeable plinths constructed around the bore and angled away to prevent pooling of surface water;
(f) All permanent bores shall display a clear label to enable identification of the unique bore number; and
(g) Reasonable security measures shall be in place to protect the bore head from unauthorised access or interference.

3.11.3 *Good industry practice*

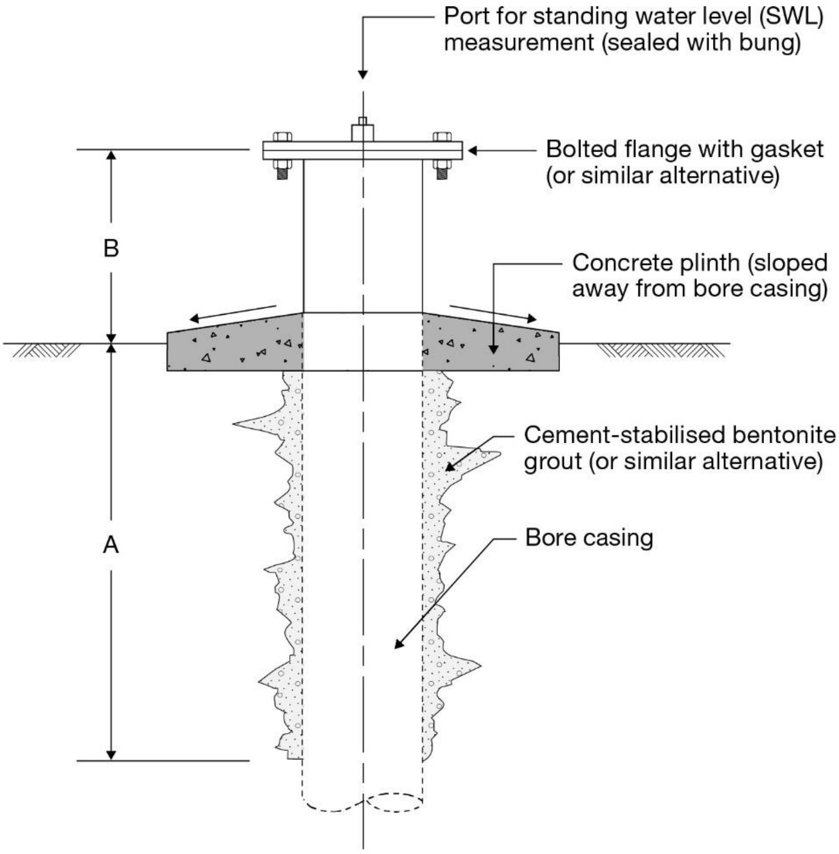
Wherever practicable, headworks should be positioned above ground and suitably identified. A means of protection should be provided against potential damage (for example, vandalism, vehicle impact, animals).

Where headworks are positioned below ground level, they should be contained in a robust chamber of suitable size to provide ease of access/egress for operational and maintenance requirements. The chamber should be sealed or covered, with a means of drainage (passive or active) to prevent headworks inundation by surface water and/or shallow groundwater intrusion, or operational leakage/spillage of groundwater.

Headworks should support ease of access to the bore for its intended use/application and maintenance requirements, including monitoring.

The impact strength of uPVC casing may be reduced significantly over time from extended exposure to UV rays.

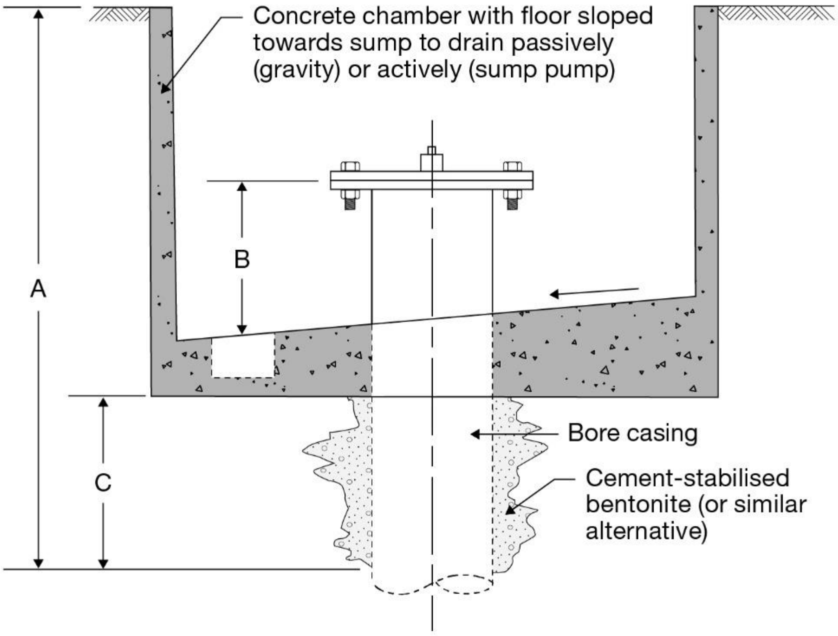
Figures 3, 4, 5, and 6 show some basic/standard bore completions.



A. Dimension to suit minimum sanitary seal depth and/or depth to closest confining layer. A minimum depth of 6 m is good practice for drinking water supply

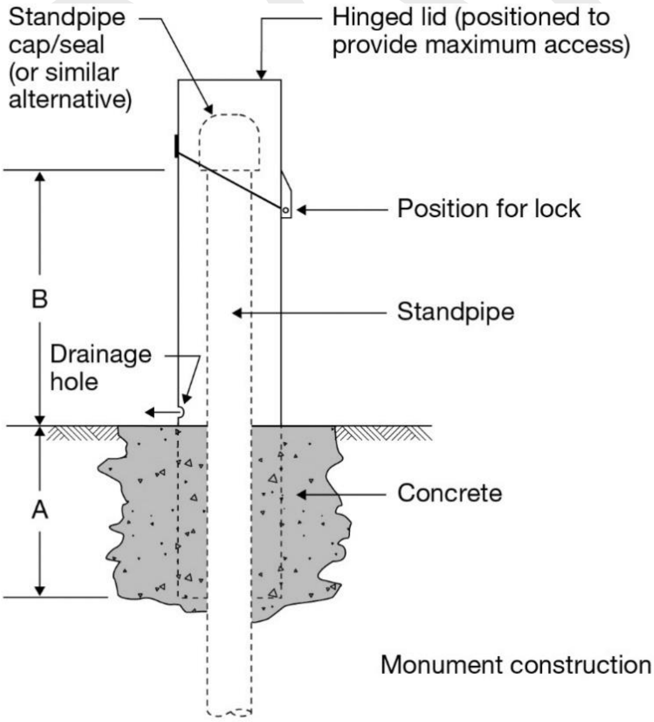
B. Dimension to suit minimum above concrete plinth of at least 0.3 m

Figure 3 – Basic/standard bore completion (above ground – no instrumentation)



C. Dimension to suit minimum depth below underside of chamber floor of 1 m

Figure 4 – Basic/standard bore completion (below ground – no instrumentation)



A. Dimension to provide secure embedment for monument

B. Dimension to suit minimum above-ground level of at least 0.5 m

Figure 5 – Basic/standard piezometer/standpipe construction (above ground)

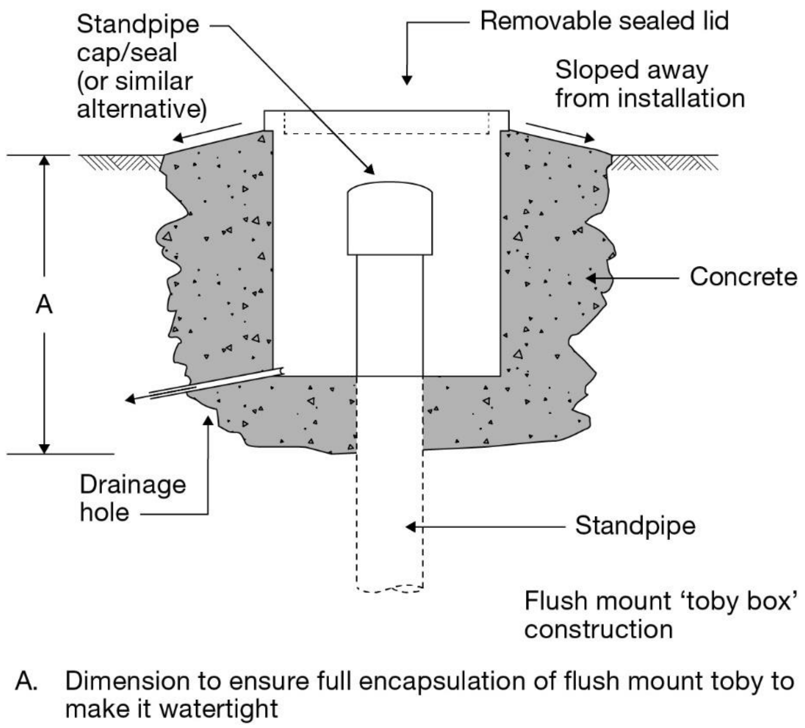


Figure 6 – Basic/standard piezometer/standpipe construction (below ground)

3.12.1 *Decommissioning*

3.12.1.1 *Principle*

To ensure that temporary and/or permanent bores are decommissioned and reported appropriately to mitigate the long-term risk of the bore contaminating groundwater resources.

