6. Annular Space & Sealing

Chapter Table of Contents

Chapter Figures

Chapter Tables

Chapter Description

This chapter covers the construction process involved in sealing the well casing into the hole to ensure that there is no movement of water or other materials along the annular space as required by the **Wells Regulation**.

Regulatory Requirements – Annular Space & Sealing of a New Well

Relevant Sections – The Wells Regulation

Casing – Subsections 13(12)* and *13(20)

Annular Space – Sections 14 and 14.1* to *14.6

The Requirements – Plainly Stated

The Wells Regulation requires the following regarding the Annular Space and Seal for new well construction:

Sealing Casing in Bedrock for New Drilled Wells
- If the aquifer is located in a weathered bedrock zone, the new drilled well must be cased to the bedrock, but the casing is not required to be sealed into the bedrock.
- If the aquifer is located in a bedrock zone that is not weathered, the casing of a new drilled well must be sealed into the bedrock with suitable sealant to prevent impairment of the quality of the groundwater and the water in the well.

Sealing Annular Space between Casings
- The annular space between casings of different diameters must be sealed with suitable sealant to prevent the entry of surface water or other foreign materials into the well.

Subsurface Movement for New Well Construction
- Any annular space, other than the annular space surrounding the well screen, must be sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between subsurface formations and the ground surface by means of the annular space.

Sealing Annular Space for New Wells
- Table 6-1on page 10 of this chapter for a summary of the requirements outlined in the **Wells Regulation** regarding the annular space and sealing for new well construction other than jetted wells or wells constructed by use of a driven point.

New Wells Constructed by Use of a Driven Point

- A person constructing a well by use of a driven point must ensure that any annular space is filled to the ground surface using a method and material approved by the Director (see “Grout Placement – When an Annular Space is Created by Use of a Driven Point” on page 44 of this chapter).

Definitions for sealant, watertight, tremie pipe and other relevant terms are stated in Chapter 2: *Definitions & Clarifications*.

See Figures 6-6 to 6-13 (pages 19 to 26 of this chapter) for illustrations of the sealing requirements described in Table 6-1 for most common wells. The requirement for jetted wells is outlined in the Plainly Stated, “Subsurface Movement for New Well Construction” section above. For wells constructed by use of a driven point, see “Grout Placement – When an Annular Space is Created by Use of a Driven Point” on page 44 of this chapter.

Table 6-1: Annular Space and Sealing Requirements

New Bored Wells With Concrete Casing and Dug (or Excavated) Wells			
	Bored Well with Concrete Casing ≥ 6 m (19.7′) deep	**Bored Well with Concrete Casing < 6 m (19.7′) deep**	**Dug (or Excavated) Well**
Minimum Diameter of Hole Greater Than Outer Casing Diameter to Create Annular Space	From ground surface to ≥2.5 m (8.2′) below ground surface Minimum Diameter is ≥15.2 cm (6″)	From ground surface to ≥ 2.5 m (8.2′) below ground surface Minimum Diameter is ≥ 15.2 cm (6″)	None
	From ≥2.5 m (8.2′) below the ground surface Minimum Diameter is ≥7.6 cm (3″)	From ≥2.5 m (8.2′) below the ground surface Minimum Diameter is ≥ 7.6 cm (3″)	
Minimum Depth of Annular Space below Ground Surface	≥6 m (19.7′)	Bottom of well	None
Bottom of Filter Pack Material around Well Screen if present	Bottom of well screen	Bottom of well screen	Bottom of well
Type of Annular Filter Pack, Granular or Native Material	Clean, washed gravel or sand Deposited only after placement of well screen and casing Only applies if well screen is present	Clean, washed gravel or sand Deposited only after placement of well screen and casing Only applies if well screen is present	Clean, washed gravel, Clean, washed sand or Native materials (soil) excavated from the well Native materials (soil) can only be used if they are not from a contaminated area and the major horizons of soil are excavated and stored separately, kept free of contamination and then backfilled within the annular space in the same relative position that the horizon originally occupied.
Maximum Top of Annular Filter Pack Material around Well Screen and Well Casing	At least the top of well screen but no closer to ground surface than 6 m (19.7′) below ground surface Only applies where well screen is present	At least the top of well screen but no closer to ground surface than 2.5 m (8.2′) below ground surface Only applies where well screen is present	No closer to ground surface than 2.5 m (8.2′) below ground surface.

New Bored Wells With Concrete Casing and Dug (or Excavated) Wells			
	Bored Well with Concrete Casing ≥ 6 m (19.7′) deep	**Bored Well with Concrete Casing < 6 m (19.7′) deep**	**Dug (or Excavated) Well**
Annular Seal Material around Casing in Remaining Open Annular Space from Filter Pack, Granular or Native Material to ≥ 2.5 m (8.2′) below Ground Surface	Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant If no well screen is used, suitable sealant must be used to fill the space from the bottom of the well up to this depth	Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant If no well screen is used, suitable sealant must be used to fill the space from the bottom of the well up to this depth	Suitable sealant that has structural strength to support weight of persons and vehicles
Annular Seal Material around Casing from ≥ 2.5 m (8.2′) below Ground Surface to Ground Surface	Bentonite granules, pellets or chips that have been screened to manufacturer's specifications and have a diameter range between 6 to 20 mm (0.23 to 0.8″) are placed immediately above the suitable sealant	Bentonite granules, pellets or chips that have been screened to manufacturer's specifications and have a diameter range between 6 to 20 mm (0.23 to 0.8″) are placed immediately above the suitable sealant	Suitable sealant that has structural strength to support weight of persons and vehicles
Where Cement is used in Suitable Sealant Mixture	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level

<table>
<tr><th colspan="4">New Drilled Wells, Other Wells* and Well Pits (Table 6-1 continued)</th></tr>
<tr><th></th><th>Drilled Well or any other Well ≥6 m (19.7′) deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)</th><th>Drilled Well or any other Well < 6 m (19.7′)deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)</th><th>New Well Pit (see Chapter 9: Equipment Installation)</th></tr>
<tr><td rowspan="2">Minimum Diameter of Hole Greater Than Outer Casing Diameter to Create Annular Space</td><td>Minimum Diameter is ≥7.6 cm (3″)</td><td>Minimum Diameter is ≥7.6 cm (3″)</td><td rowspan="2">≥7.6 cm (3″)</td></tr>
<tr><td>Minimum Diameter is ≥ 5.1 cm (2″)
If centralizers are attached to casing > 6m (19.7’) below the ground surface using rotary drilling equipment OR
If a breakaway guide is attached 2m (6.3’) above the bottom of any casing using cable tool equipment</td><td>Minimum Diameter is ≥5.1 cm (2″)
If a breakaway guide is attached 2m (6.3’) above the bottom of any casing using cable tool equipment</td></tr>
<tr><td>Minimum Depth of Annular Space below Ground Surface</td><td>≥ 6 m (19.7′)</td><td>Where no well screen is installed:
• bottom of well.
If well screen installed:
• bottom of well screen, and
• top of well screen must not be closer to ground surface than 2.5 m (8.2′).</td><td>Bottom of well pit</td></tr>
<tr><td>Bottom of Filter Pack Material around Well Screen if present</td><td>Bottom of well</td><td>Bottom of well</td><td>None</td></tr>
<tr><td>Type of Annular Filter Pack Material around Well Screen</td><td>Clean, washed gravel or sand
Placed during or after placement of well screen and casing</td><td>Clean, washed gravel or sand
Placed during or after placement of well screen and casing</td><td>None</td></tr>
</table>

New Drilled Wells, Other Wells* and Well Pits (Table 6-1 continued)			
	Drilled Well or any other Well ≥6 m (19.7′) deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)	**Drilled Well or any other Well < 6 m (19.7′)deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)**	**New Well Pit (see Chapter 9: *Equipment Installation*)**
	Clean, washed gravel or sand placed during or after placement of well screen and casing OR Clean, washed gravel or sand developed after placement of suitable sealant using surging to remove fine grained soils	Clean, washed gravel or sand placed during or after placement of well screen and casing OR Clean, washed gravel or sand developed after placement of suitable sealant using surging to remove fine grained soils	None
Maximum Top of Annular Filter Pack Material around Well Screen and Well Casing	At least the top of well screen but no closer to ground surface than 6 m (19.7′) Only applies where well screen is present	At least the top of well screen but no closer to ground surface than 2.5 m (8.2′) Only applies where well screen is present	None
Annular Seal Material around Casing in remaining Open Annular Space	Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant. If minimum hole diameter is ≥ 5.1 cm (2″) more than outer casing diameter, sealant particle size must not be subject to bridging. If no well screen is used, suitable sealant must be used to fill the space from the bottom of the annular space adjacent to the casing up to ground surface.	Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant. If minimum hole diameter is ≥ 5.1 cm (2″) more than outer casing diameter, sealant particle size must not be subject to bridging. If no well screen is used, suitable sealant must be used to fill the space from the bottom of the annular space adjacent to the casing up to ground surface.	Suitable sealant with structural strength to support weight of persons and vehicles

New Drilled Wells, Other Wells* and Well Pits (Table 6-1 continued)			
	Drilled Well or any other Well ≥6 m (19.7′) deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)	**Drilled Well or any other Well < 6 m (19.7′)deep that is not listed on Table 6-1 (except jetted and wells constructed by the use of a driven point)**	**New Well Pit (see Chapter 9: *Equipment Installation*)**
Where Cement is used in Suitable Sealant Mixture	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level

"Other wells" excludes dug wells, bored wells with concrete casing, jetted wells or wells that are constructed by the use of a driven point.

- When mixing, handling or placing any grout material (wet and dry) always follow manufacturer's specifications and recommended procedures. Consult the Material Safety Data Sheet (MSDS) for additional information on safe handling and usage.

Double Walled Casing (or annular space between inner and outer casings):

In some cases, multiple casings of different diameters are installed in wells to reach a water producing zone. This type of installation is common in municipal wells, some flowing wells and other large water taking wells. For example, the initial 20 metres (65′) of the hole may have a 40 cm (16″) diameter casing. The next 20 m (65′) of the hole may have a 30 cm (12″) diameter casing. The overlapping zone between the inner and outer casings is considered an annular space and must be sealed, for new wells, as follows:

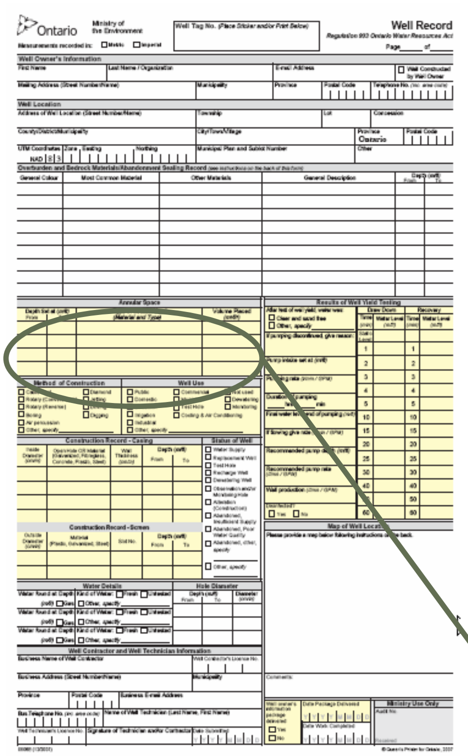
- All construction and sealing requirements for the corresponding well construction method in Table 6-1 apply with necessary modifications to the well's annular space on the outside of the outer casing.
- Except for a well pit, all construction and sealing requirements for the corresponding well construction method in Table 6-1 apply with necessary modifications to the well's annular space between the casings. This requirement does not apply if groundwater is not leaking into the annular space between the casings.
- In all cases, the annular space between casings of different diameters must be sealed with suitable sealant to prevent the entry of surface water and other foreign materials into the well.

Annular Space Constructed by any Method:

Any annular space, other than annular space surrounding the well screen, must be sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between subsurface formations and the ground surface.

WELL RECORD – RELEVANT SECTIONS

FIGURE 6-1: WELL RECORD – RELEVANT SECTIONS – ANNULAR SPACE



Annular Space

- Record 'Depth Set at' relative to the ground surface.
- Record 'Depth Set at' and 'Volume Placed' in the measurement units indicated at the top of the well record (metric or Imperial).
- Calculate 'Volume Placed' using the information found in "Calculating Amount of Materials Required" on page 32 of this chapter.

