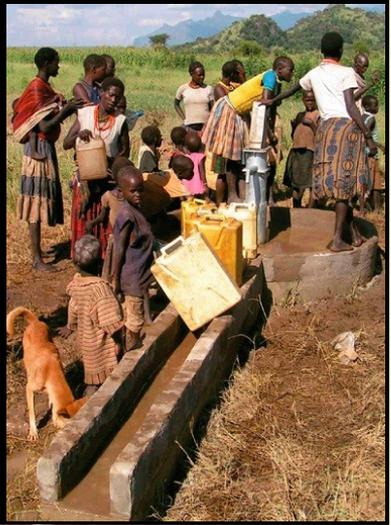


# **WATER SUPPLY WELL GUIDELINES**



**for use in  
DEVELOPING COUNTRIES**

**"More people die from unsafe water  
than from all forms of violence,  
including war."**

*- UN Secretary-General Ban Ki-moon*

**WATER SUPPLY WELL  
GUIDELINES  
for use in  
DEVELOPING COUNTRIES**

Second Edition  
October 2012

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ISBN 978-0-9884685-1-1

# WATER SUPPLY WELL GUIDELINES for use in DEVELOPING COUNTRIES

Second Edition

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## ACKNOWLEDGEMENTS

The following provided comment or support facilitating the development of these guidelines:

### Organizations—

Allegra Print & Imaging  
American Water Resources Association  
Gregg Drilling & Testing, Inc.—John Gregg, President, BSGE  
National Ground Water Association  
National Ground Water Research & Educational Foundation  
University of Oklahoma WaTER Center  
Schneider Equipment, Inc. / Schneider Water Services

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Stuart Smith, CGWP	Daniel Stephens
Ralph Taylor Jr., CWD	Keith Thompson
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Photos / images:

National Ground Water Research & Education Foundation  
 Robert Wright, Orthodox Presbyterian Uganda Mission  
 Pedro J. de Velasco R. S.J.  
 Luis Antonio Dominguez  
 W. Richard Laton, PhD, PG, CHG, CPG  
 Google Images  
 Stephen J. Schneider, BSME, MGWC

Drafts of the guidelines were circulated to thousands in addition to being presented for discussion at four conferences (see Forward). The primary author acknowledges that there were others providing input and comment; however, names were not documented at all events. He sincerely apologizes to any person or group that he inadvertently failed to recognize, or incorrectly recognized.

Special Acknowledgements –

My wife Miriam — Her enthusiastic support, input and conviction assured completion of the first and subsequent editions of these guidelines.

Luis G. Verplancken, S.J. (deceased), those continuing to support his vision and the Tarahumara people they served and serve — They continue to inspire me.

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# PREFACE

Presentations by individuals working in developing countries prompted further discussion at the 2008 National Ground Water Association (NGWA) Expo about the need for standards. That discussion resulted in the creation of draft guidelines (originally referred to as standards) related to water supply wells and their well head appurtenances for use in developing countries.

The initial draft was first presented for comment at the June 2009 Groundwater for the Americas conference in Panama City, Panama where the concept and draft document attracted significant attention.

Subsequent drafts were presented for review and comment at the:

- October 2009 International WaTER Conference, University of Oklahoma, Norman, OK
- December 2009 NGWA Expo in New Orleans, LA
- November 2010 American Water Resources Association (AWRA) Annual Conference in Philadelphia, PA.

Considerable national and international input resulted from these conferences and via e-mail list circulations, web postings and other discussion/reviews. The document came to fruition and the first edition was published in October 2011 and initially presented at the 2011 International WaTER Conference in Norman, OK.

The first edition was enthusiastically received. Many constructive comments have subsequently been provided, most of which are included in this second edition. It is hoped and expected that comments and suggestions will continue to be provided which will result in further refined editions.

These well guidelines are intended to support those working with groundwater systems in developing countries. The document is a teaching, reference and administrative tool, designed especially for those intimately involved in improving the quality and quantity of water in developing countries.

Endorsements by government and non-government organizations (NGOs), especially those involved in improving the quality and quantity of drinking water in developing countries, are encouraged.

# **WATER SUPPLY WELL GUIDELINES**

## **for use in**

### **DEVELOPING COUNTRIES**

#### **TABLE OF CONTENTS**

1	Purpose & Use.....	1
2	Cost Benefit.....	4
3	Definitions.....	5
4	Well Location.....	7
5	Drilling Methods.....	9
6	Drilling Products.....	10
7	Well Annular Surface Seal.....	11
8	Aquifer Commingling.....	23
9	Casing and Liner.....	23
10	Other Well Materials.....	27
11	Plumbness and Alignment.....	27
11	Well Development.....	29
12	Surface Completion.....	29
13	Disinfection.....	30
14	Testing.....	32
15	Well Decommissioning.....	35
16	Documentation.....	37
17	Personnel Safety.....	42
18	About the Primary Author.....	43

# 1 PURPOSE & USE

These guidelines are considered minimum requirements for basic protection of the groundwater resource and for the health and safety of those that develop and use the resource. These guidelines are intended to address basic water supply well construction, pumping equipment, and maintenance issues. Water supply wells include wells designed for domestic, municipal, community, industrial, commercial, irrigation and/or livestock water supply use in addition to aquifer storage (injection) and recovery wells.

These guidelines are encouraged to be used as an education and training tool as well as an everyday field guide for those performing the work. These guidelines may also be used as a basis in establishing national, regional or local standards in regions where there are no standards or very limited standards. In addition, these guidelines may be useful for establishing specifications in procurement or construction documents and hydrophilanthropic agreements.

This document is not intended to include or limit the countless means, methods and designs for the work except in unique situations where appropriate. It is up to those responsible for the construction to determine the appropriate means, methods and design. Regardless, hand dug or excavated wells are not encouraged by these guidelines given that there is not a strong consensus as to the appropriateness of this type of well construction. Hand dug or excavated wells pose significant concern for the safety of those constructing, maintaining and using such wells. In addition, the difficulty of constructing and maintaining a sanitary supply using the dug well technique argue against the practice except where there is no reasonable alternative. In those

situations, it should be considered a preliminary or temporary practice unless such wells are constructed in conformance to this document.

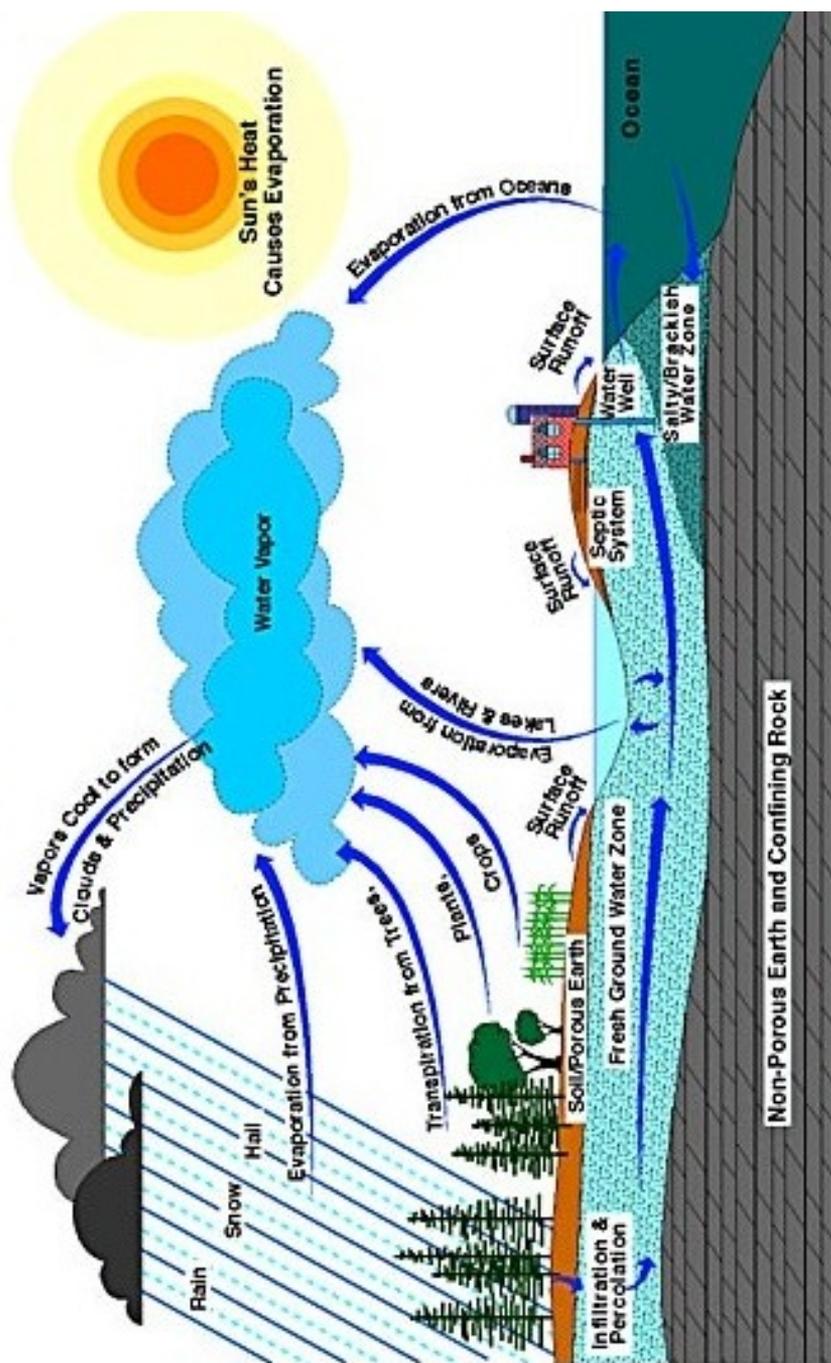
**Water well construction is not for amateurs.** It is always recommended that whenever possible, appropriately skilled and reputable local individuals, companies or agencies be encouraged to perform the work addressed herein. However, when those individuals or entities are not available, these guidelines can be used to assist in the training of local citizens toward becoming skilled service providers. They should also be made available to those using the groundwater supply systems as a guide to facilitate in the long term safe, sanitary use and protection of the groundwater resource.