To ensure that failed, temporary, or unwanted bores are restored as far as practicable to the aquifer isolation that existed before the bore was drilled and constructed.

3.12.1.2 *Minimum requirements*

Minimum requirements for decommissioning are as follows:

(a) All temporary bores shall be decommissioned on completion of the physical drilling activity/task;
(b) All permanent bores shall be decommissioned at the end of operational use or prior to the end of their useable lifespan, whichever is first;
(c) Decommissioning shall involve backfilling the bore in a manner to suit the lithology/hydrogeology and to reinstate the functionality of the original lithology;
(d) Backfilling shall include sealing low-permeability horizons within lithologies with similar or lower permeability materials, and conversely backfilling high-permeability horizons within lithologies with similar permeability materials;
(e) In all situations, backfilling shall include sealing to an appropriate depth below ground surface with a suitably low-permeability material (such as bentonite/cement grout) – or to the maximum drilled depth, if appropriate;
(f) Complete and accurate records shall be kept of the decommissioning procedure and submitted to the bore owner and regulatory authority on completion (refer reporting); and
(g) All temporary bores should be decommissioned on completion by backfilling and sealing to effectively reinstate the natural lithology.

3.12.1.3 *Good industry practice*

Reasons for decommissioning a bore include the following:

(a) The bore is no longer required;

(b) The bore is no longer suitable;
(c) The bore casing has deteriorated, and integrity cannot be restored;
(d) The bore is unsealed and/or abandoned; and
(e) The bore exhibits signs of uncontrolled flow at surface or below surface.

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:

(f) The construction of the bore;
(g) The geological lithologies encountered;
(h) The hydrogeological conditions;
(i) Regulatory requirements;
(j) Eliminating any physical hazard (for example, filling in open holes) to avoid injury and harm to people and animals;
(k) Preventing entry of any surface fluids and contaminants that may lead to contamination of groundwater; and
(l) Preserving the security of aquifers by preventing the intermixing of groundwater between aquifers (see 3.10 for guidance on sealing between separate aquifers/lithology.

Decommissioning by placing selected clean backfill from the bottom of the bore to the surface is the preferred method for all bores, including ‘bottom-up’ or tremie grouting. Fresh grout returns at surface indicates successful application, when using tremie grouting. Blinding sand should be used as a transition between coarse clean backfill and grout.

Figures 7, 8, 9, and 10 illustrate the decommissioning of various types of bore.

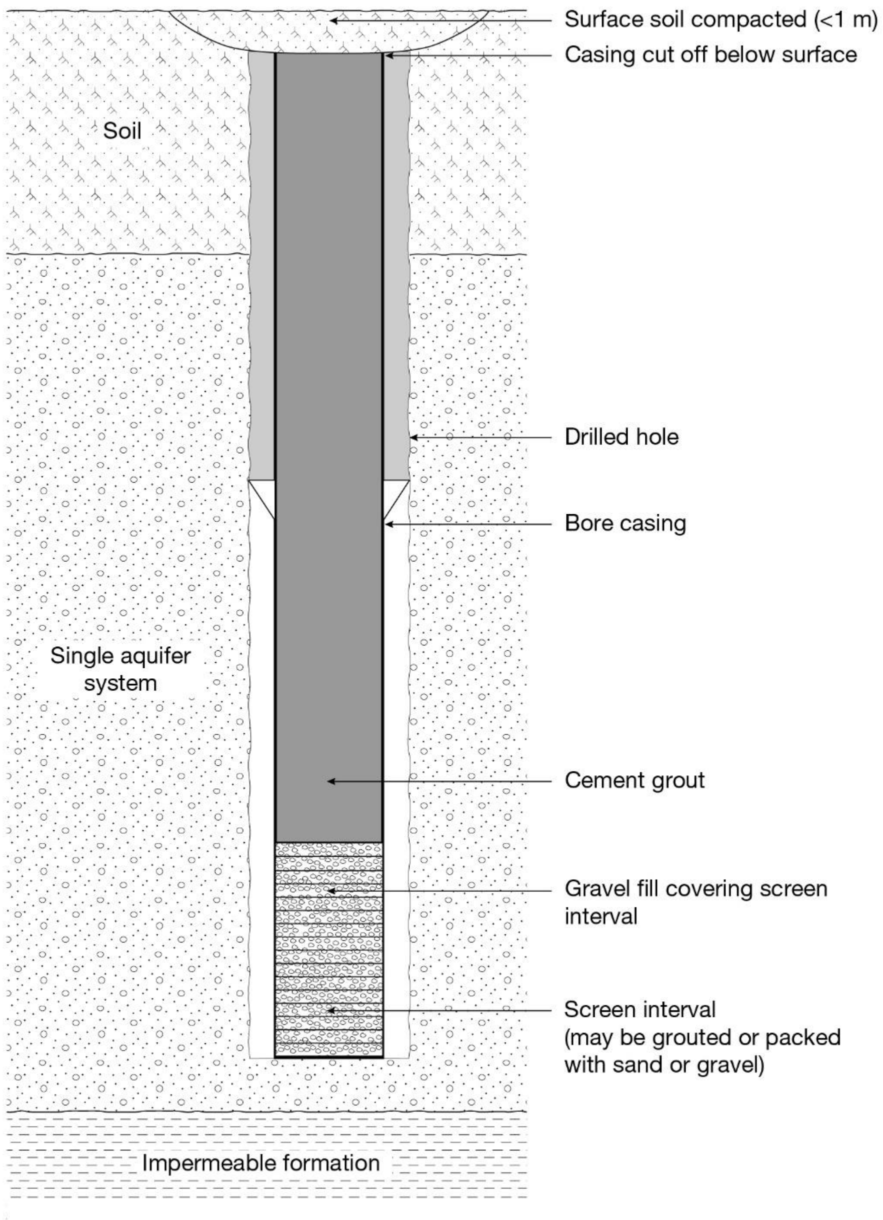


Figure 7 – Decommissioning a single-aquifer bore by fully grouting (preferred method for all bores)

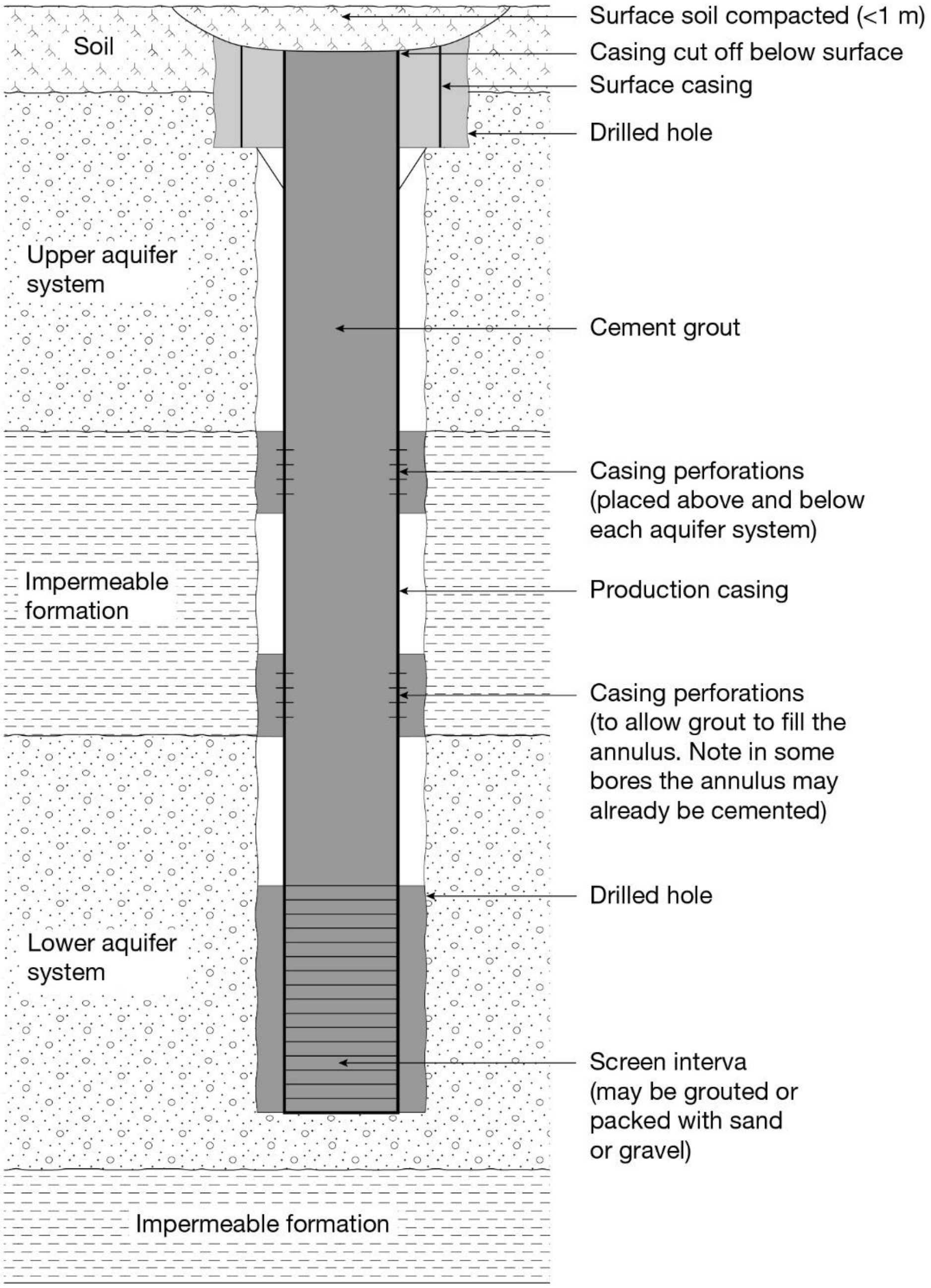


Figure 8 – Decommissioning a multiple-aquifer bore by fully grouting (preferred method for all bores)