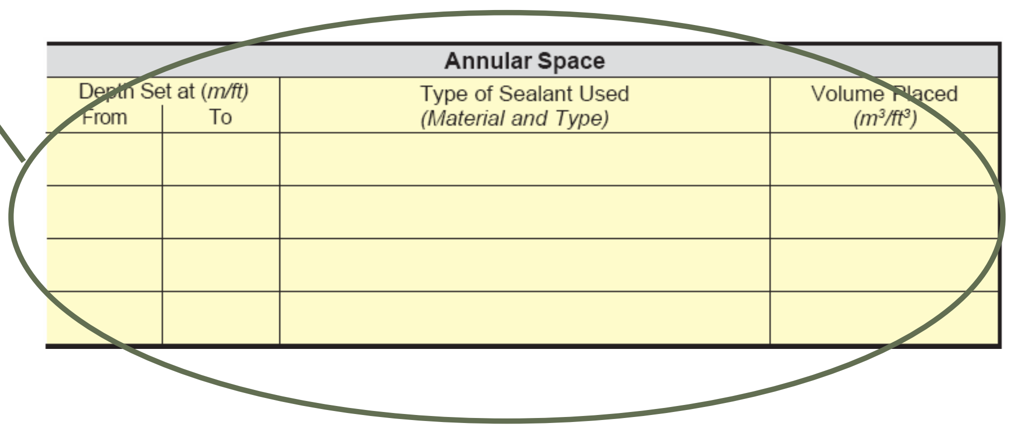
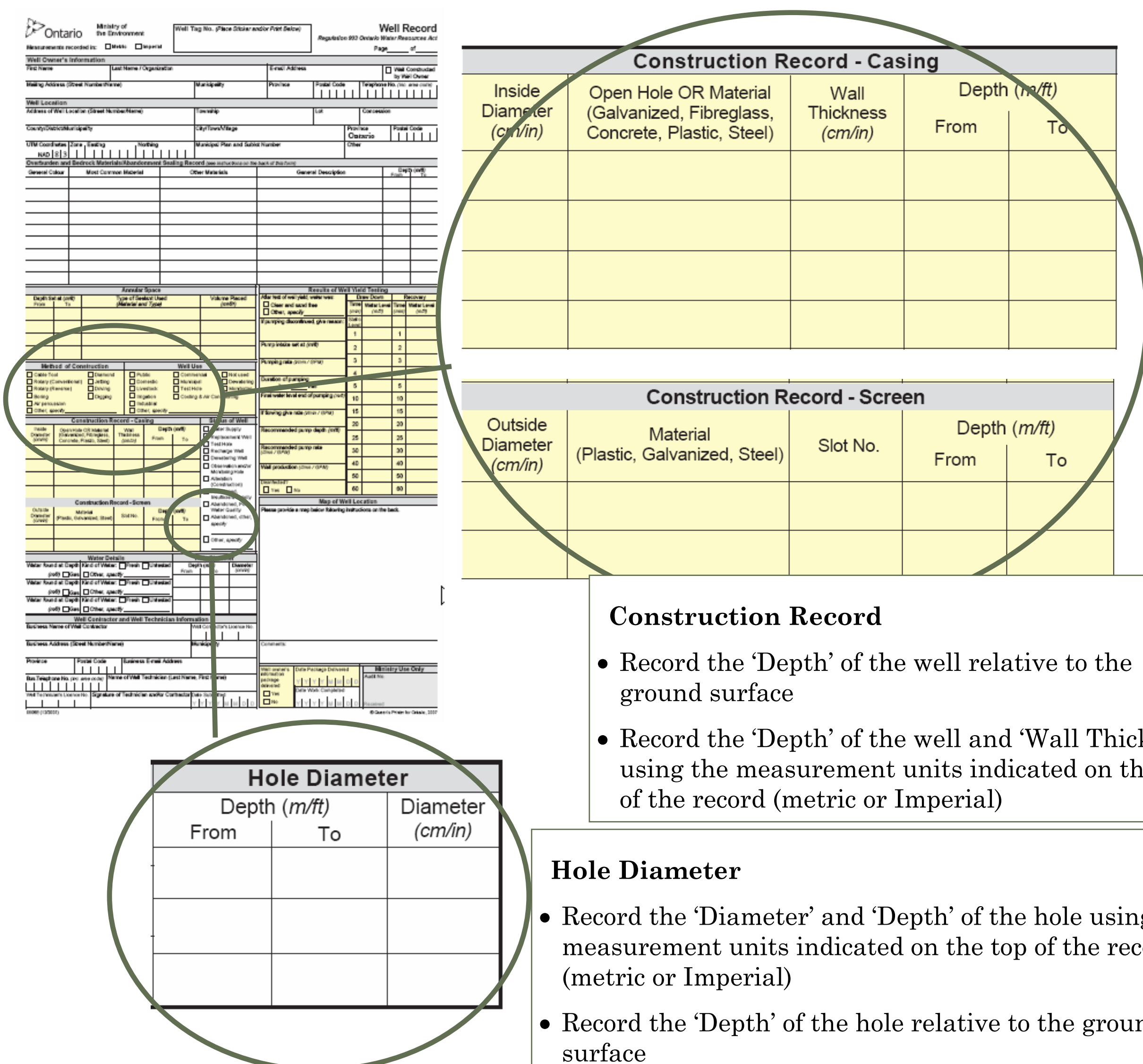


FIGURE 6-2: WELL RECORD – RELEVANT SECTIONS – CONSTRUCTION RECORD

Figure 6-2 shows where the details regarding the construction of the hole and casing the well are to be recorded on the well record.



Construction Record

- Record the 'Depth' of the well relative to the ground surface
- Record the 'Depth' of the well and 'Wall Thickness' using the measurement units indicated on the top of the record (metric or Imperial)

Hole Diameter

- Record the 'Diameter' and 'Depth' of the hole using the measurement units indicated on the top of the record (metric or Imperial)
- Record the 'Depth' of the hole relative to the ground surface

Best Management Practice – Report use of Centralizers

The use of centralizers or breakaway guides and where they are located in the well should be reported on the well record in the "Overburden and Bedrock Materials/Abandonment Sealing Record" section of the Well Record. See Chapter 13: *Well Records, Documentation, Reporting & Tagging* for the complete well record.

Key Concepts

The Annular Space

The hole must be constructed to ensure there is a minimum annular space created between the well casing and the side of the well, and in some cases between the well screen and the side of the well. Annular spaces need to be large enough to ensure suitable sealant (grout) can fill and adhere around the entire outer well casing to prevent surface water, groundwater, natural gas and other foreign materials from migrating along the outside of the well casing.

Best Management Practice – Annular Space Diameter

It is important to create hole diameters of sufficient width to ensure sealant will fill and adhere to the well's casing and formation. In most subsurface conditions, the hole diameter should be 102 mm (4″) to 203 mm (8″) larger than the outer finished casing diameter because it facilitates the use of tremie pipes and the placement of the sealant, and possibly the filter pack, in the annular space.

See Chapter 5: *Constructing & Casing the Well* for information on creating the hole.

Purpose of the Seal

Any annular space, including the space between overlapping casings within the well, must be properly filled with a suitable sealant (or grout) to:

1. Isolate a discrete zone
2. Prevent migration of surface water and other foreign materials into the well and aquifers
3. Prevent migration of groundwater between water bearing formations and subsurface formations
4. Prevent migration of groundwater between water bearing formations and the ground surface
5. Prevent aquifer depressurization by stopping the upward migration of water along the casing
6. Prevent gas migration

Examples of Improperly Sealed Annular Spaces

Figure 6-3: Visible Open Annular Space Adjacent to Drilled Well Casing

Figure 6-3 shows an annular space that goes from ground surface to the bottom of the casing (not shown) and allows for migration of surface water and other foreign materials into the well and aquifer.

Figure 6-4: Visible Open and Large Annular Space Around Drilled Well

In Figure 6-4, the annular space extends from ground surface, through an upper aquifer and to the bottom of the casing (not shown). The annular space allows for migration of surface water and other foreign materials into the well and aquifers. It also allows contaminated groundwater from this upper aquifer to mix with and impair the waters of a lower aquifer. In this case, the open space also creates a physical hazard.

This photograph also shows the use of casings with differing diameters that appear to be improperly joined.

Figure 6-5: Visible Open Annular Space Below Pitless Adapter and Horizontal Waterline to the Bottom of the Casing

Figure 6-5 shows a visible open space (i.e. annular space) below the pitless adapter and horizontal waterline. The open space extends to the bottom of the casing (not shown in photograph). Above the waterline, the person constructing the well installed a bluish grey coloured bentonite grout in the annular space from above the pitless adapter to the ground surface (see circled area). Thus, no one knew the annular space was improperly filled (or left open) below the pitless adapter until the exterior of the well was excavated. The open space acts as a direct pathway for foreign materials to enter and impair groundwater resources.

Requirements for Sealing Various Types of Wells

Figures 6-6 to 6-13 show cross-sectional illustrations and relevant graphics for various types of wells including length of well casing, types of well screen, minimum hole size, and annular space filling products around well screens and suitable sealant in the annular space around the well casing.

All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the **Wells Regulation** (e.g. Well covering during construction).

During and after construction the person constructing the well must ensure surface drainage is such that water will not collect or pond in the vicinity of the well.

For details on the hole, casing and final completion requirements not shown in Figures 6-6 to 6-13 (pages 19 to 26 of this chapter) refer to the following chapters in this manual:

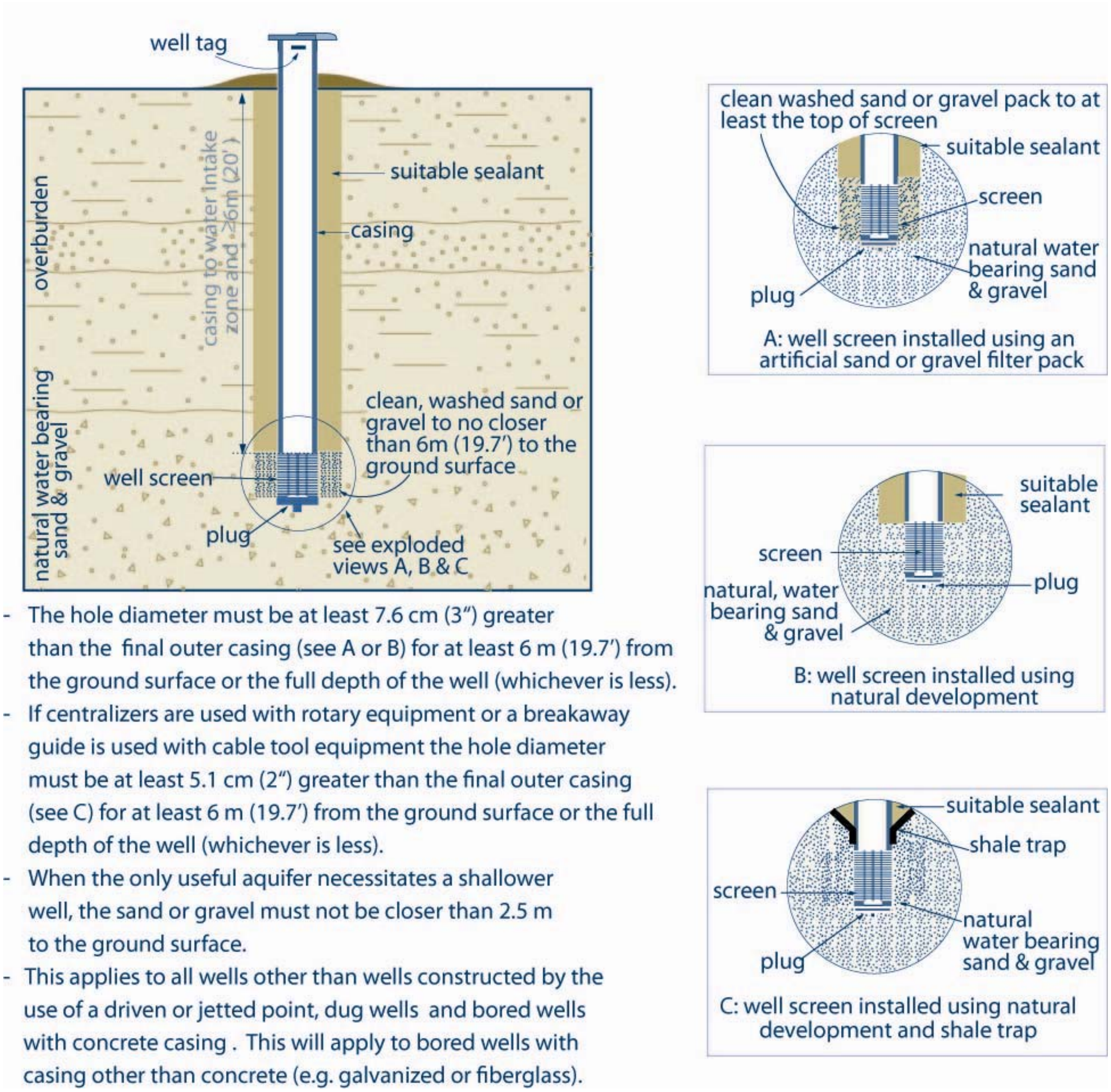
- Chapter 5: *Constructing & Casing the Well*
- Chapter 7: *Completing the Well's Structure*

The illustrations and graphics may not depict every circumstance. Each of the wells shown in Figures 6-6 to 6-13 may encounter conditions that may require specialized design or construction. For example:

- Flowing artesian conditions,
- Presence of gas,
- Breathing (sucking and blowing) conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure.