If there are standards, rules or laws in effect and applicable by other authorities, the more restrictive criteria for each requirement should be followed. These guidelines are not intended to replace any local, municipal, provincial, national or other laws or standards; these guidelines are meant to supplement such laws or standards, or in the absence thereof, to be considered the minimum standard. Respect should be afforded all licensing, permitting, construction, and other applicable laws in each area of each country.

These guidelines are written utilizing wording that suggests more of a recommendation than a mandate. For example, you will notice the use of the word “should” for most requirements. This is done because, in many rural undeveloped areas, the availability of materials specified herein or the cost of compliance may be inappropriate when considering the lives at stake. If it is desired to use these guidelines as a mandatory requirement, substitute the word “shall” or “must” for “should”. Refer to the definitions section below. For a publication using the mandatory language, contact the primary author.

FIGURE 1

# HYDROLOGIC CYCLE



## 2 COST BENEFIT

J. Whinnery (2012) in *A Well Construction Cost-Benefit Analysis: For Water Supply Well Guidelines for use in Developing Countries* compares the costs and benefits of a properly completed well versus inferior completed wells. The CBA revealed the following:

- Almost 40 times more benefit, than cost, is provided with a properly constructed, operated and maintained well system.
- An approximate 5 fold increase in net value is realized with the implementation of an operation and maintenance (O&M) program.
- Wells providing localized poor water quality should not be considered acceptable.

Construction of such a well results in a negative net present value, i.e. there is more cost than benefit (a benefit-cost ratio less than 1).

- A properly constructed well will have at least 3 times more net value than an inferior well.

The multiplier approaches infinity if water quality has also been compromised in the inferior well.

- Inferior construction that results in groundwater contamination or aquifer damage should not be considered acceptable.

Although it is not specifically analyzed in the CBA, it can be inferred that well construction which compromises aquifer quality or results in loss of aquifer head (e.g. commingling of aquifers or uncontrolled artesian pressure), will have negative impacts in the form of reduced large-scale benefits in addition to added costs of remediation or mitigation. These negative impacts will most certainly result in a negative net present value.

### 3 DEFINITIONS

**Aquifer** — A geologic formation, group of formations, or part of a formation that contains saturated and permeable material capable of transmitting water in sufficient quantity to supply wells or springs and that contains water that is similar throughout in characteristics such as potentiometric surface head, chemistry, and temperature.

**Annulus** — The space between the outside diameter of the casing and the borehole wall. It is synonymous with annular space.

**Casing** — The pipe that is a permanent part of the well, which extends above the ground surface, and around which an annular seal is placed. Casing in a well may be of multiple diameters and connected at size changes by welding, threading, grouting or with a minimum 2 meter [6 feet] overlap if the overlap is above the static water level.

**Consolidated formation** — Materials that have become firm and coherent through natural rock-forming processes. These include, but are not limited to, basalt, sandstone, claystone, shale, limestone, dolomite and granite.

**Drill fluid** — Water, air, or mud (with or without additives) used down the borehole during well construction. Drill fluid functions may include: hole stabilization, carrying or temporarily supporting cuttings, cooling of the drill bit.

**Head** — The elevation to which water rises in at a given point as a result of pressure. Head is usually expressed in meters [feet].

**Liner** — Pipe in the well that is not part of a pump but is used to line the borehole wall to prevent collapse. An annular seal is never placed around a liner.

**May** — Means the statement in which it is used expresses a specification that is suggestive, optional and is not mandatory.

**Must** — Means the statement in which it is used expresses a mandatory requirement or obligation that allows no exceptions.

**Permeability** — The ability of a formation to transmit water.

**Potable water** — Water that is safe enough to be consumed by humans with low risk of immediate or long term harm.

**Potentiometric surface** — An imaginary surface representing the level to which water will rise in a well as a result of pressure under which it is confined in an aquifer.

**Shall** — Means the statement in which it is used expresses a mandatory requirement or obligation that allows no exceptions.

**Should** — Means the statement expresses a requirement or an obligation that allows an exception only if extreme conditions warrant otherwise.

**Unconsolidated formation** — Sediment that is naturally occurring, loosely cemented, or poorly indurated including clay, sand, silt and gravel.

**Static Water Level (SWL)** — The level of water in a well that is not being affected by withdrawal of groundwater. Affects of withdrawal include withdrawal from other wells, flowing artesian, and recovery after withdrawal has stopped. SWL is usually expressed in meters [feet] below a specified point such as top of casing or ground surface. For flowing artesian wells, it may be expressed as pressure (kPa [psi]) or in head of water at the surface.

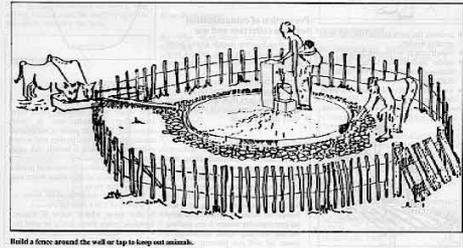
**Transmissivity** — The rate at which water is transmitted through a unit width of aquifer unit a unit hydraulic gradient.

**Well** — Any artificial opening or any artificially altered natural opening, however made, by which groundwater is sought or through which groundwater flows under natural pressure, or is artificially withdrawn or injected.

## 4 WELL LOCATION

Every well should be located in an area that is:

- At least 30 meters [98 feet] from any part of a human waste disposal area (e.g. septic drainfield, latrine).
- At least 15 meters [49 feet] from any food or related wastewater disposal area (e.g. kitchen and/or laundry wash water disposal areas).
- At least 30 meters [98 feet] from any confined animal feeding areas, animal housing or manure storage.
- At least 150 meters [492 feet] from any solid waste landfill (dump) or chemical or industrial waste disposal area.



See Figure 1.

In addition, every well should be located in an area:

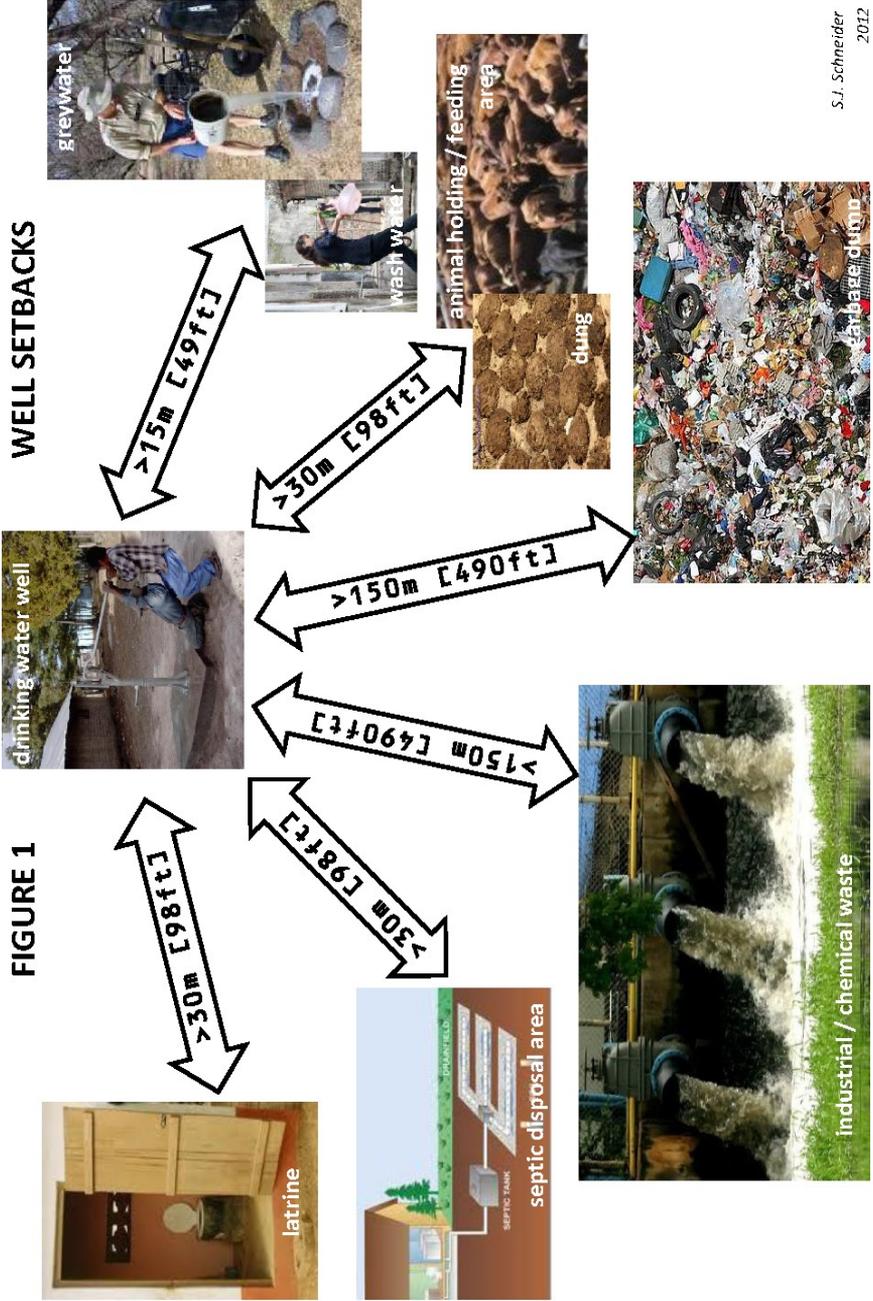
- Up-gradient of the preceding identified areas whenever possible (i.e. at a higher land surface elevation, or if the groundwater flow direction is known, then at a location of higher groundwater head).