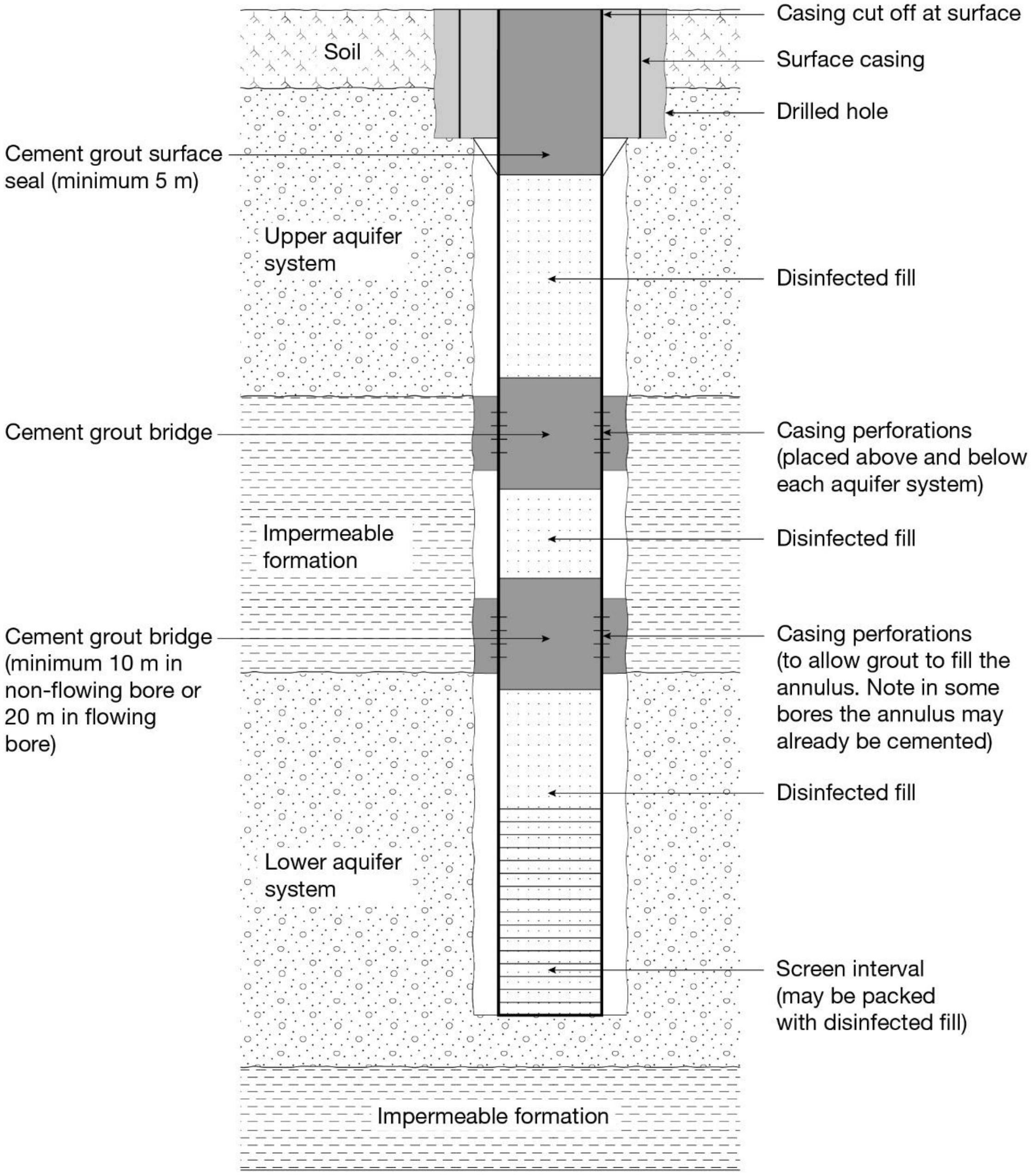


Figure 9 – Decommissioning a multiple-aquifer bore by cement grout bridges

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.

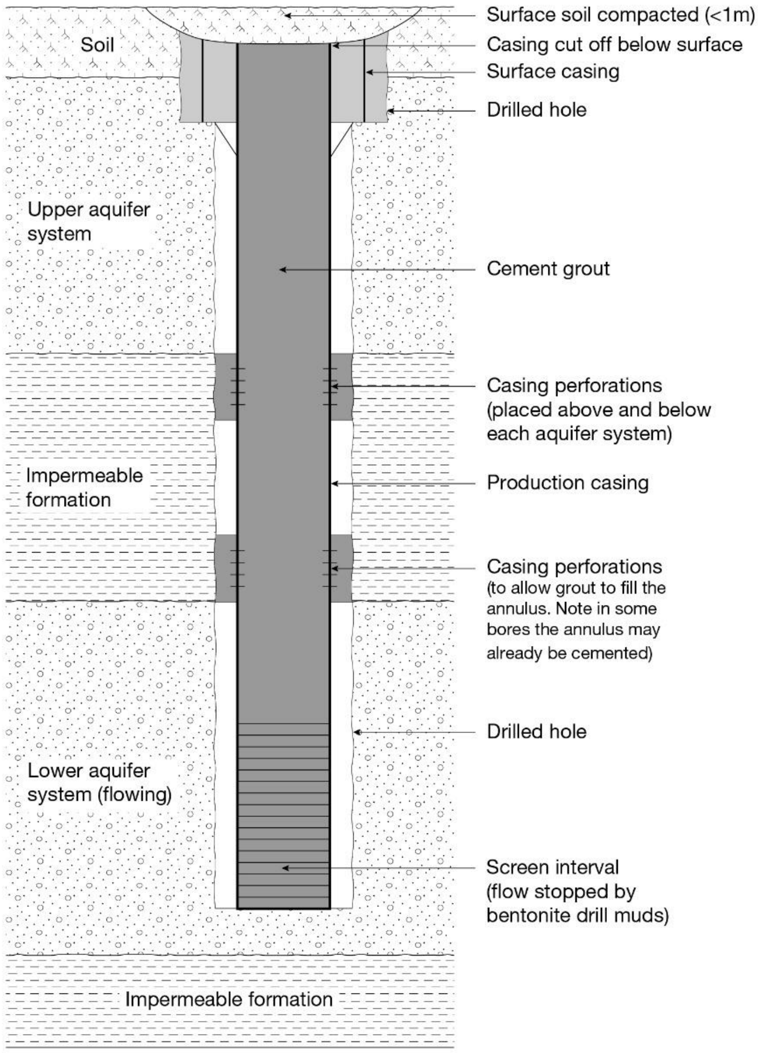


Figure 10 – Decommissioning a flowing bore by fully grouting

3.12.2 *Site reinstatement*

3.12.2.1 *Principle*

To ensure that all sites where drilling activities/tasks have taken place are restored appropriately and returned as close as possible to their pre-drilling condition.

3.12.2.2 *Minimum requirements*

Minimum requirements for site reinstatement are as follows.

(a) All drilling waste/spoil shall be contained onsite prior to treatment and disposal either onsite or offsite (as appropriate);
(b) All materials and waste products shall be removed from the site and disposed of responsibly;
(c) Any hazardous waste shall be disposed of at a licensed facility; and
(d) The site shall be left in a safe state, levelled, and resurfaced (as appropriate).

3.12.2.3 *Good industry practice*

Drilling operations can generate loud noise and vibrations that can affect nearby structures or other sensitive receptors. It is good practice to undertake a dilapidation survey prior to commencing drilling operations, particularly in proximity to buildings; heritage structures; protected trees, walls and fences; swimming pools and ponds; or other features that may be affected by noise or vibration.

Dilapidation surveys may include survey points and a photographic record of selected vulnerable features or buildings collected both before and after drilling. A good dilapidation survey can protect the driller as well as the bore owner.

3.13 Bore maintenance

3.13.1 *Principle*

To reinforce the importance of regular inspections to ensure that permanent bores which provide pathways from surface to groundwater remain in an acceptable condition.

To enable early identification of issues and facilitate appropriate remedial actions to avoid potential environmental risk.

3.13.2 Minimum requirements

The bore owner shall undertake external bore inspections on a risk mitigation basis for the life of the bore to verify that headworks and surface seals are functional, undamaged, and fit for purpose.