All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the **Wells Regulation.**

FIGURE 6-6: DRILLED WELL IN OVERBURDEN – WELL SCREENS THAT ARE ARTIFICIALLY PACKED OR NATURALLY DEVELOPED

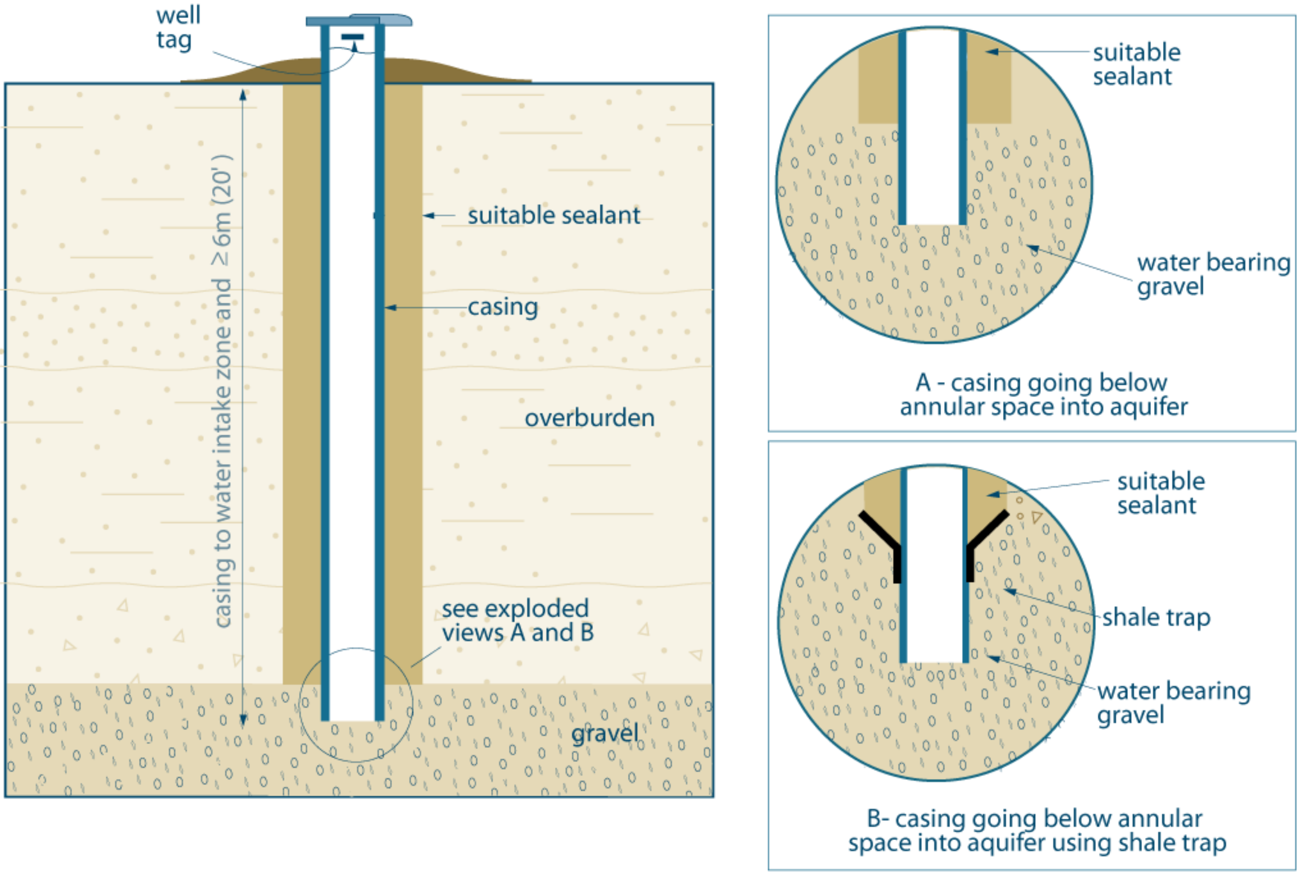


The diagram above is not to scale and is for illustrative purposes for this chapter only.

For information about the use of centralizers with rotary equipment or the use of a breakaway guide with cable tool equipment, see the section titled: "Centering the Casing" in Chapter 5: *Constructing & Casing the Well.*

For further information on the filter pack – see the section titled: "Filter Packs around Well Screens for Drilled Wells," in Chapter 5: *Constructing & Casing the Well.*

FIGURE 6-7: DRILLED WELL – WITHOUT WELL SCREEN

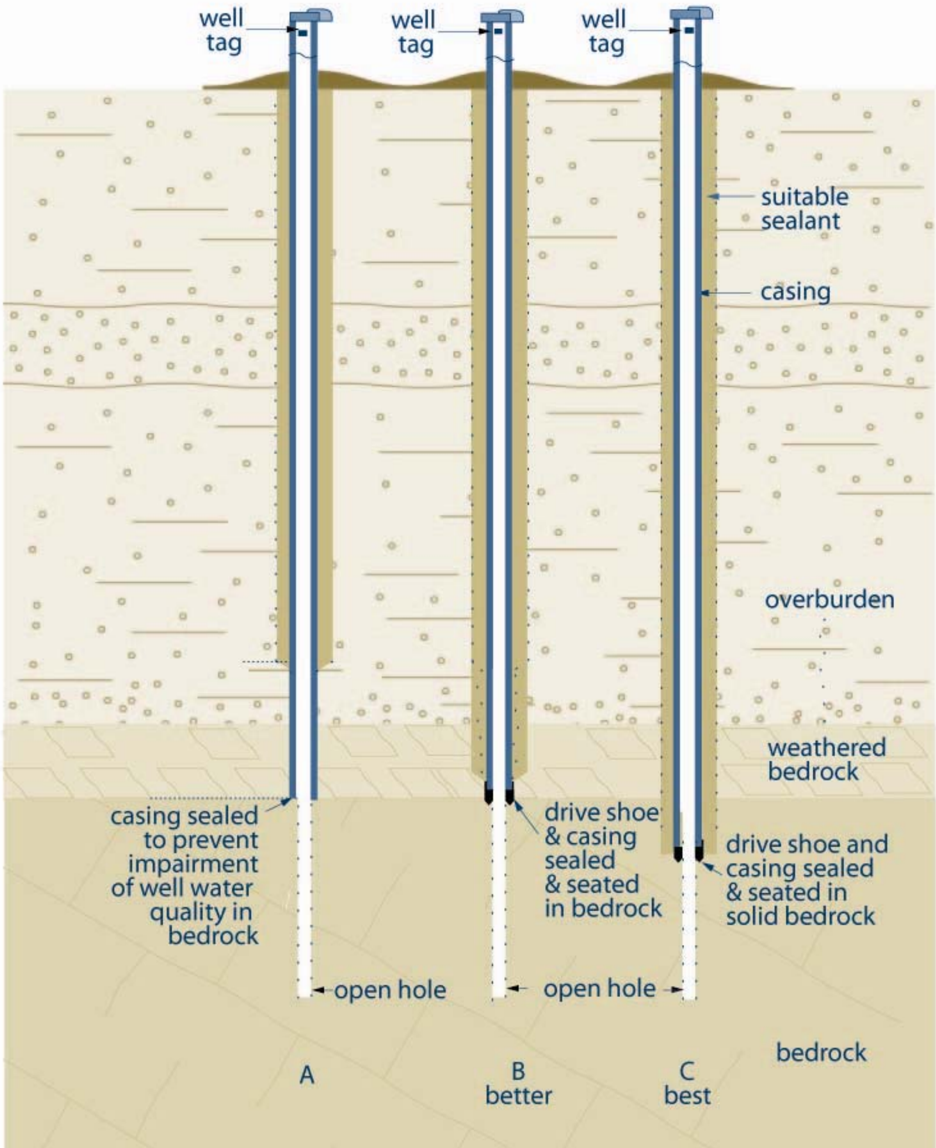


- The hole diameter must be at least 7.6 cm (3") greater than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2") greater than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).
- This applies to all wells other than wells constructed by the use of a driven or jetted point, dug wells and bored wells with concrete casing . This will apply to bored wells with casing other than concrete (e.g. galvanized or fiberglass).
- In this example, the casing has been driven below the bottom of the annular space.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

For information about the use of centralizers with rotary equipment or the use of a breakaway guide with cable tool equipment, see the section titled: "Centering the Casing" in Chapter 5: *Constructing & Casing the Well.*

FIGURE 6-8: EXAMPLES OF DRILLED WELLS IN BEDROCK

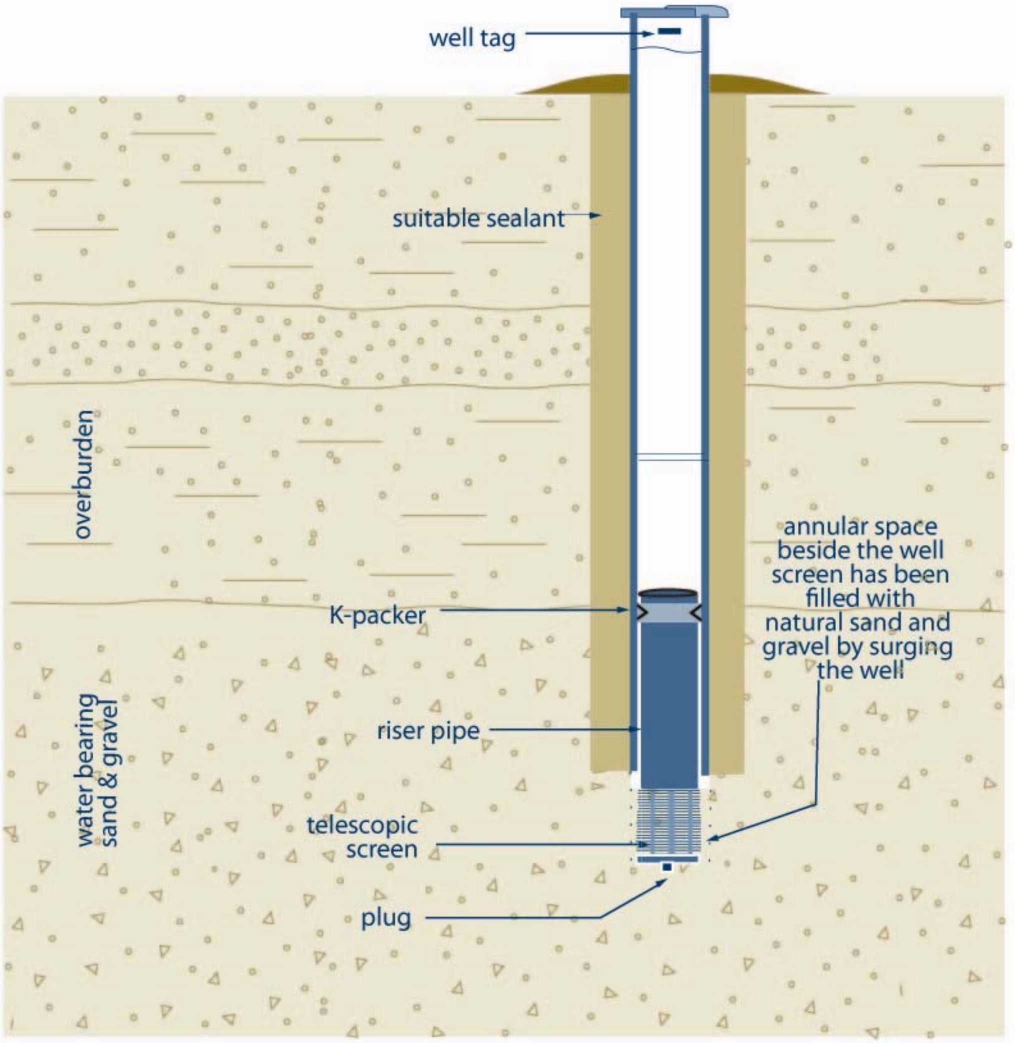


- The hole diameter must be at least 7.6 cm (3") greater than than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2") greater than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).
- In this example, the casing in A has been driven below the bottom of the annular space so that no further annular space is created.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

For information about the use of centralizers with rotary equipment or the use of a breakaway guide with cable tool equipment, see the section titled: "Centering the Casing" in Chapter 5: *Constructing & Casing the Well.*

FIGURE 6-9: DRILLED WELL IN OVERBURDEN – NATURAL DEVELOPMENT, CASING PULLED BACK EXPOSING SCREEN METHOD



- The hole diameter must be at least 7.6 cm (3") greater than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2") greater than the final outer casing for at least 6 m (19.7') from the ground surface or the full depth of the well (whichever is less).