Surface water entering a well.

FIGURE 1

WELL SETBACKS



- Reasonably accessible to the beneficiaries if it is also the point of water distribution for individuals.
- Protected from contamination from wild and open-range animals and livestock.
- Outside of floodplains and areas prone to regular flooding from surface rainwater drainage (e.g. if established, outside of 100 year floodplain without other criteria specified herein) unless the well has a more extensive annular surface seal than specified herein and its casing is extended above the highest known flood level.
- Close to power if the well is to be connected to an electric pump.
- Reasonably available for future servicing of the well.
- Protected from vandalism.



## 5 DRILLING METHODS

There is a variety of well construction techniques available. The method used must take into consideration the available equipment, personnel skills, and geology. For more details on this, a professional (e.g. a licensed or otherwise credentialed well driller or a hydrogeologist/engineer trained and experienced in well construction techniques and design) should be utilized to assist in determining well design, construction methods, and equipment selection. Again, **this is not an area for amateurs**. Common drilling methods utilized today include:

- Cable tool
- Mud rotary
- Air rotary

There are also variations of these methods, such as reverse circulation, mud filled cable tool drilling, and combinations of methods.

## 6 DRILLING PRODUCTS

Introduction of contaminants during well construction is always a concern.

Water utilized in the constructing of wells should be potable. If a potable supply is not available, construction water should be



disinfected prior to being utilized. The well should be protected from allowing surface runoff from entering the well during construction.

Organic materials of any kind should not be used as part of a drilling fluid or to assist with lost circulation, etc. This includes but is not limited to:

- Animal waste products (e.g. cow dung)
- Compost or soil containing roots or other vegetation.
- Nuts or hulls
- Wood products
- Petroleum based products.

If undesirable lost circulation is encountered, inert lost circulation materials are commercially available. Inert mineral aggregate may also satisfactorily control a lost circulation zone. Often a change in drilling method is required (e.g. utilizing a method that advances casing while drilling).

## **7 WELL ANNULAR SURFACE SEAL**

Every well **must** have an annular surface seal surrounding the permanent casing to prevent shallow and surface contaminants from entering the well. The seal should extend to at least 5 meters [16.4 feet] below ground surface or to the top of the target aquifer if the top of the aquifer is less than 5 meters below ground surface. It is cautioned that aquifers shallower than 5 meters are much more prone to contamination and, if available, a deeper source should be sought. **Additional seal depth may be required to prevent commingling (see next section), to satisfactorily control flowing artesian conditions or to properly exclude contaminants from entering the well.** In addition to the above, annular surface

seals should extend at least 1.5 meters [4.9 feet] into a very low permeability formation (i.e. clay, competent rock) located below 5 meters, if present. This is especially important if in an area prone to flooding. If a low permeability formation is not present, the seal should meet the aforementioned minimum depth and also extend below the top of the static water level. Proper annular seal depth and design is often dependent on the local geology.

**The annular surface seal is one of the most important components of a well. (see Figures 2-6)**

**SEALANT MATERIALS.** Sealant must not contain any organic material. Sealant should have very low permeability. Sealant materials include:

- **CEMENT GROUT.** A mix of Portland cement and water proportioned approximately one part water to two parts cement by weight (e.g. 21.5 kg [47 pounds] or 21.5 liters [5.7 gallons] of water to 43 kg [94 pounds] cement).
- **CHIP BENTONITE.** Commercially packaged sodium bentonite chips designed for sealing wells. The chips should be 1-2 cm [ $\frac{3}{8}$ - $\frac{3}{4}$  inch] nominal size.
- **CONCRETE.** A mix of Portland cement, water and aggregate. The aggregate should be clean sand and or gravel. The aggregate should be less than 2.5 cm [1 inch]. Cement content should be at least 15% by weight.

If the above sealants are not available, locally available products should be researched for the best available material to create a low porosity, inorganic material that can be properly placed in the annulus and that will not measurably shrink. Drilling fluid, drill cuttings, or a combination thereof should not be considered an acceptable sealant.

Table 1

**MINIMUM BOREHOLE DIAMETERS for ANNULAR SEAL INTERVALS**

Criteria		Sealant									
		cement grout	cement grout	cement grout	chip bentonite	chip bentonite	chip bentonite	chip bentonite	chip bentonite	concrete	
<b>Minimum additional borehole diameter</b> (amount larger than the largest outside diameter of the casing or its coupling, bell, or other circumferential attachment)		>4cm [>1.6in]	>8cm [>3in]	>4cm [>1.6in]	>8cm [>3in]	>8cm [>3in]	>8cm [>3in]	>8cm [>3in]	>8cm [>3in]	>8cm [>3in]	>20cm [>8in]
A. Depth of seal interval below ground surface		<30m [98ft]	any	any	<30m [98ft]	<300m [980ft]	<300m [980ft]	<300m [980ft]	<300m [980ft]	<300m [980ft]	any
B. Water in seal interval		not allowed	allowed	allowed	not allowed	not allowed	not allowed	<15m [49ft]	<150m [492ft]	not allowed	not allowed
D. Drill fluid (mud) in seal interval		not allowed	allowed	allowed	not allowed	not allowed	not allowed	not allowed	not allowed	not allowed	not allowed
D. Grout pipe used in annulus		no	yes	no	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	no
E. Grout placed through casing via cementing plugs or grout pipe		no	no	yes	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	no
F. Coupling, bell or other circumferential device used on casing		allowed	allowed	allowed	allowed	not allowed	allowed	allowed	not allowed	not allowed	allowed

The additional diameter of the seal interval must be compatible with the selected sealant and criteria A through F.

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**PLACEMENT OF SEALANT.** An oversized borehole must be constructed to contain the sealant. The casing should be centered in the borehole to assure the sealant totally surrounds the casing throughout the seal interval. Types and locations of centering devices vary with the seal material being used, the depth of the seal interval and the method of seal placement. The size of the annulus is dependent on the sealant material, the depth of the seal, how the sealant is placed, casing size and type of casing connection (see Table 1):

**CEMENT GROUT Placement—** (see Figures 2-6)

- ◇ Cement grout may be placed by pouring from the surface if:
  - ⇒ It will not be placed through standing water or a liquid drill fluid such as silty water or mud;
  - ⇒ The oversized borehole diameter is at least 4 cm [1.6 inches] larger than the outside diameter of the casing or its coupling, bell or similar circumferential device, whichever is greater; and,
  - ⇒ It is placed at depths less than 30 meters [98 feet].
- ◇ Cement grout may be placed in standing water or a drill fluid, or at depths greater than 30 meters [98 feet] when it is placed by pumping through a grout (tremie) pipe from the bottom of the seal interval back to surface. The following two methods are available:
  - ⇒ A grout pipe placed in the annulus. The pipe should be submerged in the grout at all times during pumping. The grout pipe should be completely removed from the annulus after completion of grout placement. The oversized borehole diameter should be at least 8 cm [3 inches] larger than the outside diameter of the casing or its coupling, bell or other circumferential device, whichever is greater.

⇒ A grout pipe placed inside the casing. This method forces cement back up the outside of the casing. There are several methods that utilize this approach and it should **only be used with proper training** and allowances for consequences that might occur (e.g. if grout does not return to surface prior to setting up). The oversize borehole diameter in the portion of the well sealed in this manner should be at least 4 cm [1.6 inches] larger than the outside diameter of the casing or its coupling, bell or other circumferential device, whichever is greater.

**CHIP BENTONITE Placement**— (see Figures 2-6)

- ◇ If there is no standing water or liquid drill fluid in the annulus, chip bentonite should be placed as follows:
  - ⇒ The bentonite should be poured from the surface at a controlled rate not exceeding 50 kg [110 pounds] per minute.
  - ⇒ The top of the sealant should be sounded periodically during placement to assure it is not bridging.
  - ⇒ The oversized borehole diameter is at least 8 cm [3 inches] larger than the outside diameter of the casing or its coupling, bell or other circumferential attached, whichever is greater.
  - ⇒ The depth of placement is not greater than 30 m [98 feet] if the casing has a coupling, bell or other circumferential device.
  - ⇒ The depth of placement is not greater than 300 m [980 feet] if using flush connected casing with no circumferential devices.
- ◇ If there is standing water and no drilling mud, chip bentonite should be placed as follows:



⇒ The bentonite should be screened during placement to remove fines that promote bridging by running the chips across an approximately 6 mm [ $\frac{1}{4}$  inch] mesh screen formed into a semi-circle and angled toward the well annulus at an angle to control the pour rate such that the chips are placed at not more than 11 kg [24 pounds] per minute.

⇒ The oversized borehole diameter should be at least 8 cm [3 inches] larger than the outside diameter of the casing or its coupling, bell or other circumferential device, whichever is greater.

⇒ This method should not be used through more than 150 m [492 feet] of water if using flush connected casing with no circumferential devices, and it should not be used through more than 15 m [49 feet] of water if the casing has a coupling, bell or other circumferential device.