3.13.3 Good industry practice

The bore owner should undertake internal bore inspections on a risk mitigation basis for the life of the bore to verify that internal components such as casings are intact, functional, undamaged, and fit for purpose.

Maintaining an accurate record of external and internal checks should enable comparative assessments to help monitor and understand gradual change(s) that may occur over time and help predict/schedule maintenance.

Assessments should consider a mix of non-intrusive, intrusive, and operational checks. Non-intrusive assessments could be visual or acoustic (for example, using closed circuit television, an acoustic televiewer, or an optical televiewer). Intrusive assessments are intended to be non-destructive, but require removal of certain components to complete checks (for example, headworks or submersible pumps). Operational checks are intended to provide additional information that may assist in the assessment of bore condition and predict/schedule maintenance (for example, comparing historical bore performance and identifying trends).

External checks may include the following:

(a) Bore identification is appropriately displayed and visible (if applicable);
(b) The bore area is isolated or secured (for example, fenced off from stock and clear of potential sources of contamination); for example, in areas where fertiliser, pesticides, or chemicals are used;
(c) The bore is positioned away from potential sources of contamination (for example, compost, rubbish, septic tanks, offal holes, and effluent disposal areas); for example, in areas where fertiliser, pesticides, or chemicals are used;
(d) The ground around the bore casing is sealed at surface and raised/sloped to prevent localised surface water pooling (using a concrete apron/plinth or similar alternative – without visible cracks or voids). Note: if the bore is located within a below ground chamber, the chamber should be free of water and have a suitable means of evacuating water (for example, a sump pump and float switch);
(e) The bore casing is securely capped to prevent entry of water and vermin proof, including as follows:

- Flanges gaskets are in place where flanges are used;
- Cable glands are used where cables penetrate the bore cap and are in good condition; and
- Backflow prevention devices are installed (where appropriate);

(f) Water level/inspection ports/valves are sealed (with bungs or similar alternative); and

(g) All bore head furniture is in good condition, without visual signs of leaks.

Internal checks may include the following:

(a) Annular dimensions and unimpeded access are maintained to the reported depth of the bore;
(b) The integrity of the bore casing (if applicable) and associated joints are maintained;
(c) The integrity of the bore screen (if applicable) and associated joints are maintained; and
(d) Other relevant observations are carried out (for example, sediment accumulation, growth/fouling of bore, discolouration of water, foreign objects).

Operational checks may include the following:

(a) The bore remains operational/functional for its intended purpose (as applicable) and can be verified (for example, inspection ports/bore caps can be removed and/or valves are able to be open/closed, the bore annular is accessible, measuring devices/instruments are working, the bore produces water);
(b) Bore parameters can be measured (for example, water level, flow rate, head pressure, fluid temperature, turbidity, sand content); and
(c) Other relevant observations are carried out (for example, vibration, noise, leaks).

4 Water supply bores

4.1 General

Bores that supply water can be used for numerous activities, such as irrigation, stock use, or a drinking water supply. These bores should be sited to provide a reliable and useful water supply.

Where drinking water supply is the purpose of the bore, the Water Services Act 2021 defines a drinking water supplier and details their responsibilities. Requirements of the drinking water supplier may vary depending on the depth and quality of the bore construction; therefore, it is important to refer to the relevant compliance requirements. This applies whether the bore is constructed for the purpose of drinking water supply or an existing bore is repurposed for drinking water supply.

The following sections specifically address the additional minimum requirements and good industry practices that apply to activities involving the drilling of soil and rock for the purpose of accessing and abstracting groundwater.

4.2 Bore design

4.2.1 *Principle*

To inform design considerations to suit lithology and hydrogeology (for example, above-ground artesian pressures vs below ground).

4.2.2 *Minimum requirements*

The production casing shall be:

(a) Sealed so that the supply of water can be drawn from the target water-bearing aquifer only;
(b) For non-flowing multiple aquifer bores: sealed above the production zone to seal off any non-target aquifers; and
(c) For drilling in flowing artesian conditions: sealed from above the production zone to the surface.

If grout is used to achieve this seal, the grout shall be of a minimum thickness of 20 mm around the outside diameter of the casing. Where sealing casing with an external grout seal is unachievable because of site-specific lithology, a suitable alternative sealing method shall be employed. This may be realised through drilling method selection or post-construction testing.

Bores shall be designed to prevent the mixing and/or movement of water between aquifers/water bodies with different quality or pressure (internally or externally).

Bores shall be completed with watertight headworks.

4.2.3 *Good industry practice (general)*

The bore design should take into account 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. All bores can potentially provide a means of contaminating groundwater by acting as a conduit for surface run-off, whether or not the bore is intended for water supply. It is important that the bore design considers the protection of the groundwater resource from surface contamination and/or cross-contamination. Aspects of the bore design that contribute to this protection include ensuring the headworks and casing are sealed so that there is no potential for flow outside the casing down to the aquifer.

Wherever practicable, the sealing of production casings should be applied full depth.

Wherever practicable, headworks should be positioned above ground. In the event that a below-ground installation is unavoidable, it is critical that all minimum requirements are realised by good design: see Figure 11.

Figure 11 – Below-ground installation of headworks

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

(a) The intended purpose of the bore;
(b) Geological and hydrogeological conditions, including the groundwater quality;
(c) Drilling methods and construction methods; and
(d) The location of the bore with respect to the surrounding area (for example, location on higher ground will minimise the potential for standing water around the wellhead, and regional plan rules may apply to distance from contamination sources including septic tanks, effluent ponds, landfills, chemical stores, fuel tanks, and so on).

If headworks must be below ground, the design should prevent ingress of surface water into the below-ground chamber, and a drainage system shall be in place to remove any water that does collect in the chamber to prevent pooling.

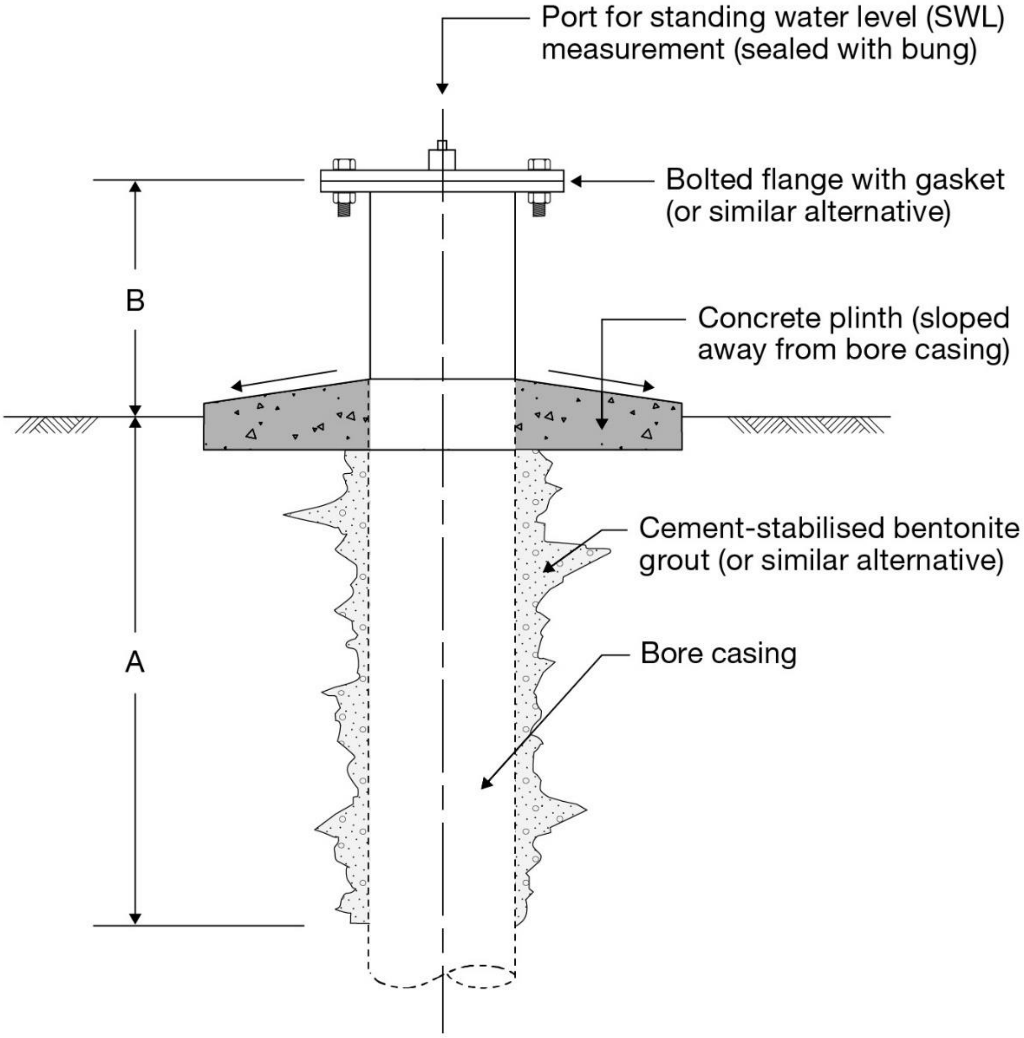
Water supply bores should be fitted with headworks that support access to the full-bore diameter to assist operational and maintenance requirements. They should support the measurement of water levels, sampling of water, and fitting of flowmeters (as applicable). They should be fitted with backflow prevention devices to prevent the contamination of groundwater.