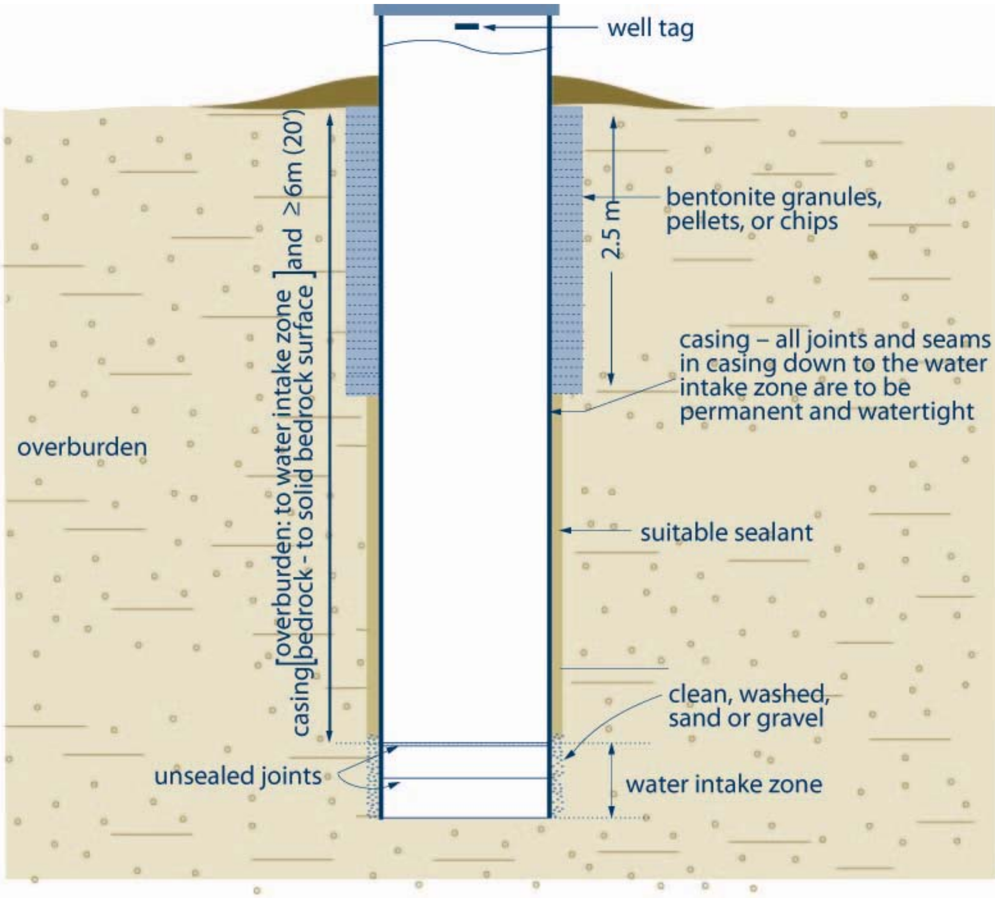
The diagram above is not to scale and is for illustrative purposes for this chapter only.

See Chapter 5: *Constructing & Casing the Well* for further information on this method of well construction.

For information about the use of centralizers with rotary equipment or the use of a breakaway guide with cable tool equipment, see the section titled: "Centering the Casing" in Chapter 5: *Constructing & Casing the Well.*

For further information on the filter pack see the section titled: "Filter Packs around Well Screens for Drilled Wells," of Chapter 5: *Constructing & Casing the Well.*

FIGURE 6-10: BORED WELLS WITH CONCRETE CASING



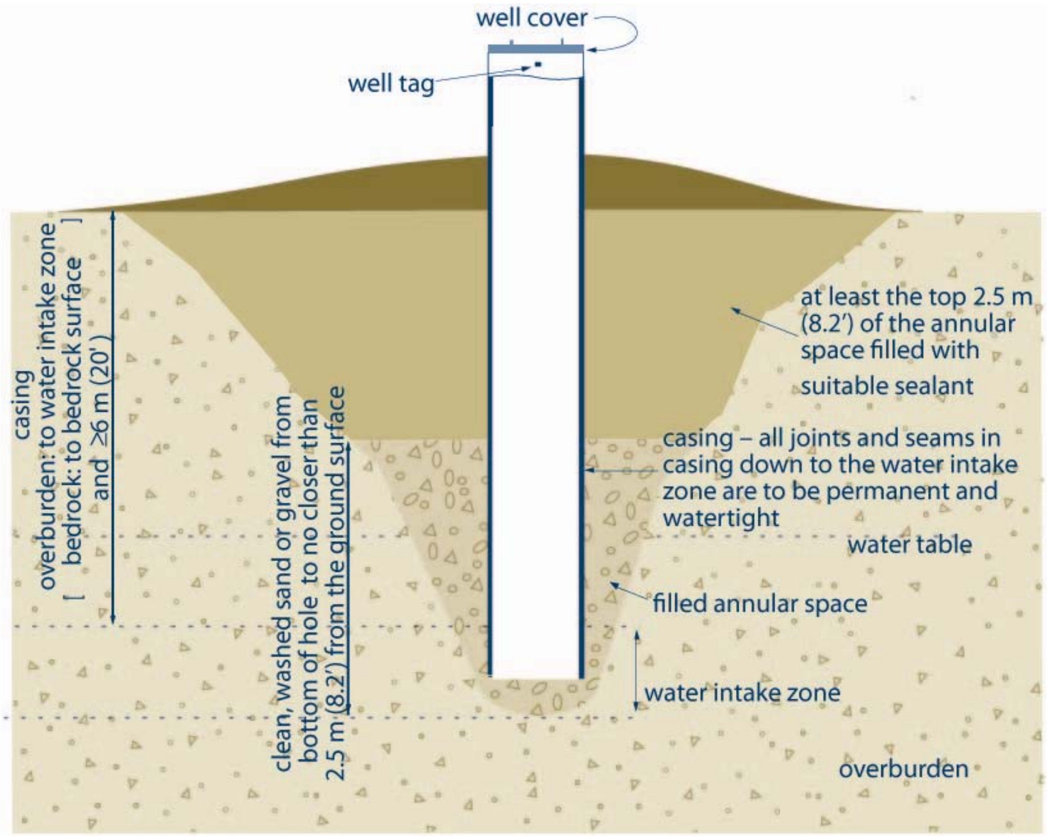
- All concrete tiles with joints that are not sealed with mastic are considered a well screen (water intake zone).
- The hole diameter must be at least 15.2 cm (6″) greater than the casing's outer diameter from the land surface to a depth of 2.5 m (8.2′).
- The hole diameter must be at least 7.6 cm (3″) greater than casing's outer diameter from 2.5m (8.2′) to at least 6m(20′) below the land surface.
- Sand or gravel must be installed from at least the top of the water intake zone or screen to no closer than 6m (20′) below the land surface unless the only useful aquifer available necessitates a shallower well in which case clean, washed sand or gravel must be installed no closer than 2.5 m (8.2′) from the land surface.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

For further information about using concrete tiles as well screens, see the section titled: "Well Screens Using Large Diameter Concrete Tiles," in Chapter 5: *Constructing & Casing the Well*.

For further information on the filter pack – see the section titled: "Filter Packs around Well Screens for Drilled Wells," in Chapter 5: *Constructing & Casing the Well*.

FIGURE 6-11: DUG WELL

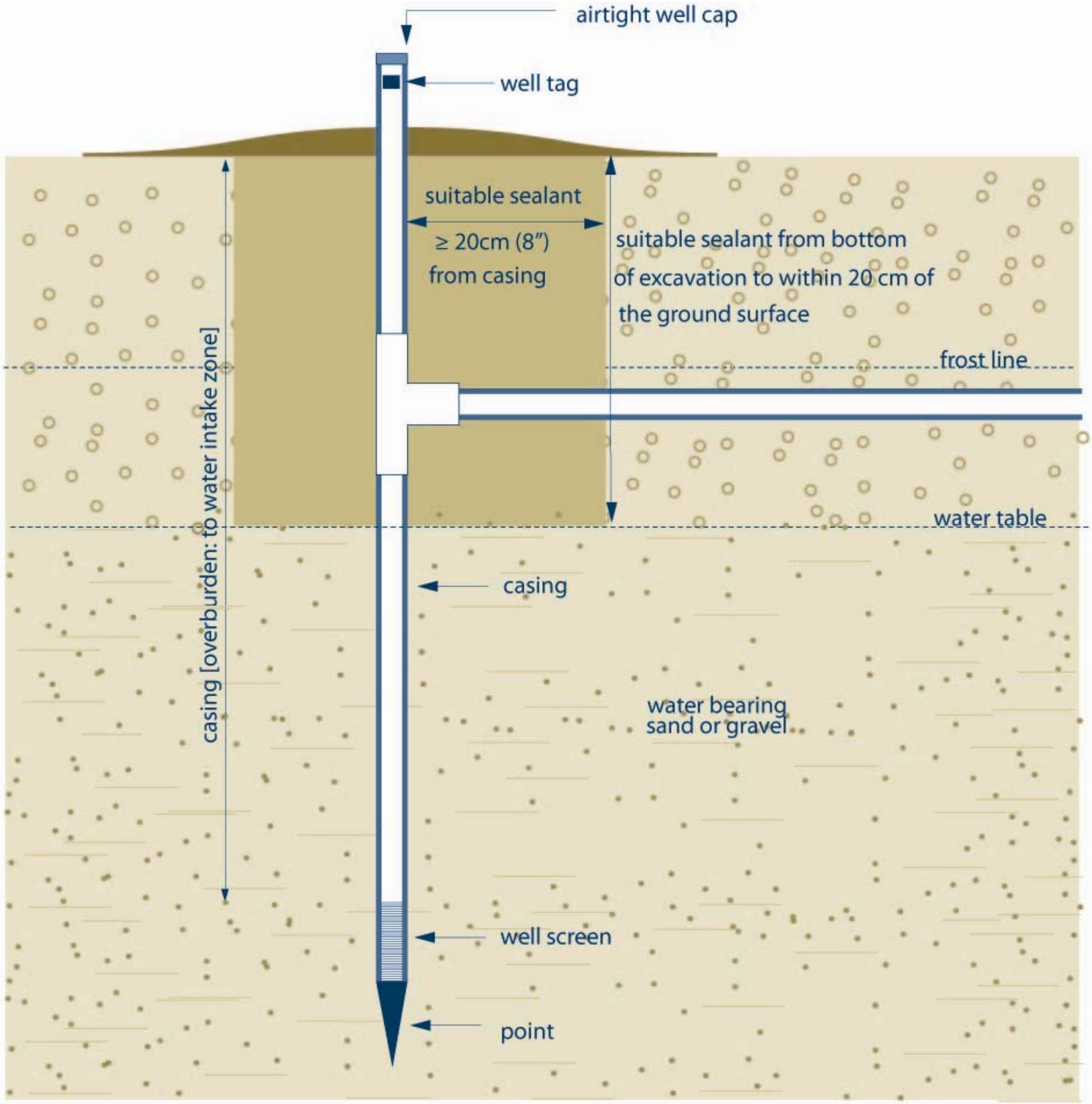


- All concrete tiles with joints that are not sealed are considered well screens (water intake zone).
- Sand or gravel can be replaced with native material (soil) that was excavated from the hole, if the well is not constructed in a contaminated area and the horizons of soil are excavated separately, stored separately, kept free from contamination and backfilled in the same relative positions that they originally occupied.
- Suitable sealant that is used to fill annular space must provide appropriate structural strength to support the weight of persons and vehicles that may move over the well area after it is filled.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

For further information about using concrete tiles as well screens, see the section titled: "Well Screens Using Large Diameter Concrete Tiles," in Chapter 5: *Constructing & Casing the Well*.

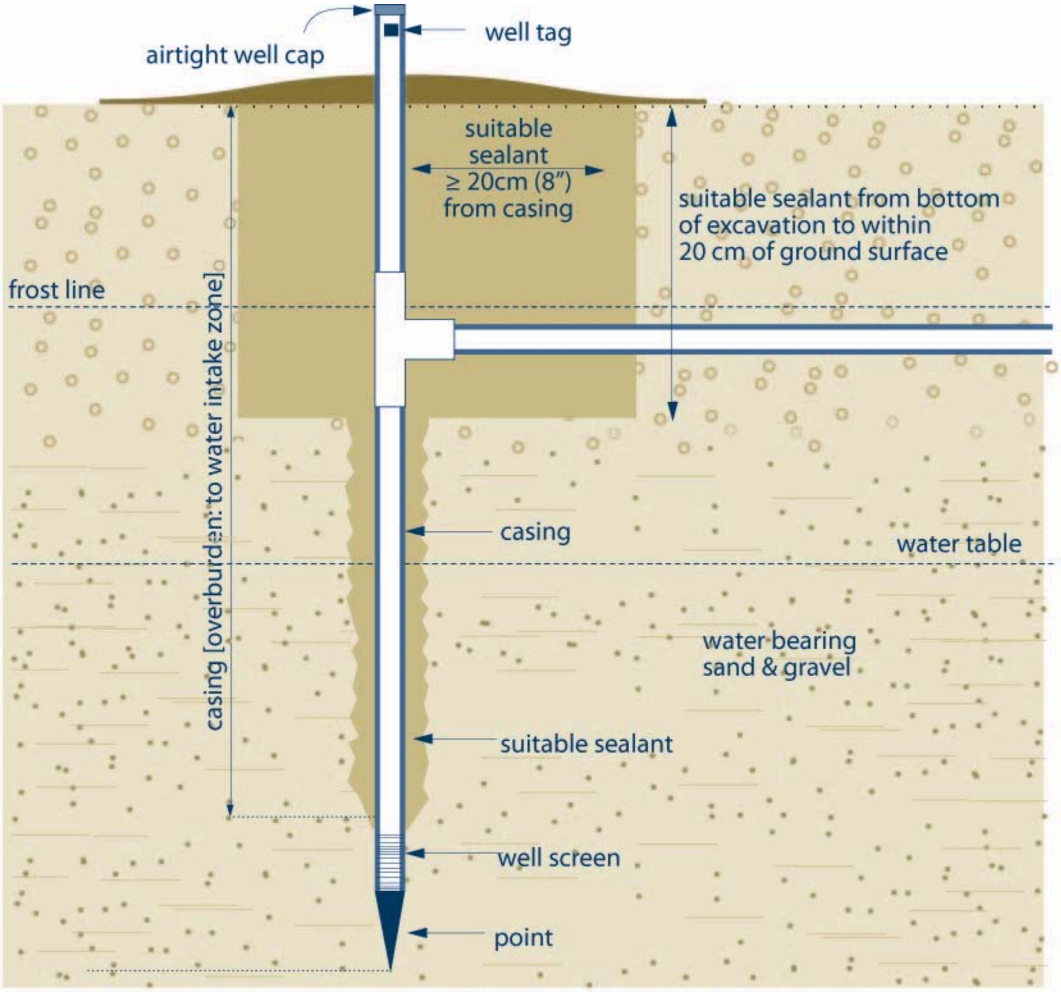
FIGURE 6-12: DRIVEN POINT WELL



- The excavation has been created as a result of installing pumping equipment. To see how this is filled see Chapter 9: *Equipment Installation*, for further instructions.
- If any annular space is created during the driving of the casing, the annular space must be completely filled using materials and a method approved in writing by the Director.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

FIGURE 6-13: JETTED WELL



- The excavation has been created as a result of installing pumping equipment. To see how this is filled see Chapter 9: *Equipment Installation*, for further instructions.
- A person constructing a well by jetting typically creates an annular space around the well casing. The person constructing a well by jetting must ensure that any annular space around a well casing is sealed to prevent any movement of water, natural gas, contaminants, or other material between subsurface formations (aquifers) or between a subsurface formation and the ground surface.