- ◇ In arid environments, bentonite should be hydrated with clean, uncontaminated water every 1m [3 feet] during placement in the upper 5m [16 feet] of the seal interval.

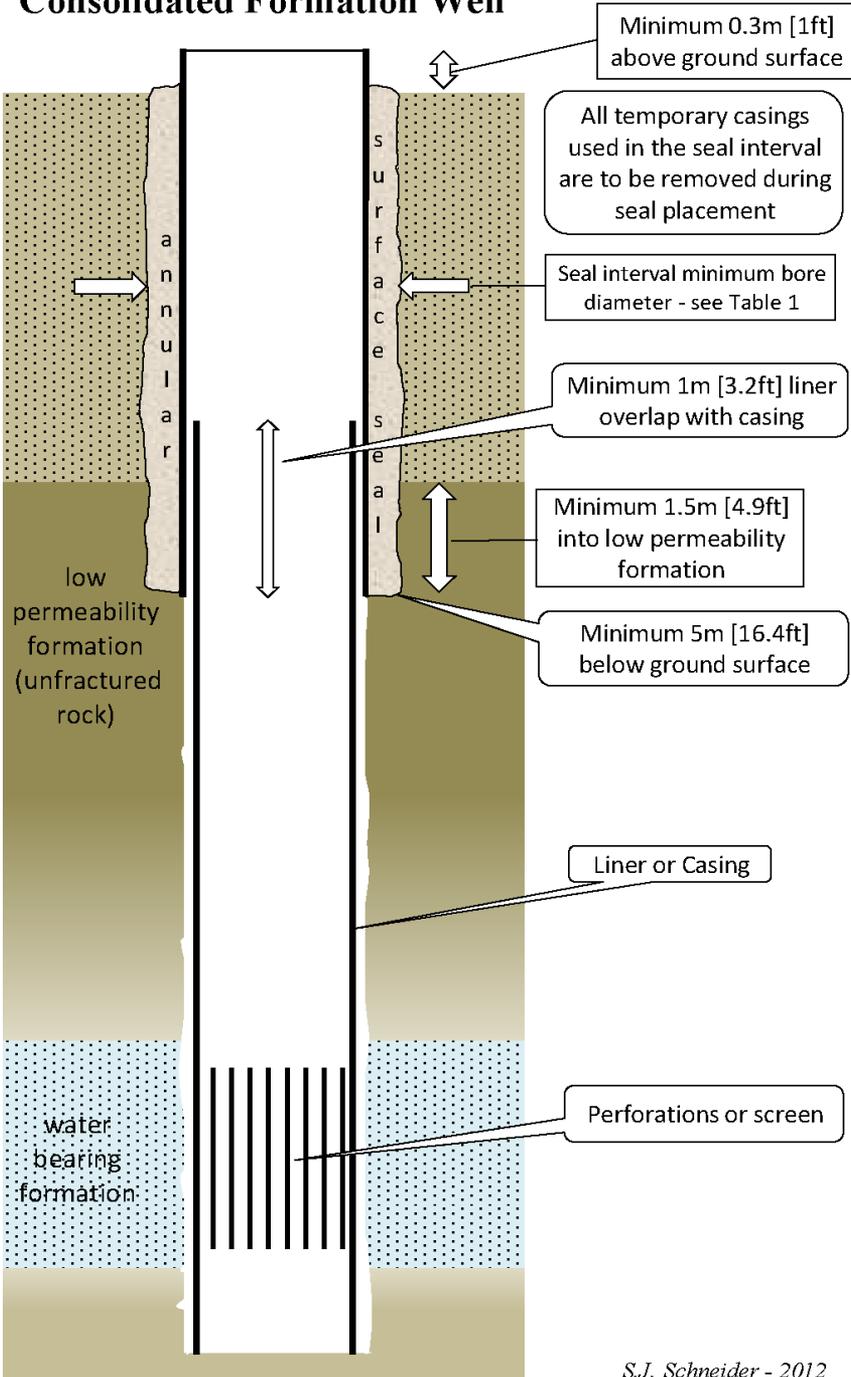
**CONCRETE Placement**— (see Figures 2-6)

- ◇ Concrete should never be placed through standing water unless it can be placed through a submerged grout (tremie) pipe, which is often difficult to do. If there is no water or other fluid in the seal interval and concrete is poured from the surface, the oversized borehole diameter should be at least 20 cm [8 inches] larger than the outside diameter of the casing or its coupling, bell or other circumferential device.

In all cases of annular seal placement, the amount of sealant actually used should be verified as being adequate to fill the volume of the annulus being sealed (see Table 2 on preceding page).