For water supply bores equipped with down-hole submersible pump assemblies (or similar), a conduit of suitable diameter should also be installed, to enable unhindered access to the static water level for direct measurement or the placement and recovery of water-level transducers. The conduit and associated access port should be an identifiable feature of the bore headworks, accessible, and sealed to prevent access when not in use.

For water supply bores with flowing artesian conditions and/or equipped with down-hole submersible pump assemblies (or similar), an access port for the provision for water sampling should be included in the headworks. The port should be sealed to prevent access when not in use.

Bores with above-ground artesian pressures should have a full diameter valve positioned in the vertical axis to enable the bore to be isolated if required.

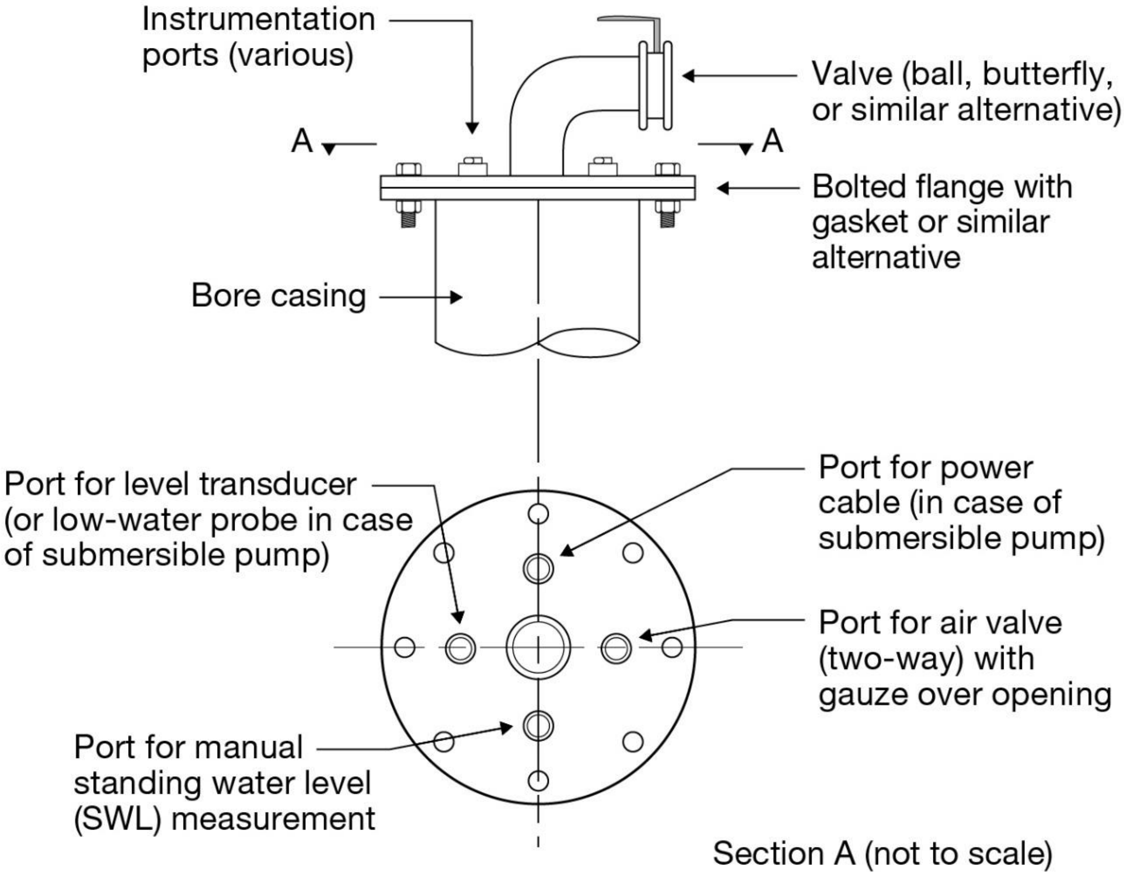
Figures 12 and 13 show a basic/standard bore completion above ground with no instrumentation and above and below ground – with instrumentation, respectively.



A. Dimension to suit minimum sanitary seal depth and/or depth to closest confining layer. A minimum depth of 6 m is good practice for drinking water supply

B. Dimension to suit minimum above concrete plinth of at least 0.3 m

Figure 12 – Basic/standard bore completion (above ground – no instrumentation)



NOTES –

1. All ports with cables are to be sealed with cable glands.
2. All spare ports are to be sealed by removable bungs.

Figure 13 – Basic/standard bore completion (above and below ground – with instrumentation)

Figure 14 shows sanitary protection of a typical bore.

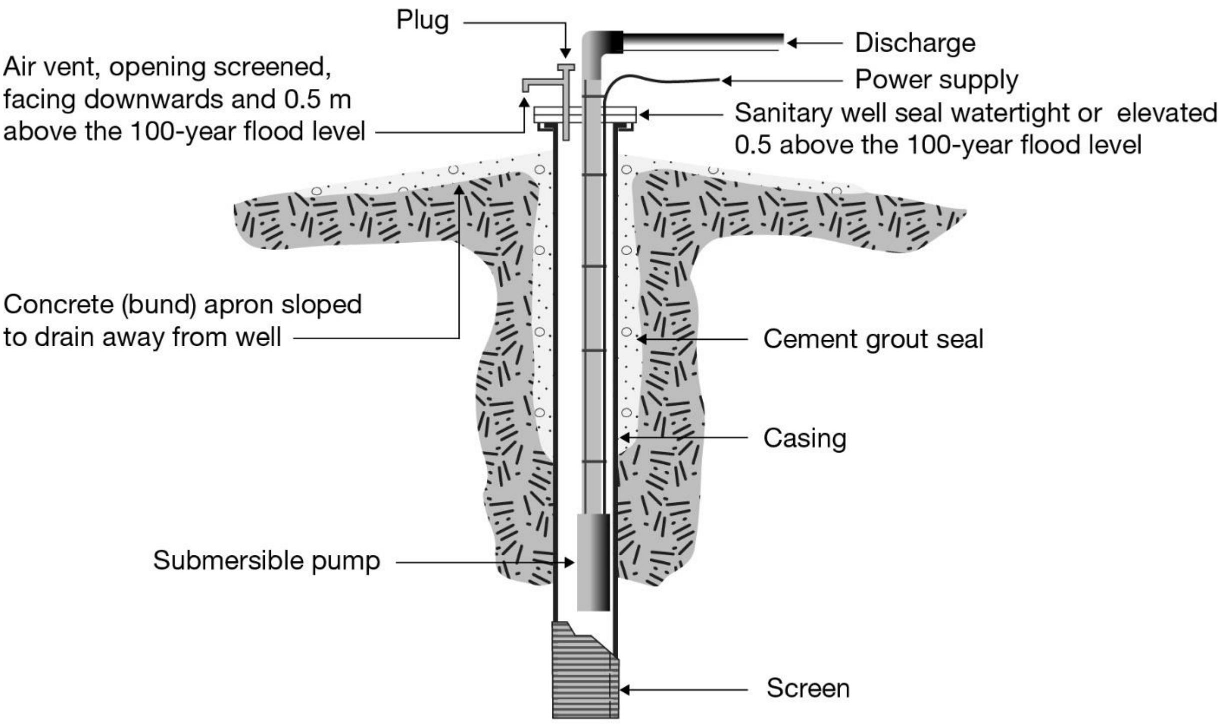


Figure 14 – Sanitary protection of a typical bore

To protect the abstracted water and aquifer from contamination, the following design details are considered good practice:

(a) The bore head is installed above ground;
(b) The bore is installed in an area of ground that is not below the surrounding ground level, in order to prevent ponding occurring around the bore head, such as during rainfall;
(c) The annulus of the casing is sealed and the bore is grouted below ground to an appropriate depth, taking account of the lithology that the bore has been installed in, to prevent the ingress of surface water via the outside of the casing;
(d) A concrete apron is installed around the bore head, extending a minimum of 1 m in all directions from the casing and sloping away from the casing so that any water on the ground surface is carried away from the bore;
(e) All apertures into the bore (for cables and so on) are sealed and watertight to prevent water ingress, and vermin-proofed to prevent access by small animals and so on;
(f) All air vents and any other apertures that are not watertight are screened to prevent access by small animals, be face downwards, and be elevated at least 0.5 m above the surrounding ground level or above any known flood levels;
(g) Reasonable security measures are in place to protect the bore head from unauthorised access or interference;
(h) If the bore head is in an area where farm animals are present, it is fenced to exclude those animals. Bore owners and drilling contractors should consult with the appropriate authorities or organisations to determine an appropriate exclusion distance between the bore head and the fencing;
(i) A mechanism at the bore head prevents backflow into the bore; and
(j) The bore head is inspected monthly for damage or defects and records are kept of all inspections for at least five years.

Figures 15, 16, 17, and 18 provide examples of bore heads with fencing in different contexts.