The diagram above is not to scale and is for illustrative purposes for this chapter only.

Comparison of Bentonite and Cement Grouts

The most common sealing materials used are bentonite and neat cement products. Both have specific, unique and desirable properties. Table 6-2 summarizes the advantages, disadvantages and application of bentonite slurry (grout) versus cement based slurries (grouts).

Table 6-2: Some General Bentonite and Cement Advantages and Disadvantages[1]

	Advantages	Disadvantages
Bentonite Based Sealants	• Suitable low permeability with high solids by weight grouts. • Generally non-shrinking and self-healing. • No heat generated during hydration. • Low density. • Sodium bentonite products expand to about 12 to 15 times their original dry volume allowing for less material to be required. • No long curing time required before proceeding with further well drilling. To achieve full gel strength bentonite takes 8 to 48 hours. • Properties such as density can be altered with additives.	• For some grout mixtures with significantly high bentonite solids content (>35%), rapid swelling rate and high viscosity result in difficult pumping through grout pumps and tremie pipes. • Mineralized groundwater (e.g.>5,000 mg/L of total dissolved solids or >8,000 mg/L chlorides) may inhibit its hydration process and its effectiveness as a sealant. This includes source water used in mixing bentonite for a grout. • Flowing well environments will likely diminish bentonite's effectiveness • When filling the annular space, bentonite grouts can leak out into open fractures in bedrock environments. • May have an impact on the groundwater chemistry and the well components because it can trade off cations such as sodium, aluminium, iron and manganese. • Additives that may be added to the bentonite slurry (organic and inorganic polymers) may affect groundwater chemistry near the well • Can make its way through filter packs and screens into the well and into water samples. Thus, it should be placed no closer than 0.9 m (3′) to 1.5 m (5′) above the top of a well screen. • Not suitable for arid climates due to potential for dehydration causing cracking and thus will not perform as a long term effective sealant.

[1] David M. Nielsen. *Environmental Site Characterization and Ground-Water Monitoring: Second Edition.* Taylor and Francis Group, Boca Ratan, FL. 2006. pages 755 – 769.

Cement Based Sealants	• Suitable low permeability. • Easily mixed and pumped. • Hard-positive seal provides structural integrity (good gel strength) and will not erode or wash-out with water movement. • Supports and adheres to casing. • Any remaining casing is rendered permanent and non-movable. • Adheres well to bedrock. • Properties can be altered with additives to reduce hydration time (calcium chloride), to make it stronger (aluminum powder), or have a higher resistance to sulphate rich environments (fly ash). • Expanding cements, Types K, M and S, have characteristics and shrinkage-compensating additives that work well as annular seals • Air-entrained cements work well in cold weather climates because cement with air-entraining agents has water tightness and freeze thaw resistance. • Provides weight and strength to overcome pressures associated with flowing wells.	• Possible shrinkage if extra water is used, if improper additives are used or if the person is not using shrinkage compensated cements. • Settling problems occur if not properly mixed or placed. • Long curing time (minimum 12 hours) increases time to complete well and install equipment in well. • Produces high heat levels during hydration process that can distort some plastic casings. The high heat of hydration in combination with weight of grout also increases the potential for plastic casing to distort or collapse. • High density results in loss of grout to some permeable overburden and bedrock formations. • If prompt equipment cleanup does not occur, equipment damage may result. • In order to properly set, mixing water needs to be cool, clean, fresh water free of oil soluble chemicals, organic material, alkalies, sulphates and other contaminants. • In order to properly set, mixing water needs to have a total dissolved solids concentration of less than 500 mg/L. • Using water that has a high pH may increase setting time. • Equipment such as a tremie pipe needs to be kept cool to prevent flash set problems to pumps and tremie pipes. • If too much water is used in the mixture, the extra water cannot chemically bind with cement (called bleed water), becomes highly alkaline and then can percolate through cement, bentonite and filter pack material causing contamination in groundwater. Voids in the cement created by this bleed water can also be subject to chemical attack and thus, will not perform as a long term effective sealing material. • Prolonged mixing can interrupt heat of hydration process and reduce strength and cement quality. • Neat cement mixtures increase the pH in the subsurface formations. An increase in pH can cause dissolved metals to precipitate from solution onto well components like the well screen, and can cause a negative bias in groundwater sample analyses compared to actual ambient groundwater concentrations. • Weight of cement may increase hydraulic pressure on filter pack and thus compromise and permanently plug the pack material and well screen. • Too thin of a cement mixture may also allow cement to penetrate, compromise and permanently plug the pack material and well screen.

Notes Regarding Table 6-2:

Suitable sealant must be compatible with the quality of the water in the well.

Sealant must be a bentonite mixture of clean water and at least 20 percent solids by weight, or a product that will be equivalent with respect to the ability to form a permanent watertight barrier (see Chapter 2: *Definitions & Clarifications,* Table 2-2.) For example, a mixture of water with cement, concrete or cement with no more than 5 percent bentonite solids by weight may be an equivalent sealant in some environments.

When evaluating bentonite as an annular sealant, consider the following:

- The position of the static water level and its seasonal fluctuations
- The ambient groundwater and mixing water quality

In some cases 3 to 8 percent of bentonite is used as an additive to cement or concrete to improve the workability, slurry weight and density of the cement slurry. However, bentonite is chemically incompatible with cement causing bentonite's swelling ability to reduce. The bentonite additive also reduces the set strength of the seal and lengthens set time.

Calculating Amount of Materials Required

Before beginning, calculate the amount of materials (sand, gravel and bentonite and/or cement) required to properly seal the annular space. Regardless of the base materials or type of grout, it is the measured amount of water and the consistent use of that ratio of water to the dry product that is ultimately the key element to achieving the appropriate grout properties.

The amount of material needed will depend on the volume of annular space that needs to be filled (i.e. width of the annular space and depth of the annular space).

Some things to remember when calculating the amount of materials required:

- Allow for possible hole increases due to drilling actions, geology and flushing media. Consider adding 10% to 15% more material to the calculated amount.
- Volume is a measurement of the amount of space occupied by a three-dimensional object as measured in cubic units [e.g. gallons, quarts or litres, cubic metres (m^3) or cubic feet (ft^3)].
- The volume of the hole that the casing will occupy must be accounted for.
- When calculating volume, make sure that all measurements are of the same type. For example, all three dimensions are metres, or inches, or feet or whichever type of measurement used.

Volumes on the packaging will typically be in metric or U.S. units.

The following formulae can be used to calculate the volume of the annular space.

METHOD 1

ANNULAR SPACE VOLUME = VOLUME OF HOLE - VOLUME OF CASING, WHERE:

$$\text{VOLUME OF HOLE} = 3.14 \times \left(\frac{\text{DIAMETER OF HOLE}}{2}\right)^2 \times \text{DEPTH}$$

AND

$$\text{VOLUME OF CASING} = 3.14 \times \left(\frac{\text{OUTER DIAMETER OF CASING}}{2}\right)^2 \times \text{DEPTH;}$$

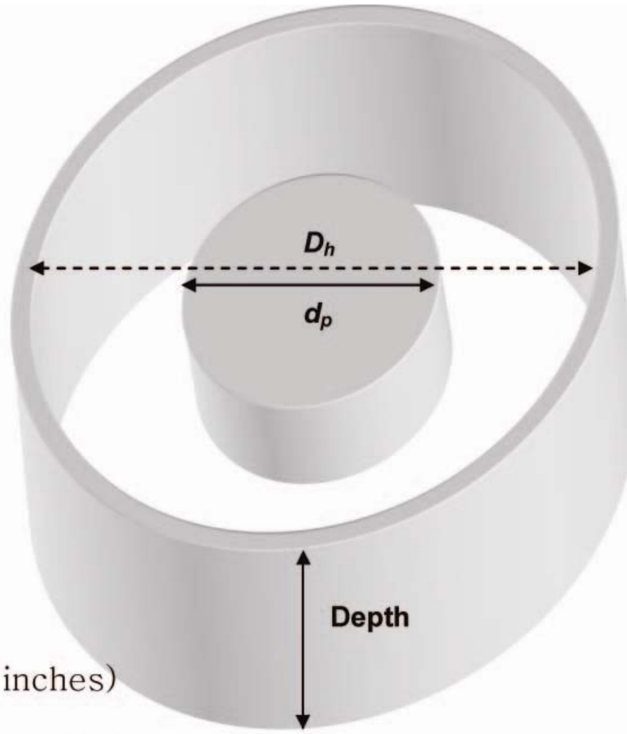
OR

$$\text{VOLUME OF HOLE} = 0.785 \times \text{DIAMETER}^2 \times \text{DEPTH OF HOLE}$$

AND

$$\text{VOLUME OF CASING} = 0.785 \times \text{DIAMETER}^2 \times \text{DEPTH OF HOLE}$$

METHOD 2



WHERE:

D_h = Diameter of Hole (mm or inches)

d_p = Outer diameter of pipe (casing) (mm or inches)

$$\left(\frac{D_h(\text{mm})^2 - d_p(\text{mm})^2}{1273}\right) \text{ x Depth (metres) = Annular Space Volume (Litres)}$$

OR

$$\left(\frac{D_h(\text{inches})^2 - d_p(\text{inches})^2}{29.45}\right) \text{ x Depth (feet) = Annular Space Volume (Imperial Gallons)}$$

The exact amount of grout required cannot always be determined due to irregularities in the size of the hole and losses into fractured rock. Be prepared with extra material onsite to add to the initial estimate on short notice.

See the section titled: “Tools” at the end of this chapter for a Grouts and Sealants Application Matrix to help calculate the amount of grout required to fill the annular space (Table 6-5).

The following tables can be used to calculate the volume of sealant (i.e. bentonite, cement, concrete) yielded per bag of product.

Table 6-3: Calculating Volume of Bentonite [at 15%, 20% and 23% Solids based on one 23 kg (50 lbs) bag of Sodium Bentonite]

	% Solids Grout		
	15	**20**	**23**
Water - Litres	125	91	76
Water - Imperial Gallons	33	24	20
Yield Volume - Litres	133.6	99.6	84.4
Yield Volume - Imperial Gallons	29.4	21.9	18.6

Table 6-4 is based on one 43 kg (94 lbs) bag of cement and the volume of concrete based on one 43 kg (94 lbs) bag of cement mixed with 0.027 cubic metres (1 cubic foot) of sand or gravel (Portland cement).

Table 6-4: Calculating Volume of Concrete and Cement

	Concrete	Portland Cement
Water - Litres	19.7	19.7
Water – Imperial Gallons	4.3	4.3
Yield Volume – Litres	60.3	33.3
Yield Volume – Imperial Gallons	13.3	7.3

One litre of water weighs one kilogram and Portland cement produces a slurry weight of 1.87 kg/L.

Mixing Bentonite Grout (Sealant)

When mixing grout, it is important to follow the manufacturer's specifications provided on the packaging or with the product.

Inhibited bentonite grouts (sealants) are a powdered type material that is designed to slow the rate of hydration just long enough to allow the bentonite to be placed into the annular space.

Best Management Practice – Mixing Bentonite Grout

When mixing bentonite material with clean water it is important to use a high shear paddle mixer in a mixing drum to thoroughly shear the bentonite particles to suspension. Once properly mixed, the bentonite grout (sealant) is pumped through a tremie pipe to fill the annular space. Positive displacement pumps with minimal shearing action are needed when placing bentonite grout (sealant) in the annular space. This technique allows for proper placement and hydration of the bentonite grout (sealant) in the annular space.

Techniques for Successful Mixing

- Mix bentonite with clean water to ensure that the bentonite sealant will last the life of the water well. 'Clean' means water that will not interfere with the reaction to make a bentonite slurry as recommended by the manufacturer and will not impair the well water.
- Do not assume that potable water sources (municipal water, etc.) are acceptable sources of mixing water for bentonite drilling mud or sealant. It is important to always test or, if available, review any water quality reports for the mixing water for pH, hardness, total dissolved solids and chlorides before mixing.
- Mix bentonite with clean water until suspension is achieved. Immediately pump material into the annular space through a tremie pipe.
- Prepare small batches to ensure that at least 20% bentonite solids by weight is maintained.
- Use gear pumps for bentonite sealants consisting of bentonite polymer and water mixtures (two step grouts).
- Use progressing cavity pumps for bentonite sealants consisting of bentonite and water mixtures (one step grouts).