FIGURE 2

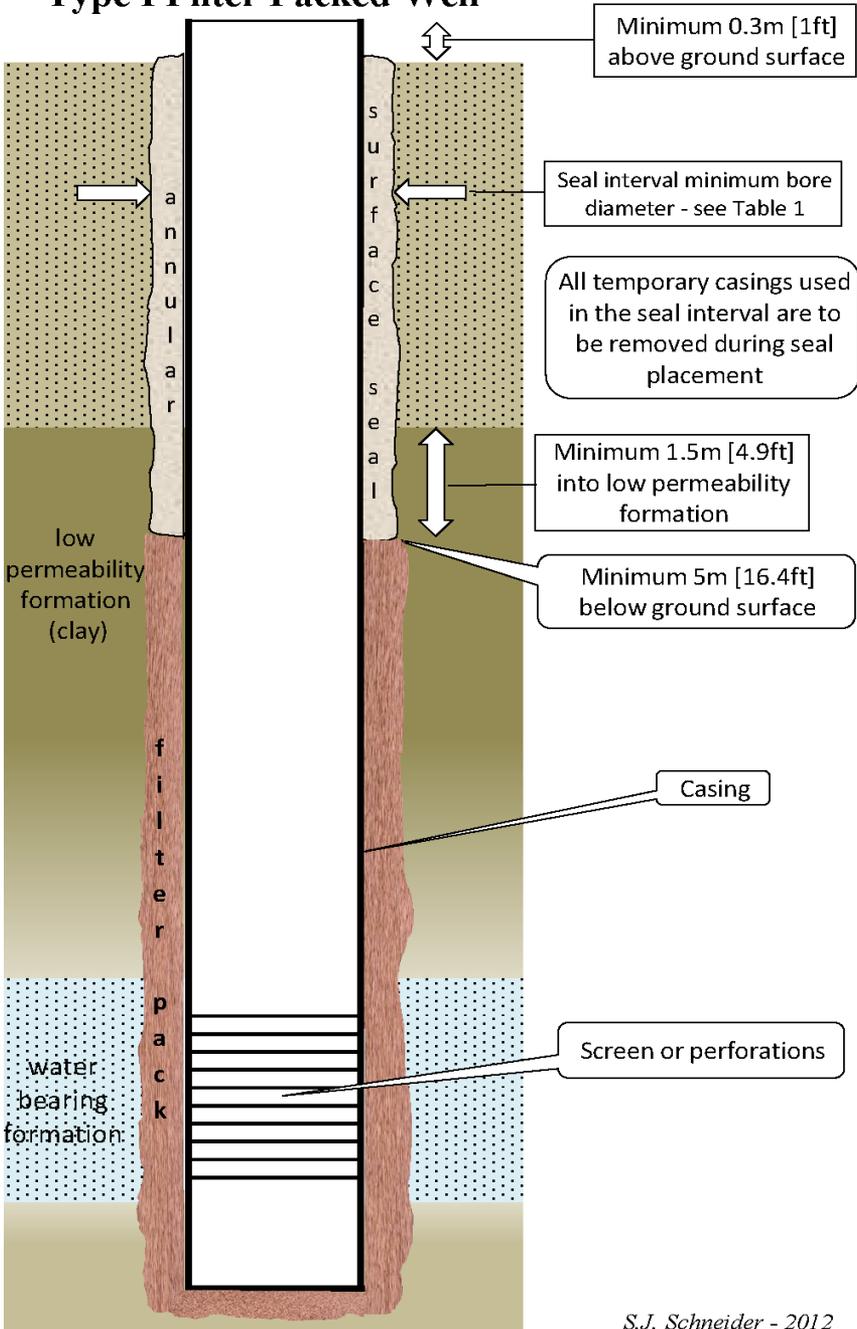
# Consolidated Formation Well



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FIGURE 3

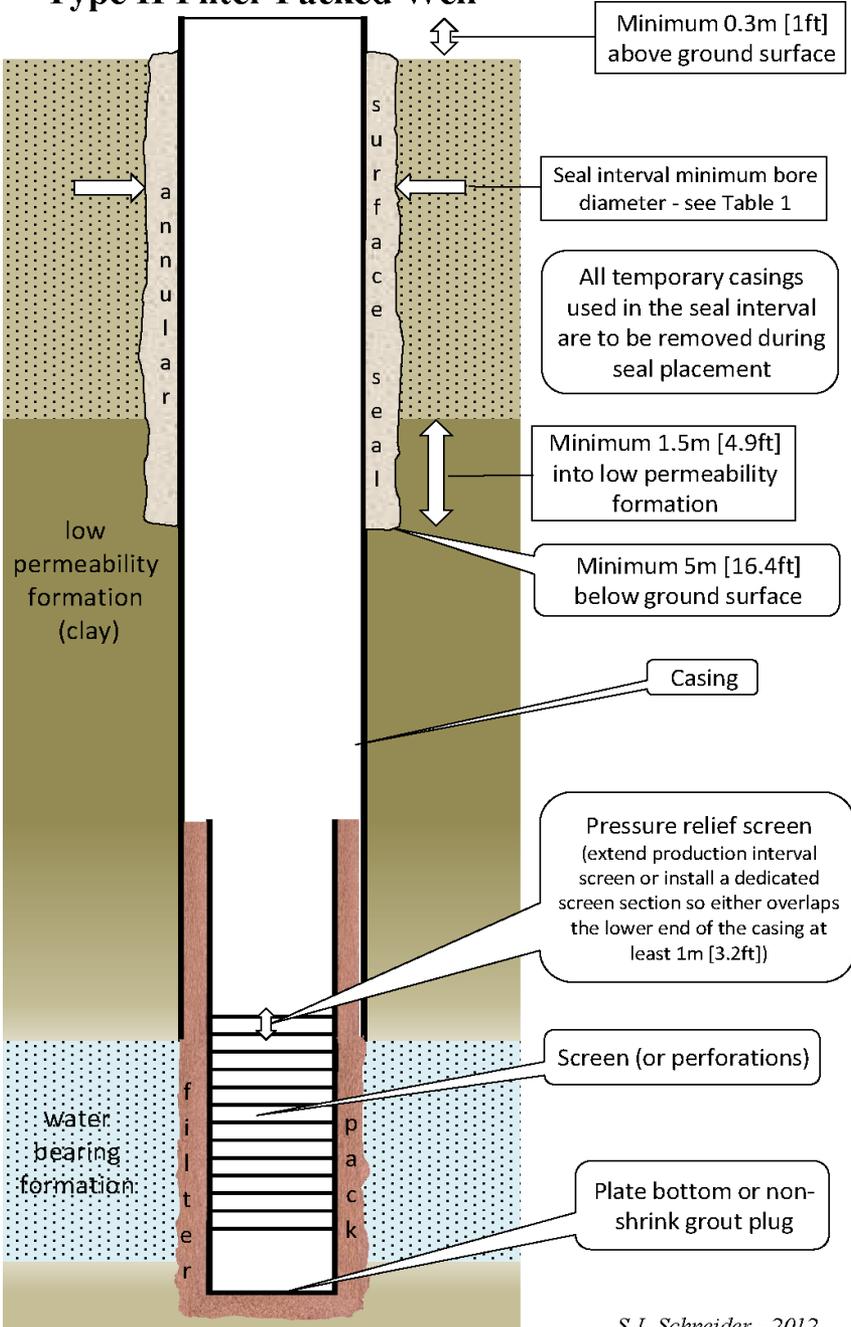
# Unconsolidated Formation Type I Filter Packed Well



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FIGURE 4

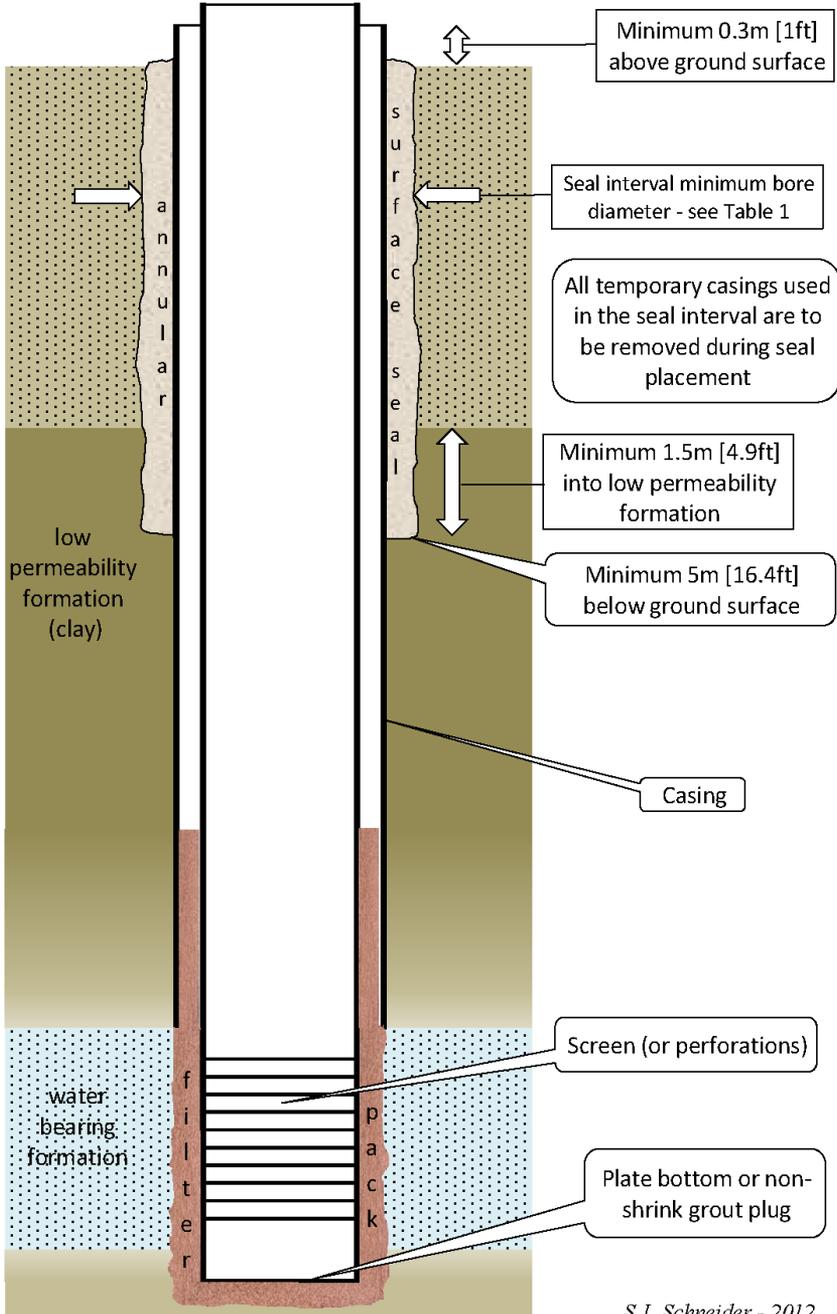
# Unconsolidated Formation Type II Filter Packed Well



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FIGURE 5

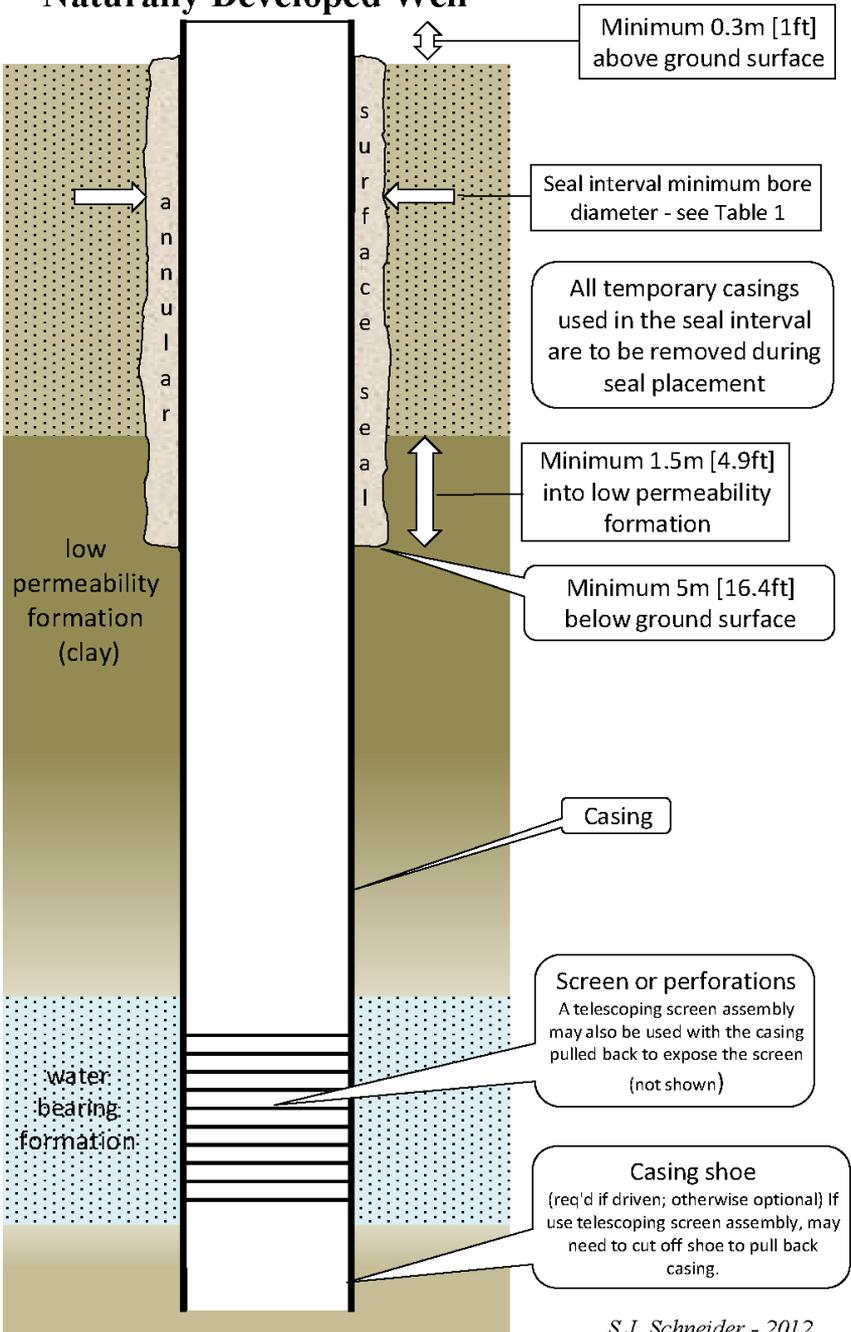
# Unconsolidated Formation Type III Filter Packed Well



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FIGURE 6

# Unconsolidated Formation Naturally Developed Well



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## **8 AQUIFER COMMINGLING**

If multiple aquifers (see definition) are encountered in a well, the well should be constructed to prevent commingling of any aquifers. This will prevent the spread of contaminants or poor quality water to other formations and prevent loss of aquifer head within an aquifer. There should be no water moving up or down the well, either inside or outside the casing or liner when the well is in a completely static (non-pumping) and recovered condition. Prevention may be accomplished by placement of additional surface seal depth or utilizing an additional lower annular seal. (see Figures 7 and 8 on pages 25 and 26).