Figure 15 – Drinking water supply bore head

Figure 16 – Drinking water supply bore head (variation)

Figure 17 – Drinking water supply bore head componentry

Figure 18 –Agricultural water supply bore head

4.2.4. *Good industry practice (aquifer-specific)*

Where drilling intersects groundwater confined by a low permeability layer and under pressure, groundwater levels will rise. If the pressure is sufficient, the bore may become flowing artesian, and where this is not managed or controlled will cause wastage of groundwater and the loss of hydrostatic pressure in the affected aquifer.

The design of water bores may vary according to the hydrogeology intercepted and should take into account aquifer protection.

4.2.5 *Single-aquifer bore*

Many bores are constructed into the upper-most aquifer system. These are referred to as single-aquifer bores (see Figure 19). In this case, as above, it is important to ensure the headworks and casings are sealed so that there is no potential for flow outside the casing down to the aquifer.

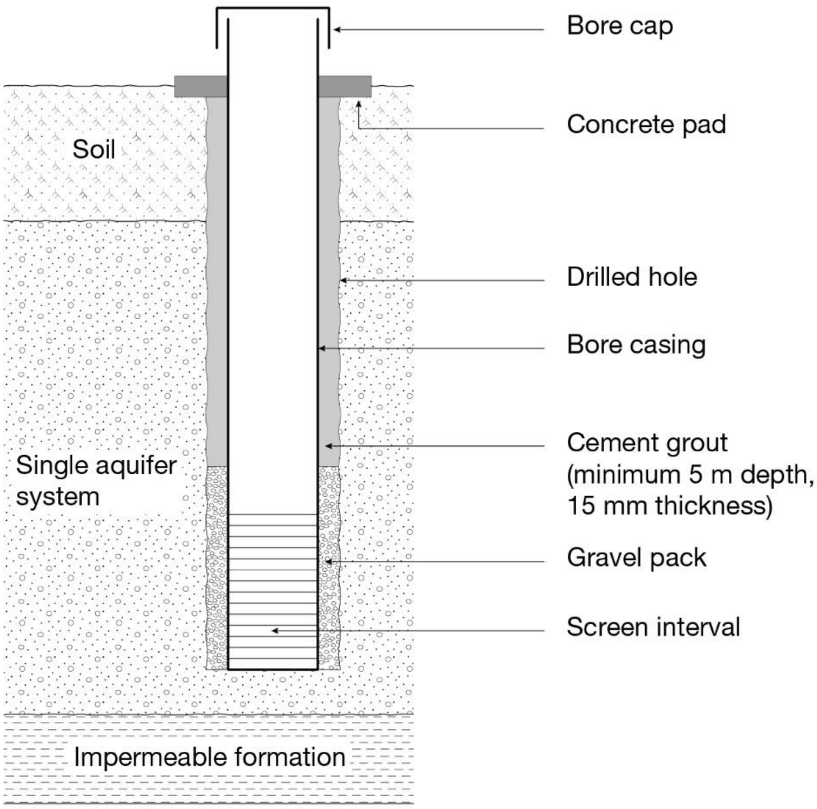


Figure 19: Single-aquifer bore

4.2.6 *Multiple-aquifer bore*

Where a bore encounters multiple aquifers, the key purpose of the design for aquifer protection is to ensure that waters of different aquifers do not mix, either through the bore casing or in the annulus between the casing and the borehole (see Figure 20).

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

Screening across multiple aquifers is a high-risk design choice. Bores should generally not be screened across multiple aquifers with differing hydraulic heads or water quality unless the aquifers are demonstrated to be in natural hydraulic connection and/or of equivalent water quality. Multi-aquifer completions may be limited by regulatory authorities and should only occur with regulatory approval. Multiple-aquifer bores may need to be supported by hydrogeological assessment, may require designs that prevent vertical leakage, and may require monitoring.

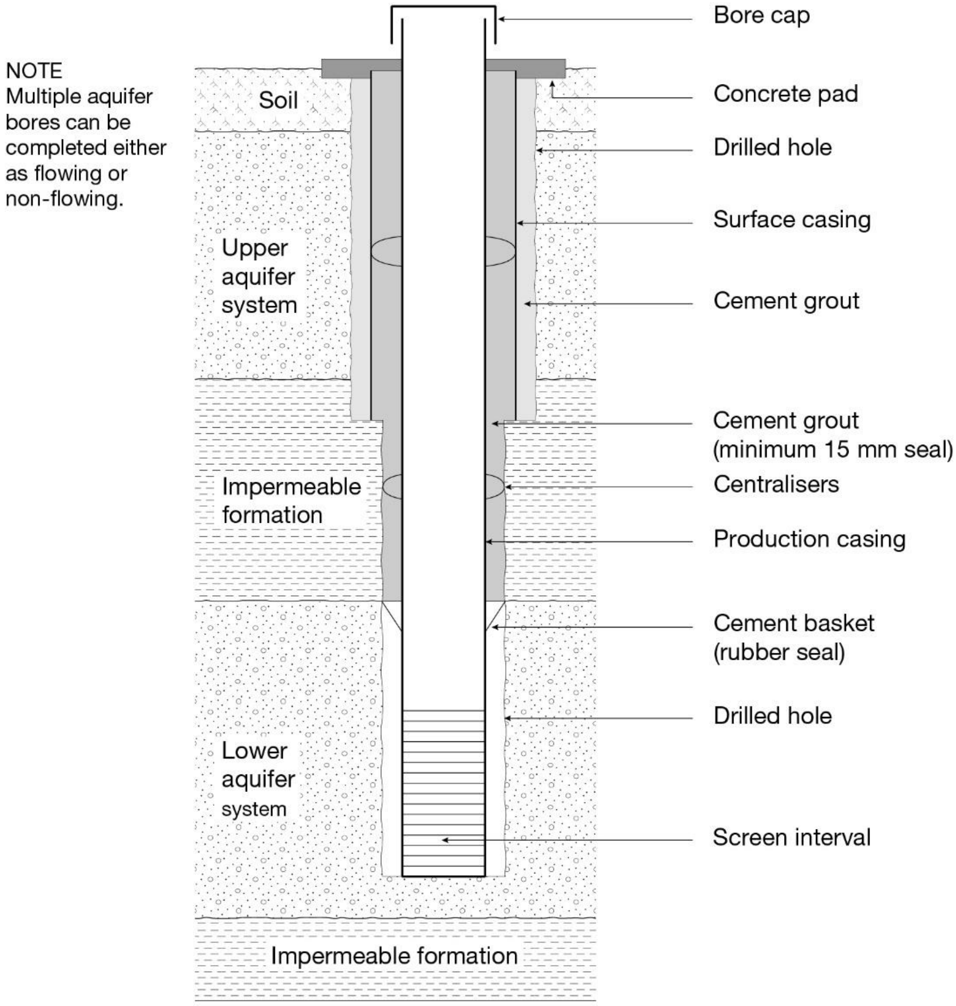


Figure 20 – Multiple-aquifer bore

4.2.7 *Artesian aquifer bore*

This section applies specifically to flowing artesian bores. When a bore intercepts an artesian aquifer, a high level of control is required throughout drilling, construction, and ongoing maintenance to ensure safety, protect the aquifer, and maintain bore integrity.

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

(a) Preventing any discharge up the outside of the casing by the setting and cementing of surface control casing;
(b) Preventing any intermixing of waters of different quality or pressure from one aquifer to another by tapping only one aquifer; and
(c) Controlling lithology pressures by selective cementing of the production casing.

During the selection process for production casing and headworks materials, consideration must be given to the depth of casing installation, grouting pressures, bore head static pressure, and water temperature, together with any risk of the corrosive nature of the water and/or lithology.

Bores should be fitted with specifically designed and approved headworks to permit the control of flow and allow for periodic maintenance and measurement. These approved headworks should make provision for measurement of flow and pressure without having to disconnect or interfere with reticulation or surface pumping systems.

Construction requirements for artesian bores can vary across New Zealand. Regulatory authorities should be consulted on requirements for artesian bore construction before drilling into an artesian aquifer.

Figure 21 gives an example of a flowing bore construction.