Consequences of Poorly Mixed Bentonite Grout

- Mixing water that is highly mineralized may inhibit the hydration process of the bentonite grout and its effectiveness as a sealant.
- If excess "hardness" is present in the mixing water, the bentonite may clump and adhere to the paddles during the mixing phase. In severe cases it can result in plugging of tremie lines and disruption of the grouting process.
- Grout that is mixed or sheared too much will start to hydrate too rapidly. This will result in difficulty pumping the grout, plugging up of the tremie line and wasting a batch.

It is important to follow the manufacturer's specifications for pH, hardness, chloride, total dissolved solids and other water quality issues.

Mixing Cement or Concrete Grout (Sealant)

Cement grout (sealant) must be made using carefully measured quantities of water and Portland cement (see Table 6-4). In concrete grout, aggregate and other materials (e.g. plasticizers) are added to cement and water. Further information on cement can be found at the following website titled "Cement and Concrete Basics:" http://www.cement.org/basics/concretebasics_history.asp

A paddle mixer in a mixing drum with either a progressive cavity or gear pump are common choices for mixing and pumping cement or concrete grout (sealant). Small portable grouting machines that combine both the mixing and the pumping operations are also often used. These machines typically have a positive displacement pump because it can work efficiently against much greater head pressures with low loss of grout volume.

Techniques for Successful Mixing[2]

Best Management Practice – Techniques for Successful Mixing

- Mixing water needs to be cool, clean, fresh water free of oil soluble chemicals, organic material, alkalies and other contaminants and have a total dissolved solids concentration of less than 500 mg/L to ensure proper setting of the grout (sealant).
- It is important that grout be mixed thoroughly and be free of lumps.
- If the mixture is purchased from a ready-mix concrete plant, the correct proportions of cement, water and other aggregate material, if present, must be verified by using equipment such as a drilling fluid balance.
- It is important to use a protective strainer on the tank from which the grout is pumped.
- Immediately pump material into the annular space through a tremie pipe.

Consequences of Poorly Mixed Cement Grout

- Mixing water that has a high level of total dissolved solids or high pH may result in increased setting times and/or failure to set.
- If the grout is not thoroughly mixed and free of lumps then partial setting may occur and the effectiveness of the seal will be compromised.
- Premature setting may occur due to the incorrect assumption of hole temperature, use of hot mixing water, improper water to cement ratios, contaminants in the mixing water, mechanical failures, and interruptions to pumping operations.
- Improper water to cement ratios may also cause excessive shrinkage of the grout.

[2] Sterrett, Robert J. 2007. *Groundwater and Wells-Third Edition*. Johnson Screens/a Weatherford Company., New Brighton, MN. P 453-454.

Grout Placement Requirements

The **Wells Regulation** has specific requirements for the placement of materials in the annular space (see Table 6-1 in "Requirements Plainly Stated").

The **Wells Regulation** requires that any annular space of any new cased well, other than the annular space surrounding the well screen, must be sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between subsurface formations and the ground surface by means of the annular space.

The **Wells Regulation** requires that a tremie pipe be used to install the suitable sealant and that the bottom of the tremie pipe remain immersed in the rising accumulation of sealant for all new wells except dug wells, wells constructed with the use of a driven point and wells constructed by jetting.

Successful placement of the grout will depend on the temperature, stability, size of the annular space and pressure in the hole, and how well the casing is centered, and the grouting placement.

Best Management Practice – Sealing the Annular Space

The following will help to assure that the sealant will provide a satisfactory seal:

- During placement of sealant, the sealant returning to the surface should be of the same consistency of that being pumped.
- The first indication of sealant returning to surface is not an indication to stop pumping.
- Where the tremie pipe is placed in the annular space, active pumping of the sealant should continue as the tremie pipe is extracted from the annular space to ensure effective displacement.
- Sealant pump suction and discharge hoses should be adequately sized to overcome friction losses and decrease chances of plugging.
- Suction and discharge hose connections to the pump should be made using quick-connect style couplings. This will save time when attempting to locate a blockage in the hose and allow faster cleanup.
- When the pump is also used for mixing, the discharge hose should be plumbed in such a manner to allow changeover from mixing to pumping sealant without shutting down the pump.
- A pressure gauge should be installed on the pump discharge and monitored to ensure that the working pressure does not exceed the hose and pipe maximum pressure rating. A sudden increase in pressure may indicate that the tremie pipe has become plugged.

Grout Placement – Inner String Method

In the inner string method of placing grout, the tremie is suspended in the casing. A cementing (float) shoe is attached to the bottom of the casing before the casing is placed in the hole. The tremie pipe is lowered until it engages the shoe.

Placing Grout Using the Inner String Method

To place grout using the inner string method:

1. Attach a float shoe or other similar device to the bottom of the casing before the casing is placed in the hole.
2. Place the casing in the hole to the bottom of the well. Then lower the tremie pipe inside the casing until it engages the shoe. This permits the grout to pass into the annular space but prevents it from leaking back into the casing while grouting.
3. Place water or drilling fluid into the casing to prevent the grout from coming back up the casing.

   For shorter strings of casing [i.e. 6 to 30 metres (20′ to 100′)] seal the tremie pipe at the top of the casing using one or two stacked top well seals. The barrier created by the well seals along with the weight of the drilling fluid or water will minimize the amount of grout that can travel back up the inside of the casing string during and after the pumping process.
4. Pump the grout through the tremie pipe and float shoe and force it upward around the casing.
5. Disconnect and remove the tremie pipe.
6. Clean up all grouting equipment.

7a. Where bentonite grout is used and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. Bentonite takes 8 to 48 hours to achieve full gel strength.

Best Management Practice – When Bentonite Grout Settles

The bentonite grout should be topped up to the original level before drilling continues if there has been settling or subsidence in the annular space.

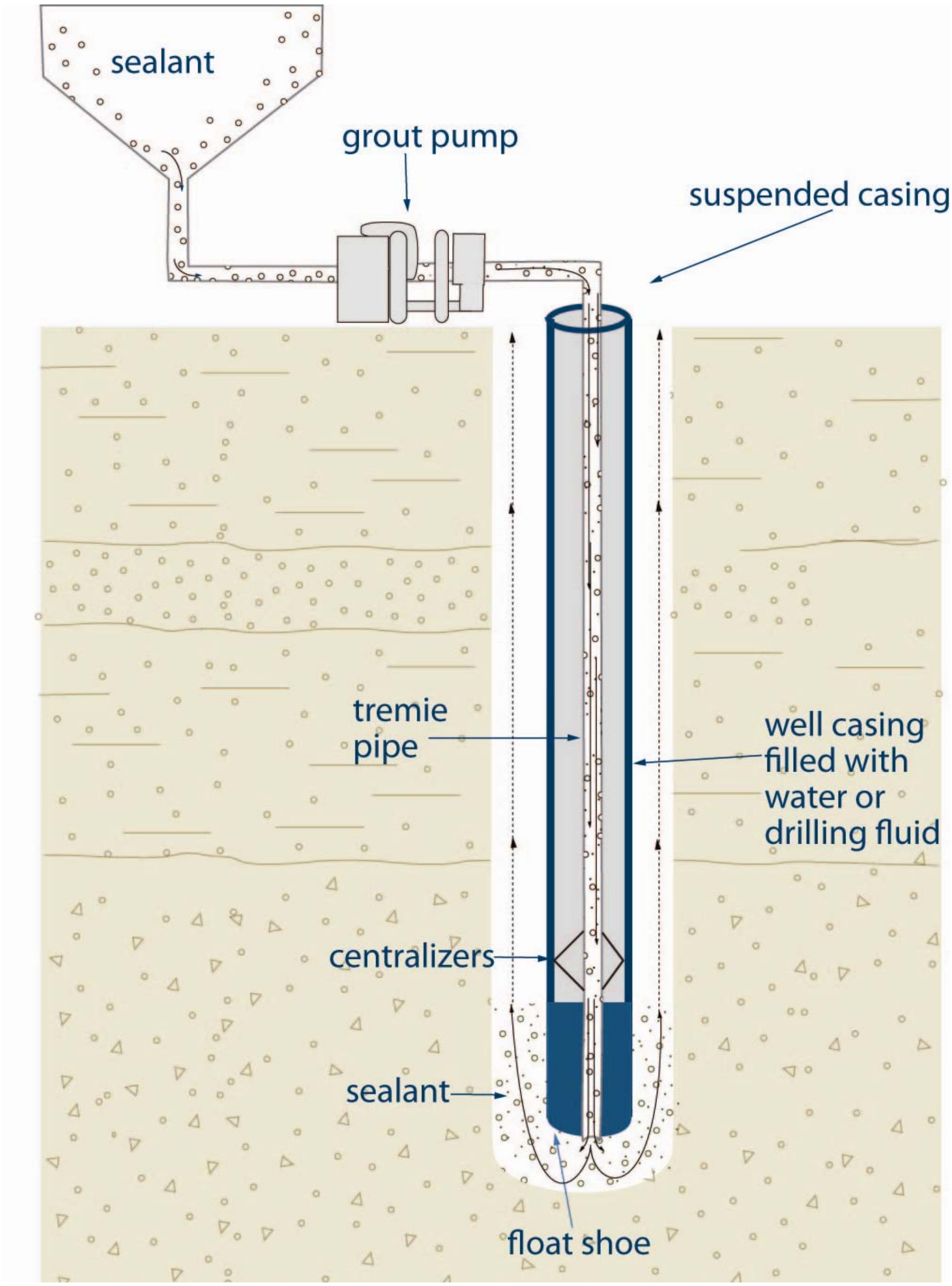
7b. Where cement grout is used, cement must be allowed to set according to manufacturer’s specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.

8. Drill out or remove the float shoe or other device from the bottom of the casing.

The sealant at the bottom of the casing is vulnerable when drilling restarts. The sealant must be physically and structurally sound and capable of withstanding the initial pressures of drilling. It is important to avoid upward movement of flushing media or grout column on the outside of the casing when starting to drill after placement of grout. This upward movement can be caused by the displacement of water in the casing when using the percussion drilling action or when using air or water based flushing media.

FIGURE 6-14: PUMPING GROUT DOWN TREMIE PIPE – INSIDE CASING

Figure 6-15: Inner String Method of Grout placement



The diagram above is not to scale and is for illustrative purposes for this chapter only.

All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the **Wells Regulation.**

Grout Placement – Tremie Pipe Outside Casing Method

When using this placement method, the grout material is pumped or placed using a tremie pipe that is installed in the annular space.

Best Management Practice – Use of a Grout Pump

When a grout pump is used with a tremie pipe, it is important that any fluid (i.e. drilling mud or water) of less weight than the grout be displaced from the annular space ensuring that any voids or spaces are filled with grout (sealant).

Best Management Practice – Use of a Larger Diameter Tremie Pipe

It is important to use as large a tremie pipe as possible because it:

- Reduces the amount of friction loss that is natural for a small diameter tremie pipe
- Reduces the velocity of grout entering the annular space
- Enhances the efficiency of the displacement process
- Significantly improves the effectiveness of the overall seal

The annular space must meet regulatory requirements (see Table 5-5 of Chapter 5: *Constructing and Casing the Well*, and Table 6-1 of this chapter) and be large enough to accommodate the tremie pipe (Best Management Practice: Size of Hole, on page 26 of Chapter 5: *Constructing and Casing the Well.*))

Placing Grout Using the Outside Casing Method

To place grout using the tremie pipe outside casing method:

1. Close the lower end of the casing with a drillable plug to ensure the grout that is placed in the annular space cannot enter the casing.

   Another option is to drive the casing into the undisturbed formation below the hole.

2. Install the tremie pipe into the annular space and ensure the tremie pipe reaches the bottom of the annular space.

3a. If a pump is used, the grout is pumped down the tremie pipe discharging into the bottom annular space. Continued discharge of grout into the bottom of the annular space causes the rising accumulation of grout to the ground surface.

   The pump must be capable of developing enough pressure to overcome the friction caused by moving the grout through the tremie pipe and up the annular space.

Issues with a grout pressure head that may prevent the upward placement of grout with a pump are not usually a concern since the grout that is rising to the ground surface is at or below the grout pump elevation.

In some circumstances it may be advisable to pull the tremie pipe at about the same rate that grout is filling the annular space after the first mixed batch of grout is pumped into the annular space. This will minimize the grout pressure head on the tremie pipe outlet and reduce any chances of the tremie pipe being stuck in the hole due to hydration of the grout.

3b. If a pump is not used, the grout is poured down a tremie pipe above the ground surface. The grout flows from the tremie pipe into the bottom annular space by force of gravity. The tremie pipe is raised slowly and the bottom of the tremie pipe remains in the rising accumulation of grout until grout reaches the ground surface.

Ontario The bottom of the tremie pipe must remain submerged in the rising accumulation of grout until placement of the grout is complete.