## **9 CASING AND LINER**

See Section 3 for definitions of casing and liner.

Casings and liners should be PVC (polyvinyl chloride) or black steel pipe meeting the specifications of Table 3.

PVC casing should be protected from long term exposure to sunlight (ultraviolet light). Protection may include an outer steel protector casing, a concrete tile (or masonry box) and lid or cover, a building, a pump, etc.

**CAUTION:** If cement grout sealant is used around PVC casing, care should be taken to prevent PVC exposure to excess heat of hydration from cement curing that can permanently deform the pipe. Cement grout placed in excessively large borehole areas (e.g. caverns, voids, wash-outs) will result in a significant increase in heat that will likely cause this to happen which could make the well unusable, requiring its proper decommissioning. If PVC casing is sealed using cement, cold water may be circulated in the well bore during the early curing process (recommend at least 24 hours) to attempt to prevent damage to the casing. Nevertheless, it is better to use steel casing (if available) when sealing with cement.



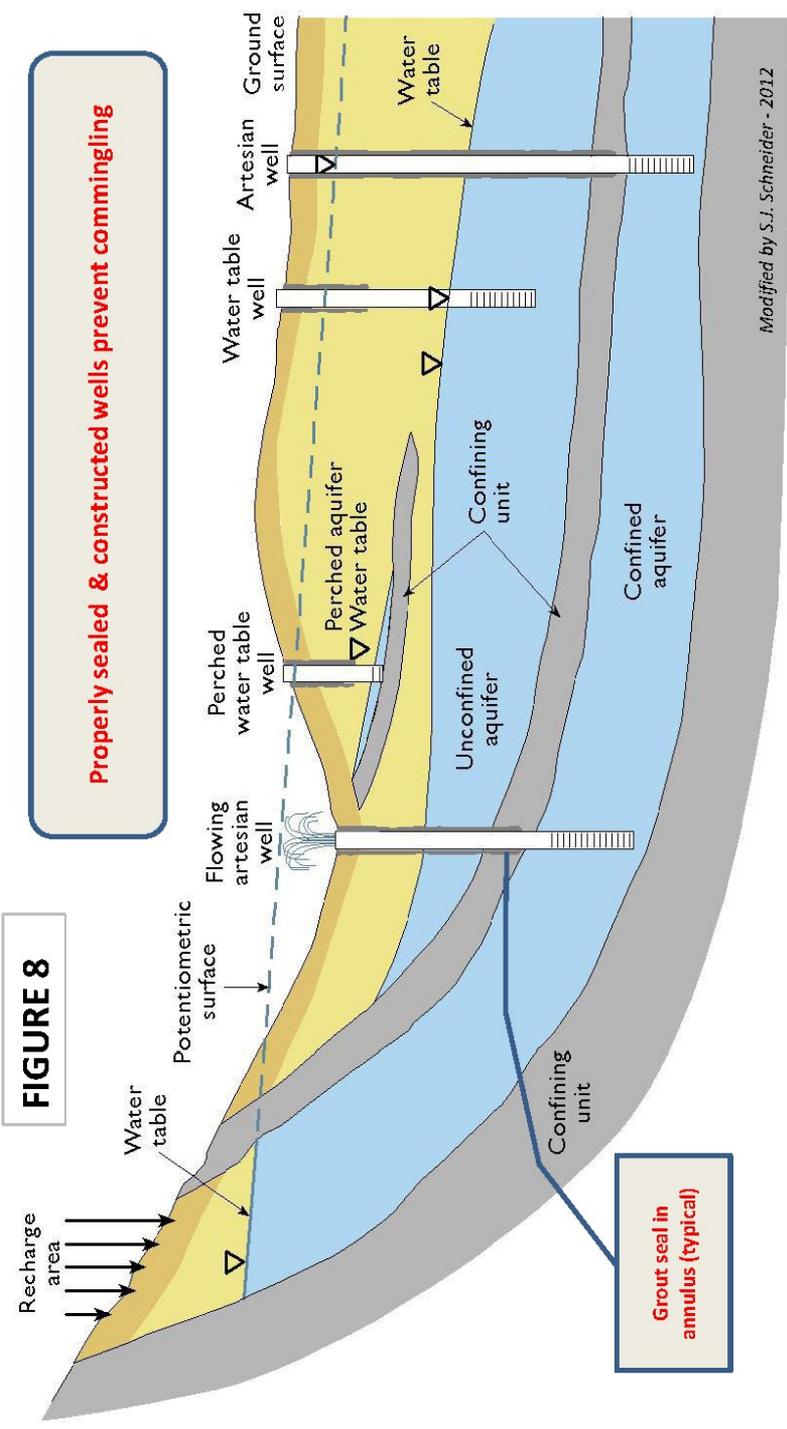
PVC strength reduces rapidly with increasing temperature.  
Heat of hydration from cement curing may cause failure.

All casing should be new or like new. It should be cleaned of any contaminants and inspected for any mechanical damage, holes, pitting, etc.

PVC casing should never be driven. If driving steel casing, a drive shoe is recommended.

The casing and or liner diameter should be sized to allow easy placement of the pumping equipment. Typically, the inside diameter of the casing and liner in the pump placement interval of the well should be at least 1 cm [ $\frac{1}{2}$  inch] larger in diameter than the largest part of the in-well pump components if the pump components are less than 10 cm [3.9 inches]. Larger clearances are always better and should be used with larger pump systems.





**FIGURE 8**

**Properly sealed & constructed wells prevent commingling**

**Grout seal in annulus (typical)**

*Modified by S.J. Schneider - 2012*

Modified after Harlan and others, 1989

## 9 OTHER WELL MATERIALS

Other well materials, including but not limited to gravel or filter pack media, annular backfill or filler, screens, packers, plugs and shale traps should be clean and free of organic material prior to placement in the well. Proper design, material selection and skilled installation will ensure a satisfactory well completion for its intended use. **Improper screen or filter pack design is the most common cause of a sand producing well.** Such wells result in premature pump failure, degradation of surface seals from subsidence, casing shifting or breaking and poor water quality. These wells are often abandoned without proper decommissioning. There are many publications available to assist with the correct design and selection of screens, filter packs and other unique well materials. Driscoll *Groundwater and Wells* is one.

## 10 PLUMBNESS AND ALIGNMENT

Water supply well plumbness (drift) and alignment is extremely important since wells are usually equipped with down-hole pumps or pumping equipment. Acceptable plumbness and alignment also facilitates well completion and maintenance.

Unless otherwise specified, the well should be plumb within one percent of true vertical. In other words, it should not drift from vertical more than 0.3 meter in 30 meters [1 foot in 100 feet].

There should be no noticeable bends or dog-legs, especially in the portion of the well wherein pumps or pumping equipment is to be installed. Excess misalignment makes screen, liner, pump and other material installation and removal difficult or impossible. In addition, it causes excess or premature wear of the pump equipment or well casing or liner.

The well alignment shall be such that its screen assembly, liner(s) and pumping equipment can be freely installed.

**TABLE 3 - CASING & LINER MATERIALS**

diameter mm [in]	maximum depth	material	minimum wall thickness	suggested material standards
< 127 [5]	Note A	low carbon steel	schedule 40	ASTM A53B, API 5L, AS 1395, A120
≤ 355 [14]	Note A	low carbon steel	6.35 mm [.25 in]	ASTM A53B, API 5L, AS 1396
> 355 [14]	Note A	low carbon steel	9.53 mm [.375 in]	ASTM A53B, API 5L, AS 1397
any	30m [98ft]	PVC	SDR 26 (Note B)	ASTM F480, ASTM D2241, ASTM D1785, AS/NZS 1477
any	60m [196ft]	PVC	SDR 21 (Note B)	ASTM F480, ASTM D2241, ASTM D1785, AS/NZS 1478

Note A: Maximum depth and wall thicknesses should be considered based on hydrostatic pressures the casing or liner may see naturally during grouting and during pumping. Wall thickness may also need to be increased based on drilling methods (e.g. driving casing), depth, and other factors that may increase the column and/or collapse loading. Consult technical professionals in these situations.

Note B: SDR = Standard Dimension Ratio = pipe outside diameter / pipe wall thickness. If used only as a liner in consolidated formations, depth limit does not apply to SDR 21.

Stainless steel is usually too costly to consider but may be desired for ASR applications or other unique situations. Wall thickness tolerance is often used to the fullest extent possible (minus 10%) on this material. In no event should the resulting wall thickness be less than 4.77 mm [.188 in]. Note A especially applies to these applications.

Fiberglass has less strength than PVC, is normally less available and more costly, hence no specifications are provided herein as it is unlikely it would be selected as a casing or liner material.