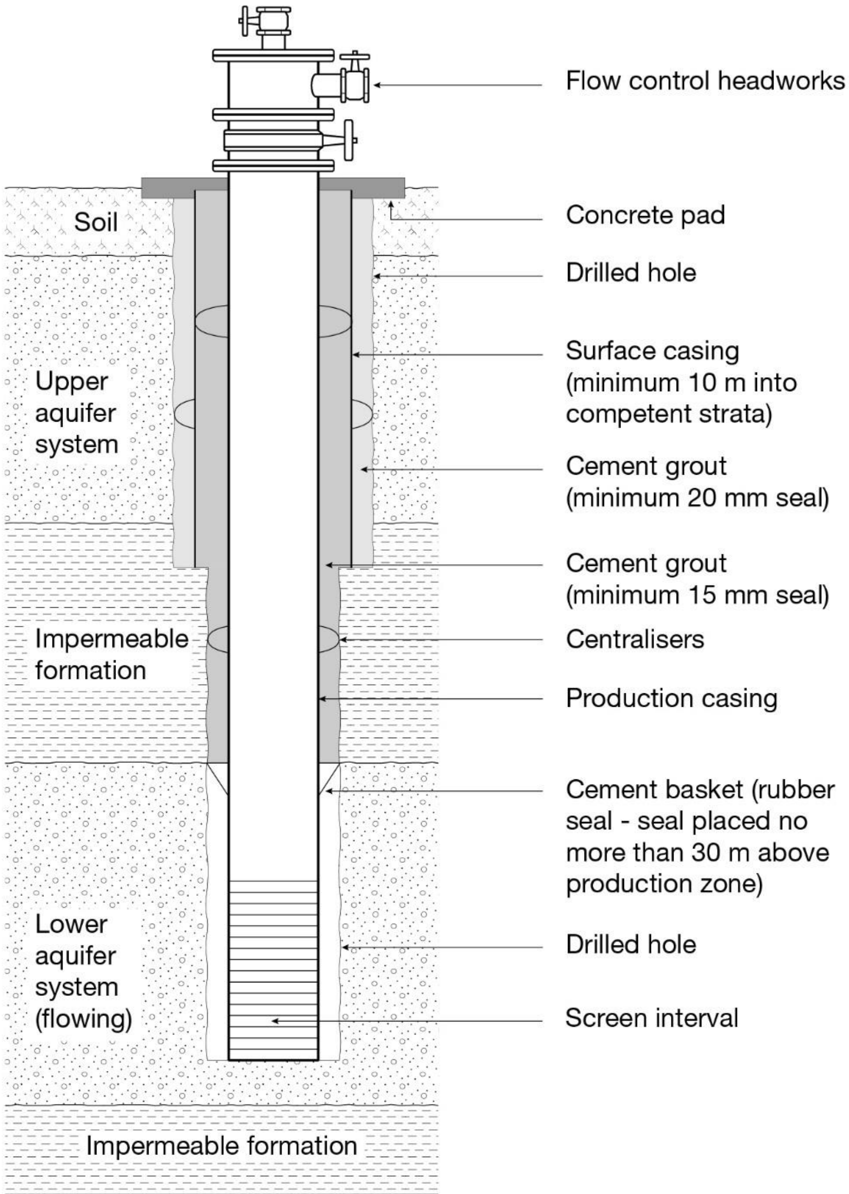


Figure 21 – Flowing aquifer bore

4.3 Plumbness/straightness/centralising

4.3.1 *Principle*

To reinforce the importance of keeping bores, casings, screens, and similar conduits aligned for the free unhindered passage of submersible pump assemblies or tools used for maintenance purposes.

To reinforce the importance of centralising bore casings, screens and conduits to ensure the effective placement of annular backfill materials and support the function of external filter packs and seals.

4.3.2 *Good industry practice*

Good industry practice for plumbness/straightness/centralising is as follows.

(a) Bores should be sufficiently plumb, straight, and within the tolerances required for the intended application;
(b) Where used, bore casings, screens, and similar conduits should be located central (centralised) to the bore to support the placement of backfill materials; and
(c) Where practical, centralisers should be used to provide uniform radial clearance.

To provide sufficient annular space to centralise installations such as casings, screens, and similar conduits, the receiving borehole should provide a minimum of 25 mm external radial clearance for installations less than 100 mm diameter and 50 mm clearance for installations greater than 100 mm diameter.

A basic plumbness and alignment test should be carried out on completion of the bore, to test the unhindered passage of a gauging tool that is greater than the length and diameter of the proposed submersible pump assemblies or 10% smaller than the inner diameter of the bore, casing, screen, and similar conduits (as applicable) over a minimum length of 20 times the same inner diameter.

4.4 Groundwater sampling and analysis

4.4.1 *Principle*

To ensure that it is possible to take a representative sample which can be analysed to identify and understand the specific properties of the groundwater intercepted by the bore.

4.4.2 *Explanatory*

Groundwater sampling during bore construction is often needed to enable water quality analysis (microbiological, chemical, and radiological where appropriate).

Determining groundwater quality will assist in making decisions regarding the suitability of the water relevant to the intended purpose of the bore, which may influence decisions on factors such as:

(a) Construction requirements;
(b) Whether to continue construction;
(c) Selection of materials (for example, in corrosive waters);
(d) Modifications in construction (for example, screen setting);
(e) Aquifer separation requirements;
(f) Suitability of the bore for the desired purpose; and
(g) The planned operation of the completed bore.

4.4.3 *Minimum requirements*

Prior to sampling, the driller shall ensure that all drilling fluids have been removed (muds, polymers, and so on) via development, pumping, or purging.

4.4.4 *Good industry practice*

It is important to ensure that the water sample is representative of the aquifer and is not contaminated by bore construction materials or the sampling procedure.

Regulatory authorities may have specific quality parameters and/or test requirements. The requirements for sampling set out in the National Environmental Monitoring Standards (see www.nems.org.nz) should be followed.

Using portable equipment to enable direct field measurement of basic groundwater quality parameters can assist in making timely decisions. Water quality monitoring equipment should be regularly calibrated, in good working order, and operated according to the manufacturer's procedures and instructions. All monitoring equipment should be thoroughly cleaned after each use.

For any water sampling undertaken before completion, consideration should be given to the stability of the bore when taking samples.

4.5 Bore/aquifer development

4.5.1 *Principle*

To maximise bore performance and/or efficiency.

To maximise and understand bore performance, efficiency, and the minimum test requirements to measure and define both bore and aquifer parameters to inform the decision-making process during bore construction.

4.5.2 *Minimum requirements*

Minimum requirements for bore/aquifer development are as follows:

(a) At the completion of bore construction, all drilling fluids, foreign materials, and/or sediment shall be removed from within the bore using a cleaning and/or development method suitable for the conditions;
(b) Cleaning and/or development methods shall be selected and employed to aid the removal of any drilling fluid and drill cuttings that may have been lost into the aquifer formation and be impeding the flow of groundwater into the bore;
(c) Cleaning and/or development methods shall be selected and employed to remove, reduce, or stabilise the migration of lithology materials (for example, clay/silt/sand) into the bore;
(d) Removed solids shall be disposed of to an appropriate location; and
(e) The quality and quantity of discharged bore development fluids, including groundwater, shall be considered relative to the receiving environment to avoid contamination or flooding. Local rules may specify standards for discharges from bore development.

4.5.3 *Good industry practice*

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

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:
(a) Air lifting and jetting;
(b) Surging;
(c) Pumping;
(d) Bailing; and
(e) Adding dispersants and detergents.

The bore development process should employ techniques that progress from gentle to vigorous agitation. Too harsh a technique in the early stages of development can result in damage, reduced yield, or erosion of the screen or slots.

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

Rapid dewatering 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.

During bore development, records should be kept of all observations.

The development of a water bore should not be concluded before a continuous clean, sediment-free supply of water is obtainable at the full flow capability of the bore. A sediment-free supply is regarded as a supply with a sediment content of no more than 5 g/1000 litres. Measurements can be made with a Rossum sand tester or in an equivalent manner.

A pump can be used for final development of the bore.

Development can be considered satisfactory when the following have been achieved:

- The bore produces less than 5 g/1000 litres of sediment when pumped at the required flow rate for one hour;

- The bore is clean of sediment from the top to the base, and the water is relatively clear and free of fines; and
- There is no further increase in yield versus drawdown of the bore with continued development.

After development, the bore should be left clean and free of any other obstructions for the full depth, including sump where applicable.

Figure 22 shows how effective development (right-hand side) allows movement of fluid in both directions through screen openings. Where movement is only in one direction (left-hand side), the proper development effect cannot occur.

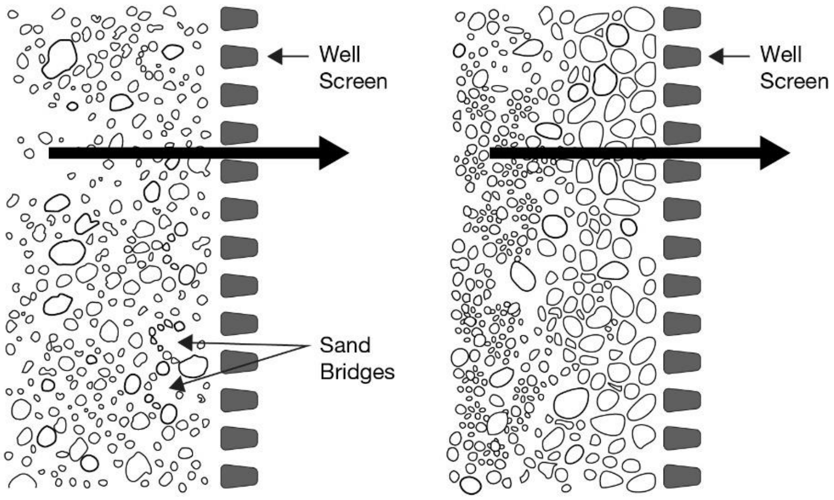


Figure 22 – Pre and post effective development

Figure 23 shows the development of prepacked screen in a natural formation.