4. Grouting may be complete when the grout leaving the annular space at the ground surface is of the same consistency as the grout being introduced into the bottom of the annular space.

5. Disconnect and remove the tremie pipe.

6. Clean all grouting equipment.

7a. Where bentonite grout is used and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. To achieve full gel strength bentonite takes 8 to 48 hours.

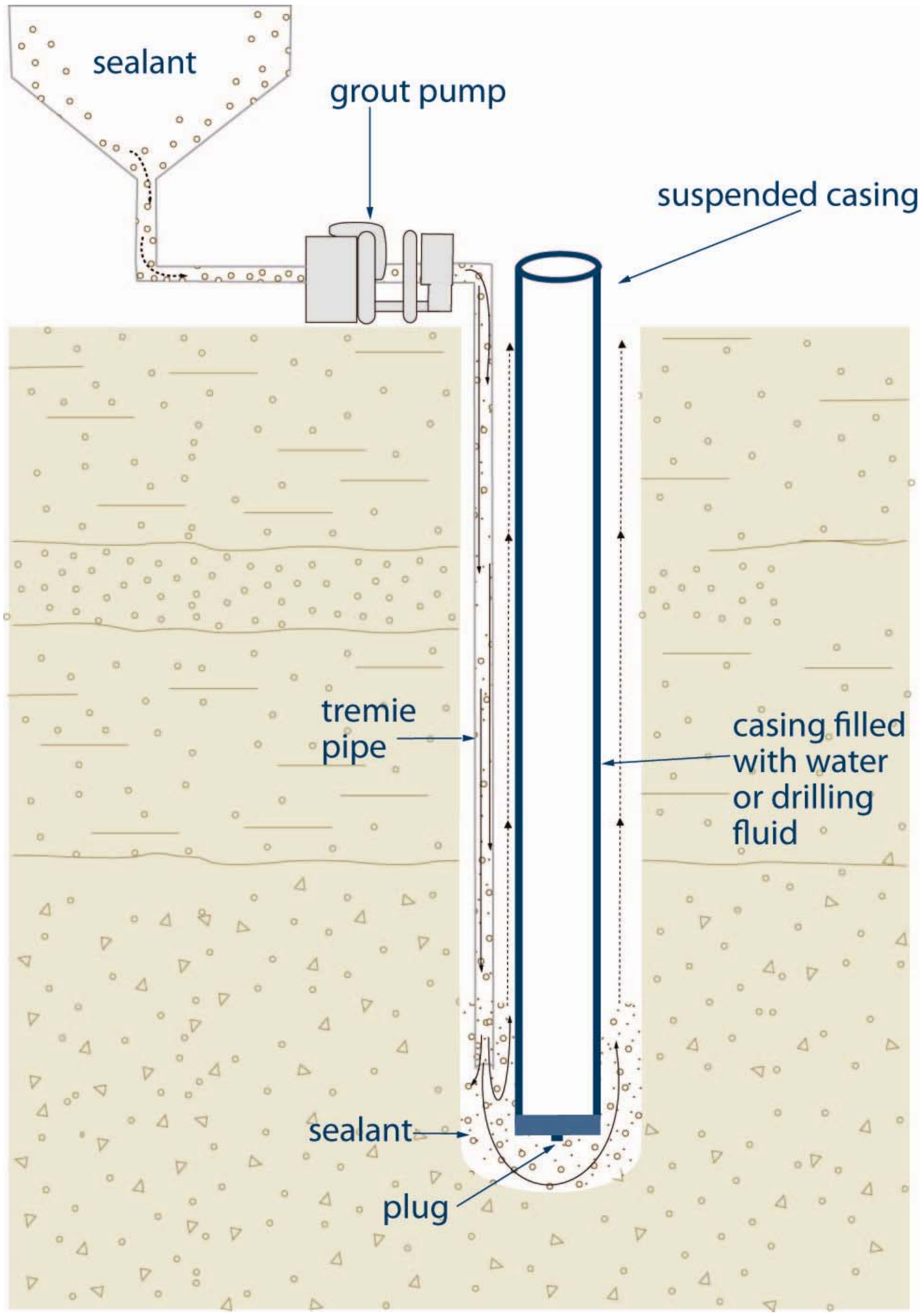
Best Management Practice – When Bentonite Grout Settles
If there has been settling or subsidence in the annular space, top up the bentonite grout to the original level before drilling continues.

Ontario 7b. Where cement grout is used, cement must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.

8. Drill out or remove the plug from the bottom of the casing.

The sealant at the bottom of the casing is vulnerable when drilling restarts. The sealant must be physically and structurally sound and capable of withstanding the initial pressures of drilling. It is important to avoid upward movement of flushing media or grout column on the outside of the casing when starting to drill after placement of grout. This can be caused by the displacement of water in the casing when using percussion drilling action or when using air or water based flushing media.

FIGURE 6-16: OUTSIDE CASING METHOD



The diagram above is not to scale and is for illustrative purposes for this chapter only.

All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the **Wells Regulation.**

FIGURE 6-17: INSTALLING TREMIE PIPE OUTSIDE CASING

FIGURE 6-18: A SUCCESSFUL SEAL

FIGURE 6-19: TREMIE REMAINS IN HOLE DURING GROUT PLACEMENT

FIGURE 6-20: HOLE EXCAVATED BESIDE DRILLED WELL

FIGURE 6-21: BENTONITE GROUT IN ANNULAR SPACE

Figure 6-20 shows a hole excavated beside a drilled well. The photograph shows the bluish-grey coloured bentonite grout that has filled the annular space of the drilled well adjacent to the black coloured drilled well casing. The bentonite has also adhered to the sand and gravel overburden. The pop can adjacent to the casing near bottom of excavation provides approximate thickness of grout.

In Figure 6-21 the same drilled well is depicted. The bluish grey coloured bentonite grout can be seen. The grout has filled the annular space of the well adjacent to the black coloured drilled well casing and adhered to the sand and gravel overburden.

Grout Placement – Pouring Without Tremie Pipe

When filling the annular space of dug wells and the upper 2.5 metres (8.2′) of bored wells with approved concrete casing, a tremie pipe is not required.

Ontario

The grout (sealant) must provide appropriate structural strength to support the weight of persons and vehicles that may move over the annular space of a dug well or well pit.

Care is needed when filling the annular space around a large diameter casing that is thin walled (e.g. fiberglass or corrugated steel) to reduce the risk of distorting the casing wall or casing joints. Care is also needed when pouring suitable sealant to ensure that bridging will not occur.

Grout Placement – Displacement Method

The displacement method involves calculating a volume of sealant (grout) material needed to fill the annular space.

1. In many cases, a starter casing is placed into the hole to support the sides of the well. The sealant is typically installed into the drilled hole by a gravity method such as pouring the material from the ground surface. In this case the starter casing acts as a tremie pipe.

   For further clarification of the definition of Tremie Pipe see Chapter 2: *Definitions and Clarifications*, Table 2-1

   In other cases a tremie pipe is lowered into the open hole and the grout is placed into the open hole through a tremie pipe.

2. A well casing with a plug located on the bottom of the casing is installed into the hole. The grout (sealant) is displaced by the casing and pushed up into the annular space.

3. If the sealant does not fill the entire annular space beside the well casing, then the sealant must be topped up using a tremie pipe to fill the entire annular space to the ground surface.

4a. Where bentonite grout is used and before further well construction proceeds, allow the bentonite time to achieve gel strength. To achieve full gel strength bentonite takes 8 to 48 hours.

Best Management Practice – When Bentonite Grout Settles

If there has been settling or subsidence in the annular space, top up the bentonite grout to the original level before drilling continues

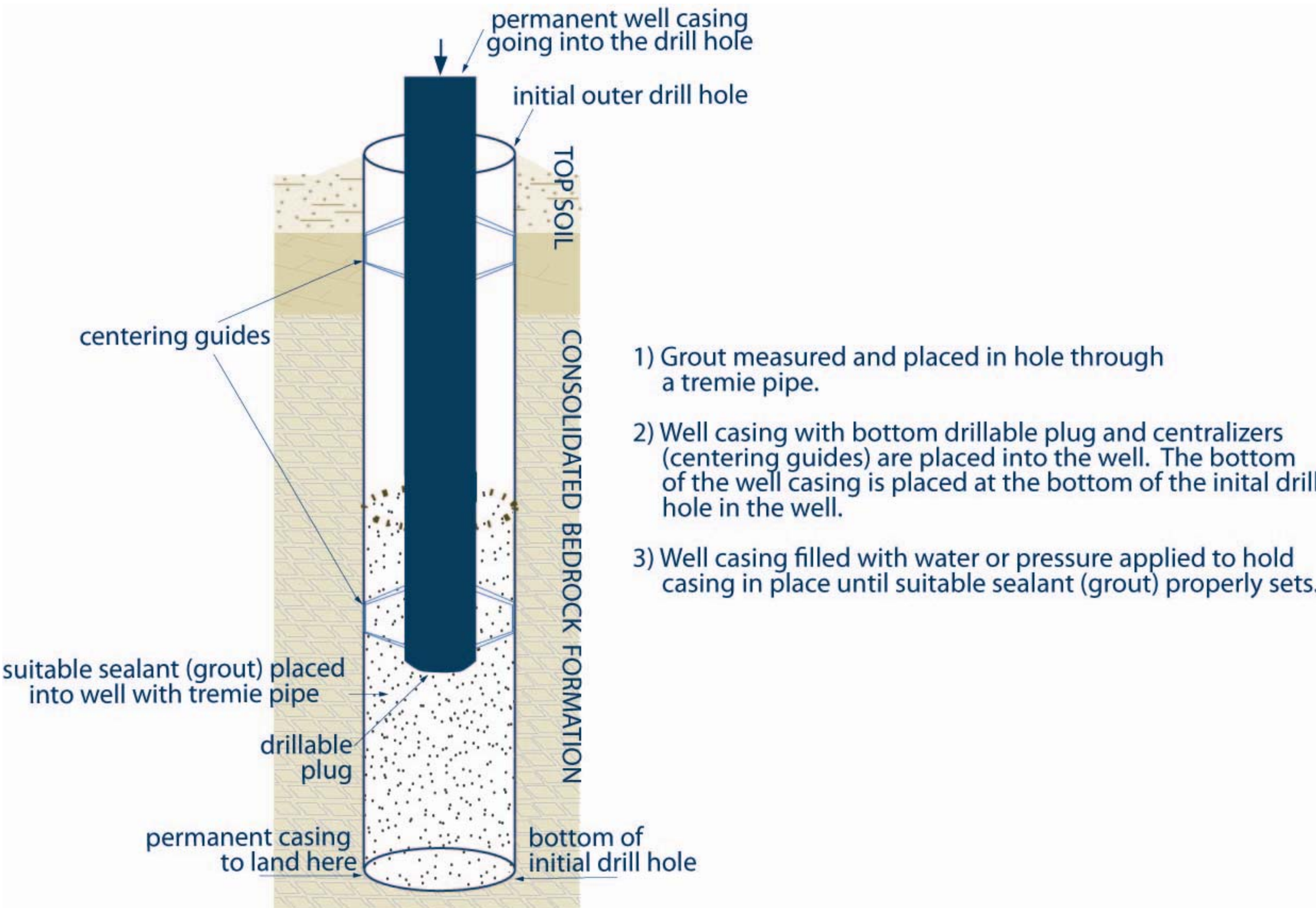
Ontario

4b. Where cement grout is used, cement grout must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.

5. Drill out or remove the plug from the bottom of the casing.

The displacement method using a tremie pipe allows the sealant to be continuously deposited into the hole. The casing with plug can then be installed into the well and meets the requirements of the **Wells Regulation**. The volume of sealant placed in the hole must be able to rise from the bottom of the annular space to the ground surface.

FIGURE 6-22: GROUT DISPLACEMENT METHOD



The diagram above is not to scale and is for illustrative purposes for this chapter only.

All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the **Wells Regulation.**

GROUT PLACEMENT – DOUBLE PLUG PROCEDURE[3]

The method is more common in the construction of oil and gas wells than water wells. It involves calculating a volume of grout (sealant) material needed to fill the annular space. As this method involves installing the pre-determined batch inside the well casing and pushing it into the annular space from below the well casing, care must be taken to determine if the volume of grout (sealant) within the well casing exceeds the volume of the entire annular space.

When determining the volume of grout needed, it is important to include an amount of grout that will leave 3 m (10′) to 4.6 m (15′) of grout (sealant) in the casing after the annular space has been filled.

1. A casing with a plug is installed in the hole. The casing is held above the bottom of the well. A pump and pipe are hooked onto the casing above the ground surface.

Plugs should be made of material that is easily drilled through (e.g. cement).

2. Grout (sealant) is pumped into the casing above the plug. In this case the casing acts as the tremie pipe.
3. A second plug is installed above the grout. The use of a plug helps ensure slurry and water separation, resulting in a proper grout seal at the lower end of the casing.
4. Clean water or drilling fluid is then pumped into the casing causing the plugs and grout to move down the casing. As the plugs move down the casing, water or drilling fluid inside the casing is displaced. The process allows the lower plug to fall below the bottom of the casing and the grout moves up and into the annular space.

5a Where bentonite grout is used and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. To achieve full gel strength bentonite takes 8 to 48 hours.