## 11 WELL DEVELOPMENT

All water supply wells should be developed to ensure that they do not produce excessive sand (less than 25 milligrams per liter [parts per million] is recommended) that could cause premature pumping equipment failure and/or compromise the structural integrity of the well. Additional filtration on the surface may still be desired, especially for drinking water. Development also improves the efficiency of the well. There are many publications available to assist with the selection of the proper approach, tools to use and when to use them during a well's construction.

## 12 SURFACE COMPLETION

The area immediately surrounding a well should be sloped away from the well to drain water from the well vicinity.

If the well is equipped with a hand pump, a raised concrete apron should be placed around the well. The apron should extend at least 10 cm [4 inches] above the highest ground around the well. The casing should extend above the concrete apron as far as the pumping equipment will allow. The apron should extend around the well at least 1 meter [3 feet ] in all directions. The apron should



Well head with good apron and drainage

be designed to drain any water, whether from rain or spillage, away from the well.

If the well is not equipped with a hand pump, the casing should extend at least 0.3m [1 foot] above the highest ground surface around the well.

All wells should be sealed between the pumping equipment and the well casing. If the well is equipped with a hand pump and concrete apron, the pump base in contact with the apron should be sealed to prevent any liquid from entering.

All wells should be equipped with a vent to prevent vacuum drawing contaminants into the well. The vent should be screened to prevent bugs and insects from entering the well. The vent should be positioned at least 0.3m [1 foot] above the concrete apron or highest ground around the well, whichever is higher. The vent should be facing downward to prevent any liquid (and contaminants) from running, or being drawn, into the well through the vent. The vent should be of a rugged design to prevent damage from vandalism and the environment.

All wells should be equipped with an access port in order to measure the water level. The access port should be at least 1.5 cm [0.6 inch] diameter. The access port should be securely plugged (e.g. wrench tightened thread or lock) when not being used to prevent access from unauthorized personnel. Deep wells should be equipped with a dedicated probe pipe, normally attached to the pumping equipment, to facilitate water level measurements. Probe pipes should be at least 1.5 cm [0.6 inch] diameter.

### **13 DISINFECTION**

All wells and the equipment installed in them should be disinfected prior to their use. Chlorine is a commonly used disinfectant. A 50 mg/l [ppm] concentration is commonly accepted for disinfection.

Table 4 provides suggested quantities of chlorine agents to achieve 50 mg/l initial concentration. Depending on the well chemistry and other concerns, additional chlorine may be required to fully effect disinfection. Chlorine disinfectant requires contact time to be effective. At least 12 hours of contact should be allowed. Chlorine is heavier than water. Agitation within the well will result in a better disinfection.

**TABLE 4**  
**CHLORINE DISINFECTANT REQUIRED**  
**for 50 mg/l [ppm] CONCENTRATION in**  
**30 METER [98 FEET] of WATER in a WELL**

Hole Diameter		Hole Volume		65% Dry Weight*		5% Liquid**	
centi meters	inches	liters	gallons	grams	ounces	liters	ounces
5.1	2	62	16	5	0.2	0.1	2
10.2	4	247	65	19	0.7	0.2	8
12.7	5	386	102	30	1.0	0.4	13
15.2	6	556	147	43	1.5	0.6	19
20.3	8	988	261	76	2.7	1.0	33
25.4	10	1544	408	119	4.2	1.5	52
30.5	12	2224	587	171	6.0	2.2	75
35.6	14	3027	800	232	8.2	3.0	102
40.6	16	3953	1044	304	10.7	4.0	134
45.7	18	5003	1322	384	13.6	5.0	169
50.8	20	6177	1632	474	16.7	6.2	209
61.0	24	8894	2350	683	24.1	8.9	301
76.2	30	13898	3672	1067	37.6	13.9	470
91.4	36	20012	5287	1537	54.2	20.0	677

\*65% dry weight is often found as granular calcium chloride.

\*\*5% liquid is often found as liquid bleach.

The quantity of other compounds required to obtain the same concentration is proportional to the above percent concentrations.

The quantity of the above compounds required to obtain a concentration other than 50 mg/l [ppm] is proportional to the above quantities.

Every time in-well equipment is installed or re-installed it should be cleaned and disinfected prior to installation and use. If the well is, or even might be, used for human consumption, it should also be tested for E-coli (see chapter 14). Equipment removed from a well awaiting repair before re-installation should never be placed directly on the ground and should be protected from exposure to vegetation, rodents and other animals.



Protect pump and drop pipe from direct contact with the ground

## 14 TESTING

Wells should be tested for yield (flow rate) and basic potability. An appropriate down-hole water level measurement device is required for every well construction or well maintenance project. The static water level in the well should be measured near the beginning of a yield test. Typically, yield testing on low capacity, low demand wells is performed with the permanent pump. Often a simple



Bucket timing flow from a domestic well



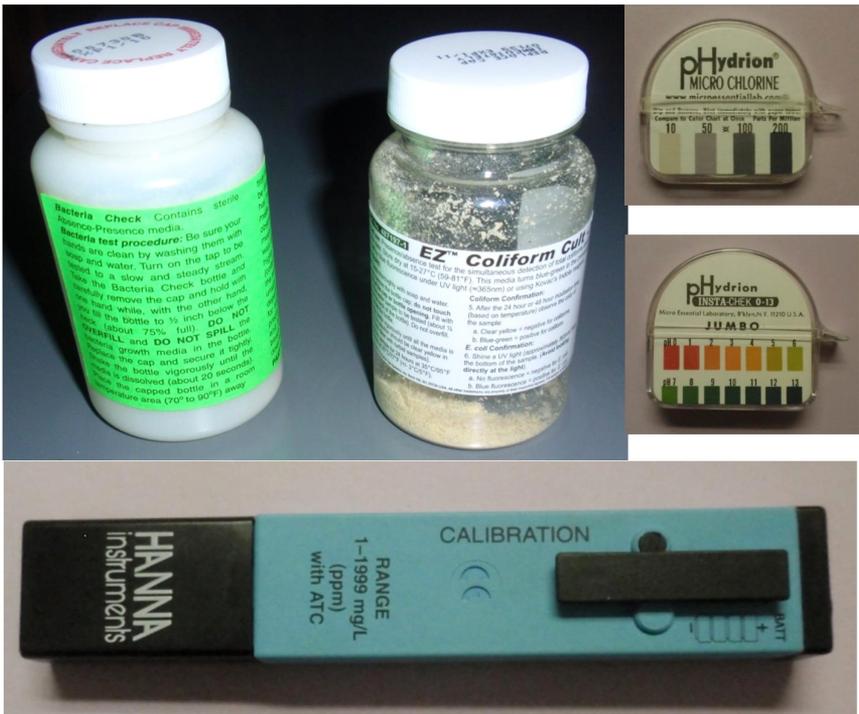
Orifice tube measuring flow from a municipal well

computation using the time it takes to fill a container of known volume is used to determine a flow rate. The duration of the test for small capacity wells should be at least one hour. Large demand wells (e.g. irrigation, community) should be tested longer than an hour, sometimes 24 hours or longer if they will be expected to run continuously for several days. The yield of large demand wells should be measured using more sophisticated measurement devices (e.g. flowmeters or orifice tubes). These devices provide a more accurate determination of the flow rate. In addition, the pumping water level should be taken frequently throughout the yield testing of large demand wells in order to graphically extrapolate the data to forecast long term pumping water level. Such data is also useful for determining well efficiency and aquifer characteristics such as transmissivity.

Each well should be tested for potability after all disinfectant has been thoroughly removed from the well and prior to initial use for

human consumption. Potability consists of testing for Escheichia coli (E-coli). No E-coli should be present. A simple method to test for E-coli is to perform a test for coliform bacteria. If there is no coliform bacteria, there is no E-coli; however, a positive coliform test does not necessarily mean that E-coli is present. If a coliform test comes up positive, it is recommended that the well be sampled and tested again (since it is not uncommon to get a false positive) or that it be sampled again and specifically tested for E-coli.

Other tests should be considered depending on the intended use of the well and known or suspected minerals and contaminants in the area. Such other tests include, but are not limited to: nitrates, arsenic, fluoride, salinity, radionuclides.



Basic testers available (CW: coliform, chlorine, PH, TDS)

## **15 WELL DECOMMISSIONING**

All wells that are not completed during construction, are damaged beyond repair, or are replaced because they are contaminated should be permanently decommissioned. Permanent decommissioning should restore the boundaries between aquifers and the boundary from ground surface to the first aquifer utilizing sealants specified previously herein. Casing(s) and liner(s) should be removed during decommissioning if possible and feasible.

Chip bentonite for decommissioning should only be used in uncased and un-lined portions of boreholes. Chip bentonite may be used inside cased portions of a well that has been documented to have been properly annularly sealed as prescribed herein.

If placing cement grout inside a casing or liner, the casing or liner shall be thoroughly perforated to permit the grout to migrate outside of the casing or liner.

Concrete may be used for decommissioning that part of the uncased borehole that is above the water level in the well at the time of placement. It may also be used inside the casing but only if it is used opposite that part of the casing that has been documented to have a proper seal around it. Concrete may also be used to decommission dug wells but only from 1m [3 feet] above the static water level and to depths no greater than 15m [49 feet].

In all cases of decommissioning, the volume of sealant actually used should be verified as being adequate to fill the volume of the space being sealed (see Table 5).

If permanent decommissioning is not desired or feasible, all wells shall be properly secured to prohibit children from accessing it and from foreign material or contaminants from entering it.