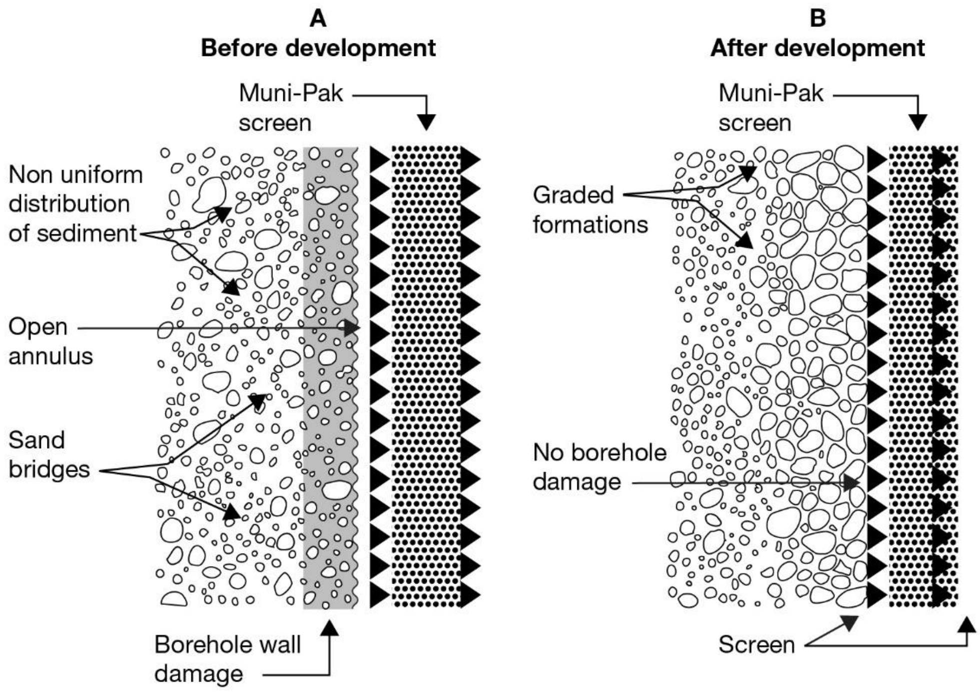


Figure 23 – Development of prepacked screen in natural formation

Figure 24 shows how development can improve bore permeability.

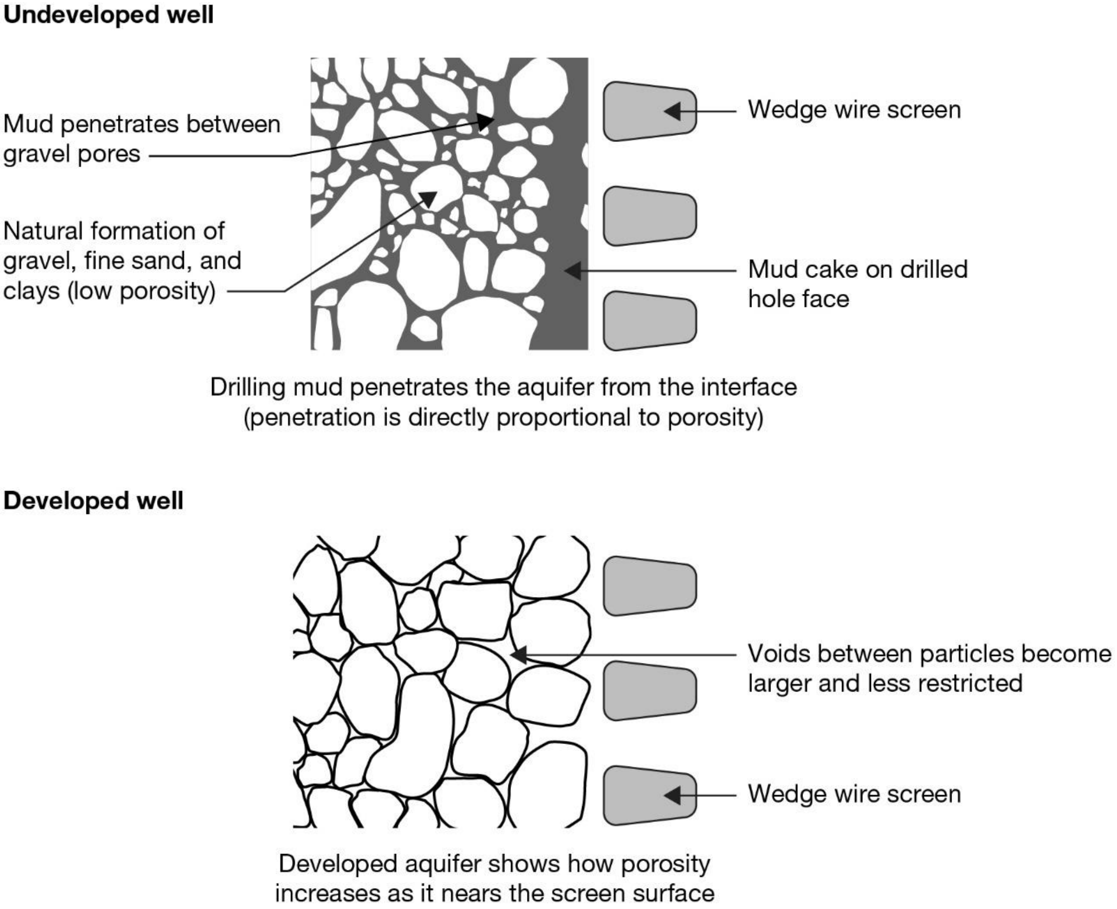


Figure 24 – Improving bore permeability through development

4.6 Bore performance and efficiency

4.6.1 *Principle*

To understand bore performance, efficiency, and the recommended test requirements to measure and define both bore and aquifer parameters.

4.6.2 *Good industry practice*

At the completion of bore and aquifer development, a stepped rate aquifer test with a minimum of four steps of equal duration should be undertaken to understand the relationship between flow rate (yield) and drawdown from the static water level.

Prior to the start of the stepped rate test, the static water level should be measured for a suitable period of time to demonstrate stability or observe and measure changes due to external influences (for example, neighbouring aquifer abstraction).

At the conclusion of the stepped rate test, the static water level should be measured for a suitable period of time to demonstrate stability or observe and measure changes due to external influences (for example, neighbouring aquifer abstraction).

Throughout aquifer testing, the migration of sediment (fines, sand, and so on) should be observed and measured to understand the stability of the aquifer material and response to changes in flow rate.

If the bore owner is looking to take water, and that take would not be covered by a permitted activity rule, the relevant regulatory authority will set out the minimum requirement for aquifer testing, which may exceed the testing outlined above.

To maintain an accurate running record of static and operational water levels, flow rates, and other observations, such as sediment content, it is important to enable the assessment of bore performance. Observed changes that may occur over (longer periods of) time, including abrupt/sudden changes in performance, may help predict/schedule maintenance.

5 Injection bores

5.1 Principle

To ensure that the construction of injection bores considers and provides for the suitable and sustainable discharge of water into below-ground water bodies and formations.

To ensure that the natural characteristics of the receiving lithology are protected from risks such as over-pressurisation during injection.

5.2 Explanatory

Groundwater injection bores are used to inject water by gravity (passively) or pressure (actively) into an aquifer. Construction requirements are similar to those for groundwater abstraction bores. Injection bores are commonly used in ground-sourced heating systems (open loop), managed aquifer recharge schemes, and groundwater remediation projects.

The principle, minimum requirements, and good industry practice provided herein specifically address the injection of water for heating/cooling and storage or recovery purposes. They do not address injection for waste disposal purposes, which is outside the scope of this standard.

5.3 Minimum requirements

In addition to minimum sanitary seal requirements for all bores (see 3.10), injection bores (whether single or multi-aquifer) (see Figure 25) shall have a fully grouted external grout seal between the natural formation and bore casing extending above the screened zone back to surface and/or extending through suitably robust aquitards to prevent the unintentional short circuiting of injected water between aquifers and/or back to surface.

Injection bores shall reinject water only into targeted aquifers/lithology and prevent the potential for water to mix with non-targeted aquifers/lithology.

Injection pressures shall be limited to avoid physical damage by over-pressurisation of the receiving lithology and damage to the bore construction itself.

5.4 Good industry practice

Injection bores should be equipped with pressure and flow monitoring equipment to provide a direct measurement and record of operational parameters, including, as a minimum, flow rate and pressure.

Bore performance should be monitored and routinely assessed for trends, including rapid interrogation of the data in the event of a change in operational conditions.

Operational limits should be set for maximum acceptable reinjection pressure and warning alarms raised when the pressure is close to being exceeded. In the event pressures are exceeded, the system should incorporate safety-by-design features to reduce or stop injection until the issue can be rectified.

Headworks and associated piped delivery systems should incorporate suitable air relief features to prevent air accumulation leading to injecting air into the formation or generating false injection pressures.

Careful consideration should be given to the water quality of both the injected water and the receiving groundwater body, to avoid degradation of the groundwater. This may include microbiological and chemical parameters, along with suspended sediment and temperature. In general, injecting water from a shallow less secure groundwater source into a deep more secure groundwater source is not recommended.

To minimise problems such as clogging and increasing injection effort, the injection of sediment-laden water should be avoided.

Figure 25 – Injection bore