Best Management Practice – When Bentonite Grout Settles

If there has been settling or subsidence in the annular space, top up the bentonite grout to the original level before drilling continues

Ontario

5b. Where cement grout is used, cement grout must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.

6. Drill out or remove the plugs from the bottom of the casing.

Landing collars below the lower plug can be used to reduce the potential for over or under displacement of the grout (sealant). Wire lines attached to the upper plug can also be used to assist in accurately measuring depths when the plugs come together and reduce the risk of damage to the well casing.

---

[3] Sterrett, Robert J. 2007. *Groundwater and Wells-Third Edition*. Johnson Screens/a Weatherford Company., New Brighton, MN.P. 461-462

Grout Placement – When an Annular Space is Created by Use of a Driven Point

Construction by a driven point means a method of well construction that uses a solid point or cone that is driven into the ground. This does not include a cutting shoe unless a solid point is installed on an inner rod. This method is not machinery specific.

For example, the type of machinery that can be used to drive the solid point or cone into the ground can include direct push technology, rotary, percussion, pneumatic hammers, sonic, non-powered manual methods, and cone penetration testing equipment.

Creating and Sealing Annular Spaces of Driven Point Wells

The driving action during the installation of a driven point well pushes the formation to the sides of the point well and typically does not create a measurable annular space. However, excavations need to be created to connect the driven point well to the horizontal pipe (waterline). The horizontal pipe connects the driven point well to the building's plumbing. As part of backfilling these excavations, a suitable sealant needs to be placed from the bottom of the trench to within 20 cm (8″) of the ground surface (Note: for further information see Chapter 9: *Equipment Installation* and Figure 6-23 in this chapter). This suitable sealant also needs to be placed from the well casing a minimum distance outward of 20 cm (8″) in the excavation. The sealant placed in the horizontal pipe excavation (trench) around the well casing reduces the risk of surface water runoff and other near surface sources of contaminants from migrating down the outside of the well casing and impairing the well water.

For further information on backfilling trenches from driven point wells see Chapter 9: *Equipment Installation*.

If any annular space is created during the driving action, then the annular space must be sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between a subsurface formation and the ground surface. In the case of a well constructed with the use of a driven point, any annular space created must be filled using a method and material approved by the Director.

To ensure that any annular space that may be present does not act as a pathway for contaminants to enter the well water and aquifer, the person constructing a well with the use of a driven point may create an annular space outside of the well casing on purpose and must fill it with suitable sealant. If this is the case, the person constructing the well could follow the best management practice that follows. If the person constructing a well with the use of a driven point proposes this or an alternative method, that person must write to the Director proposing how an annular space will be created and sealed around a well (see information provided after Figure 6-23). If the Director agrees with the approach, the Director will provide the person constructing the well with written approval to proceed with the method and materials.

Best Management Practice – A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point

This Best Management Practice is shown in Figure 6-23 on page 53:

1. Excavate a hole below the frost line. This hole is part of a trench that will take the horizontal pipe (waterline) from the driven point well to the building's plumbing.

2. Below the excavated area, drive a well casing with a driven point (or a dynamic cone) that has an outside diameter of at least 11.75 cm (4 5/8″) into the water producing zone. The casing can be driven into the ground with machinery such as direct push technology or by manual methods.

3. Insert a driven point well screen and casing that has a diameter of about 6.7 cm (2 5/8″) into the well. Ensure the driven point well is centered in the 11.75 cm working casing.

4. Pull back the 11.75 cm diameter casing leaving the one-time use drive point in the well while:

   a) Filling the annular space around the screen portion of the drive point with a clean sand or gravel. The top of the sand or gravel should come no closer than 6 m (19.7′) below ground surface or 2.5 m (8.2′) below ground if the only useable aquifer necessitates a shallower well. Recognizing there is a potential for the sand or gravel to bridge due to the small diameter of the well and annular space, it is important to calculate the volume of the annular space around the screen and ensure the same volume of sand or gravel materials is placed into the well. Clean sand or gravel will also need to be poured slowly from the top of the annular space to prevent bridging.

   b) Filling the annular space above the sand or gravel by:

      i) Installing a tremie pipe to just above the sand or gravel. The casing portion of the well's annular space is filled with suitable sealant from the top of the well screen to the floor of the excavation using the tremie pipe and a grout pump. The suitable sealant will typically consist of at least 20 percent solids of sodium bentonite by weight.

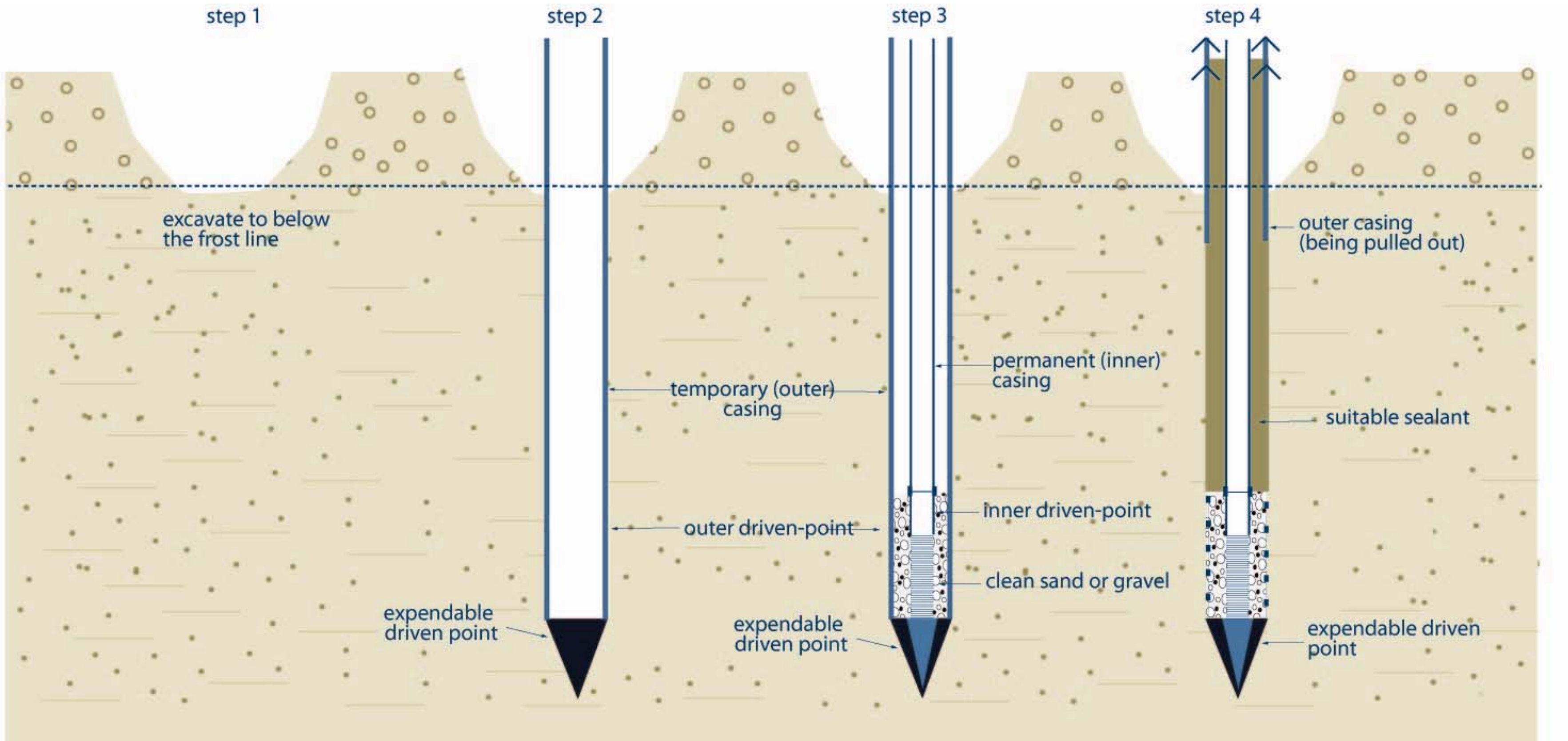
      OR

      ii) Placing sodium bentonite chips or pellets. Recognizing there is a potential for the bentonite chips or pellets to bridge due to the small diameter of the well and annular space, it is important to calculate the volume of the annular space and ensure the same volume of plugging materials are added to the well. Sodium bentonite chips and pellets should also be poured slowly from the top of the annular space to prevent bridging. At different intervals, the sodium bentonite chips or pellets will need to be hydrated with clean and potable water to allow the bentonite to expand in the annular space.

5. The filling of the well in the excavation should be completed as shown in Chapter 9: *Equipment Installation*.

For Steps 2 through 4, in the Best Management Practice above, different diameters of driven point wells can be used, however, it is important that the initial hole be at least 5 cm (2″) larger than the outer diameter of the final well casing to prevent bridging problems in the annular space.

FIGURE 6-23: SUGGESTED METHOD OF CREATING AND SEALING ANNULAR SPACE IN A DRIVEN POINT WELL



Step 4, a T-connection is installed on top of the casing to allow for the horizontal waterline to connect to the well. Additional casing is added on the well from the T-connection to above the ground surface and the trench is backfilled in accordance with the Wells Regulation (see Chapter 9: *Equipment Installation*).

Lining up the two points helps to centre the inner string. The inner driven point, in some cases, may rest on top of the initial point (e.g. if it is solid).

The diagram above is not to scale and is for illustrative purposes for this chapter only.

WHERE DOES THE PERSON CONSTRUCTING THE WELL HAVE TO GO TO SEEK A WRITTEN APPROVAL FROM THE DIRECTOR?

If the person constructing the well wishes to seek the written approval of the Director, that person may contact the Water Well Help Desk:

- Address of Water Well Help Desk, Environmental Monitoring and Reporting Branch of the Ministry of the Environment, 125 Resources Road, Etobicoke ON M8P 3V6;
- By telephone: 1-888-396-9355 (for Ontario residents only);
- By fax: 416-235-5960; or
- By e-mail: helpdesk@waterwellontario.ca

WHAT INFORMATION IS NEEDED FOR A WRITTEN APPROVAL?

Ontario

The Ministry assesses each case individually and on its merits. As a minimum, applicants contacting the Ministry for a written approval should provide a written request with the following information:

- The name of the individual(s)/entity that owns the well
- The location of the well
- The purpose and use of the well
- The reason for the sealant material and methods
- If applicable, written certification by the manufacturer/installer/professional engineer that the material and method will properly fill the annular space

The person constructing the well may be required to retain a *Professional Engineer or Professional Geoscientist* who would have to prepare a scientific report showing the appropriate scientific rationale to support the application. The person constructing the well would then have to submit the report along with the request for written approval to the Ministry for its consideration.

How does the Director's Decision Process Work?

The request for written approval should be submitted to the Ministry along with any and all supporting documents such as a hydrogeological and/or a well design report. The person constructing the well and others should be cautioned that obtaining a written approval will not be a simple and automatic process because the Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long-term environmental, social and economic well-being.

The Ministry will review the request, supporting information and other information generated from internal and external parties with an interest in the application.

Based on the information, the Ministry will contact the person constructing the well in writing, indicating the Ministry has done any of the following:

- Issued the written approval to the person constructing the well
- Refused to issue the written approval and thus, requires the person constructing the well to use another prescribed option
- Requested additional information from the person constructing the well to allow the Ministry to make a decision

Tools for Annular Space & Sealing

Table 6-5 provides an example of the types of reference charts and tables that can be used to volumes of holes and casing.

Table 6-5: Calculating Casing and Hole Volume

Diameter		Volume			
Millimetres	Inches	Cubic metres/metre	Cubic feet/ft	US gal/ft	Imp gal/ft
51	2	0.002	0.022	0.161	0.134
64	2½	0.003	0.032	0.241	0.201
76	3	0.005	0.054	0.402	0.335
89	3½	0.006	0.065	0.483	0.402
102	4	0.008	0.086	0.643	0.536
114	4½	0.010	0.108	0.804	0.670
127	5	0.013	0.140	1.046	0.871
140	5½	0.015	0.161	1.206	1.005
152	6	0.018	0.194	1.448	1.206
165	6½	0.021	0.226	1.689	1.407
178	7	0.025	0.269	2.011	1.676
191	7½	0.029	0.312	2.332	1.944
200	7¾	0.031	0.334	2.493	2.078
203	8	0.032	0.344	2.574	2.145
216	8½	0.037	0.398	2.976	2.480
222	8¾	0.039	0.420	3.137	2.614
229	9	0.041	0.441	3.297	2.748
241	9½	0.046	0.495	3.700	3.083
248	9¾	0.048	0.517	3.860	3.217
254	10	0.051	0.549	4.102	3.418
279	11	0.061	0.657	4.906	4.088
305	12	0.073	0.786	5.871	4.893
311	12¼	0.076	0.818	6.112	5.094
324	12¾	0.082	0.883	6.595	5.496
381	15	0.114	1.227	9.169	7.641
438	17¼	0.151	1.625	12.144	10.120
445	17½	0.155	1.668	12.466	10.388
457	18	0.164	1.765	13.190	10.992
508	20	0.203	2.185	16.327	13.606
610	24	0.292	3.143	23.485	19.570
635	25	0.317	3.412	25.495	21.246
762	30	0.456	4.908	36.675	30.562
914	36	0.657	7.072	52.840	44.034