**TABLE 5 - WELL VOLUMES & MINIMUM AMOUNT OF SEALANT REQUIRED FOR DECOMMISSIONING**

Hole Diameter		Hole Volume		Bentonite Chips		Neat Cement*	
centi meters	Inches	l per m depth	ft <sup>3</sup> per ft depth	kg per m depth	lb per ft. depth	kg per m depth	lb per ft. depth
5.1	2	1.9	0.02	2.0	1.4	3.3	2.3
10.2	4	8.4	0.09	9.2	6.2	15.1	10.1
12.7	5	13.0	0.14	14.2	9.6	23.4	15.8
15.2	6	18.6	0.20	20.3	13.7	33.5	22.5
20.3	8	32.5	0.35	35.6	23.9	58.6	39.4
25.4	10	51.1	0.55	55.9	37.6	92.1	61.9
30.5	12	73.4	0.79	80.3	53.9	132.2	88.9
35.6	14	99.4	1.07	108.7	73.1	179.1	120.4
40.6	16	130.1	1.40	142.2	95.6	234.4	157.5
45.7	18	164.4	1.77	179.8	120.9	296.3	199.1
50.8	20	202.5	2.18	221.5	148.9	364.9	245.3
61.0	24	291.7	3.14	319.0	214.4	525.6	353.3
76.2	30	456.2	4.91	498.9	335.3	821.9	552.4
91.4	36	656.8	7.07	718.3	482.7	1183.5	795.4

\*Weight of dry cement mixed with water to form neat cement slurry.

Cement/water slurry ratio is 1.9 kg/l [16 lb/gal or 94 lb sk/6 gallon water]



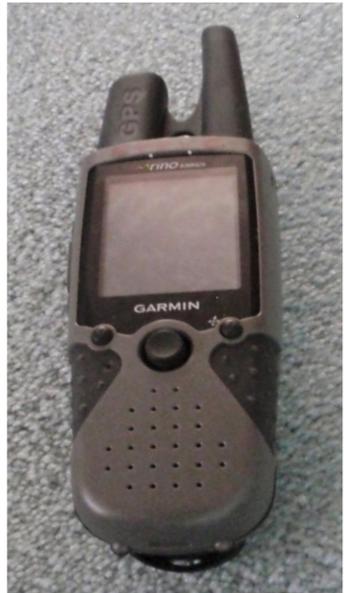
## 16 DOCUMENTATION

### WELL RECORD:

A log or record should be made and maintained on each well (including well decommissioning).

Documentation should include:

- Well location by two methods in order to minimize errors. One method should be GPS (global positioning system), the other may be by a legal description or other locally used documentable location criteria.
- Well identification number or nomenclature. The number or nomenclature shall be permanently imbedded or attached in/on the concrete apron, exposed casing, or the pumping equipment if the first two are not an option. The identification number / nomenclature should be on all documents containing the other information specified herein and it should be noted as to where that identification is located on the well.
- Well owner or user. Identify as to whether they are the owner, user or both.
- Well constructor's name and/or organization.
- Depth drilled and depth of completed well.
- Formation description by depth, including: predominant material(s), color, size and hardness or texture.



GPS - Essential tool for documenting well location

- Annular seal depth and material used.
- Depth and height above ground of all casings and liners, diameters, types of material (e.g. PVC, steel), and schedules or wall thicknesses.
- Full description (material, size, quantity, etc.) and location by depth of all perforations, screens, pack, and any other component of the well.
- Date and depth to static water level.
- Date and results of yield test.

The log or record of each well's construction details should be filed in accordance with any local regulations. A copy should also be provided to those in charge of operating and maintaining the well



A permanent well identification number or nomenclature should be on every well and in related documentation

and it should also be filed in a secure central web based repository that provides public access. (Sample form on next page)

Filings are used to facilitate the operation and maintenance of the well, to aid in the future proper decommissioning of the well, and to identify and quantify the availability of groundwater resources in the area.



SWL measurement with electric probe.

#### **PUMP RECORD:**

A record should be created by the pump installer, and maintained by the well owner/operator, of the current pump

installed in the well. The record should contain the type of pump (e.g. hand, solar submersible, merry-go-round, etc.), drop pipe and rod dimensions as applicable, depth of set, voltage and phase if electric powered, manufacturer, model, serial number and any other pertinent information. (Sample form on page 41)

#### **WATER QUALITY RECORDS:**

Documentation of all water quality tests should be maintained by the owner/operator. Records should include: Dates and results of the chemical tests performed, name of individual obtaining the sample, the source location of the sample, the date that the sample was taken, name of the laboratory or individual performing the analysis, and test method(s) utilized.



# PUMP INSTALLATION RECORD

Well ID # / nomenclature \_\_\_\_\_

Owner \_\_\_\_\_

Type of Owner: Land\_\_\_\_ User\_\_\_\_ Both\_\_\_\_

Date of Installation \_\_\_\_\_

Type of Pump \_\_\_\_\_

Manufacturer \_\_\_\_\_

Model Number \_\_\_\_\_ Serial # \_\_\_\_\_

If Electric Powered: Volts \_\_\_\_\_ Phase \_\_\_\_ Amps \_\_\_\_\_

Type of Drop Pipe / Column \_\_\_\_\_

Drop Pipe / Column: Inside Diameter \_\_\_\_\_ Length \_\_\_\_\_

Size, type & material of rod / shaft \_\_\_\_\_

Water Level Access? Probe Tube\_\_\_\_ Plug/Cap\_\_\_\_ None\_\_\_\_

Water Level Access: Inside Diameter \_\_\_\_\_ Material \_\_\_\_\_

Well Pump Chamber (e.g. Casing): Inside Diameter \_\_\_\_\_ Material \_\_\_\_\_

Static Water Level \_\_\_\_\_

Well Depth \_\_\_\_\_

Installer \_\_\_\_\_

All Depths Reported Are In: Meters\_\_\_\_ Feet\_\_\_\_ Datum\* \_\_\_\_\_

All Diameters Reported Are In: Millimeters\_\_\_\_ Inches\_\_\_\_

Other Information: \_\_\_\_\_

\* Datum is reference from which all depths are reported (e.g. ground surface, top of pad, etc.)

## 17 PERSONNEL SAFETY

Well construction and pump installation usually involves operation of power driven equipment with part of the machinery operating over the operators head. Tools and equipment can be heavy and are often dropped. Dust is often created during the drilling operation and sealant materials may give off harmful dust during their use. Personal protection equipment (PPE) should always be used as appropriate for the operation.

PPE required would likely include:

- Hard Hat
- Eye Protection
- Gloves
- Leather Shoes
- Dust Mask
- Hearing Protection



S.J. Schneider  
2011

## **18 ABOUT THE PRIMARY AUTHOR**

Stephen J Schneider (Steve) manages the drilling division at Schneider Water Services of St. Paul, OR, USA a contracting business employing approximately 25 people in water related activities including: drilling, pumps & water systems installations, water treatment and service. Raised in the industry, he continues to work for the same company for over 37 years.

With a BS degree in mechanical engineering from Oregon State University, Steve worked for the US Department of Defense as a civilian engineer, which included writing/editing many technical specifications. He has maintained drilling and pump installer licenses in both states of Oregon and Washington for many years. He is a National Ground Water Association (NGWA) Master Ground Water Contractor (MGWC).

Steve has presented educational seminars via Webinars, at NGWA Expos, and at Oregon Ground Water Association (OGWA) conventions, and was the first non-government presenter of required continuing education related to well construction rules in Oregon.

Steve has also served on:

- Oregon Ground Water Advisory Committee, including as Chair
- Oregon well construction Rules Advisory & other committees
- NGWA Standards Development Oversight committee
- NGWA Developing Countries Interest Group, including as Chair
- NGWA Policy & Code committee, including as Chair
- NGWA McElhiney Lecturer Task Force
- NGWA initial strategic planning session
- NGWA item writing sessions
- OGWA board of directors, including as President
- OGWA government affairs committee, including as Chair
- OGWA meetings/conference committees

- Pacific NW Ground Water Association, including as Vice President
- National Ground Water Research & Education Foundation (NGWREF), 2011 & 2012 as President

Steve continues to be active in NGWA's Developing Countries Interest Group and has made several trips to, and continues to work with, a mission in Mexico developing groundwater supplies for the indigenous Tarahumara Indians.

*PDF version of this book and a related cost-benefit analysis are available at:*

**[http://seidc.com/pdf/  
Hydrophilanthropy\\_Well\\_Guidelines.pdf](http://seidc.com/pdf/Hydrophilanthropy_Well_Guidelines.pdf)**

*“As of January 2012, the National Ground Water Association congratulates this initiative and looks forward to its continuing evolution to capture best practices in groundwater protection and in water well design, construction, and operation and maintenance.”*

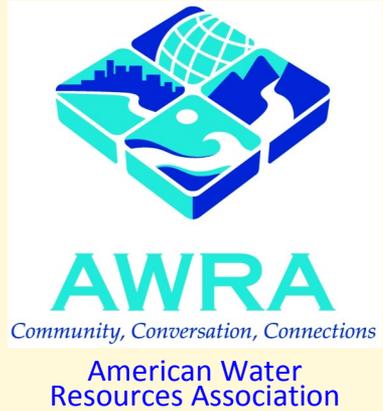
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ENDORSEMENTS and/or FINANCIAL SUPPORT  
provided by:

*John Gregg, Gregg Drilling & Testing, Inc.  
Steve & Miriam Schneider  
and the following organizations*



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ISBN 978-0-9884685-1-1