

GROUND WATER, continued

CALIFORNIA WELL STANDARDS

Standards for the siting, construction, development, and destruction of water wells are contained in two California well standards bulletins put out by California Department of Water Resources (DWR). The first bulletin was published in 1981 as DWR Bulletin 74-81, and contained standards for water supply, domestic, industrial, agricultural, recharge, air-conditioning, and monitoring wells. Standards for wells were later updated in DWR Bulletin 74-90 published in 1991, and monitoring wells were put into a separate section, but the second bulletin was not integrated with the first one, and as a result the well standards were difficult to follow. The DWR Southern District, Division of Planning and Local Assistance, has combined the two bulletins into one and placed it online at the following website:

http://www.dpla.water.ca.gov/sd/groundwater/california_well_standards/well_standards_content.html.

That document is the basis for the following summary.

Note that the Department of Health Services referenced in the standards is now called the California Department of Public Health (www.cdph.ca.gov).

Exempted from the well standards are: oil and gas wells, geothermal wells, and construction wells used for dewatering excavations or stabilizing slopes.

Well Location (Chapter II, Section 8)

Table 4-9 shows the criteria to evaluate when siting a well:

TABLE 4-9 : WELL SITING CONSIDERATIONS	
Minimum Horizontal Separation of Well From	
Sewer	50 feet
Septic Tank or Leachfield	100 feet
Cesspool or Seepage Pit	150 feet
Animal Enclosure	100 feet
Gradient	Upgradient of pollution; consider reversal of gradient when pumping
Flooding and Drainage	Located outside of flooding areas; above 100-year floodplain or recorded high tide for community supply wells; positive drainage provided
Accessibility	Located an "adequate distance" from structures

Sealing the Upper Annular Space (Section 9)

The space between the well casing and the borehole wall (annular space) must be sealed to prevent contaminants from reaching the well from the ground surface. Table 4-10 shows the minimum depth seals must extend below the ground surface for a variety of conditions and well types.

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Water Supply and Industrial Wells	50 feet
Domestic, Agricultural and All Other Wells	20 feet
Areas of Shallow Ground Water	10 feet (with approval)
Encroachment on Contaminant Sources	50 feet (with approval)
Areas of Freezing (more than 265 days per year) and Vaults	Top of seal no deeper than 4 feet

Conditions for Sealing the Annular Space

When sealing the annular space, sometimes a temporary conductor casing is used to keep the annular space open. Once the permanent casing is in place, and as the seal is placed between it and the borehole wall, the temporary casing is removed. In most materials, the conductor casing is placed in an oversized hole that is at least 4 inches greater in diameter than the outside diameter of the well casing. The following requirements apply (Table 4-11):

Unconsolidated, Caving material	Oversized hole; temporary conductor casing installed at least to the minimum depth of annular seal and removed as seal is emplaced; sealing material is neat cement or powdered bentonite
Unconsolidated material with clay layers	Oversized hole; sealing material is neat cement or bentonite; seal extends at least 5 feet into a clay layer if it is within 5 feet of the minimum seal depth
Soft consolidated formations	Oversized hole; sealing is not required between permanent conductor casing and borehole beyond minimum seal depths
Consolidated formations	Oversized hole; Seals in heavily fractured rocks should extend into a solid material; conductor casing may be required to retain overburden
Gravel-packed Wells with Conductor Casing	Oversized hole; annular space between the conductor casing and the borehole is sealed. The gravel pack (between the conductor casing and inner casing) can extend to the surface as long as it has a welded cover to prevent contamination from entering the well.
Gravel-packed Wells without Conductor Casing	Oversized hole; sealed at least to minimum depth between casing and borehole; gravel pack ends at base of seal

Sealing Materials

During the setting and curing of cement-based seals, attention must be paid to controlling the heat of hydration generated by the chemical reaction between water and cement.⁴¹ Excessive heat is generated by large pours or too much cement, but even proper mixtures will generate heat. By keeping the cement wet, the water will form hydrates instead of evaporating due to the heat, which will keep the seal from drying too quickly and cracking. Table 4-12 gives the characteristics of Portland cement and Table 4-13 the requirements for sealing materials. Portland cement must conform to the requirements of ASTM C 150.

⁴¹ Portland Cement Association, 1997.

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TABLE 4-12: TYPES OF PORTLAND CEMENT	
CEMENT TYPE	CHARACTERISTICS
Portland Cement Type I	General Purpose; cures in 24 hours
Portland Cement Type II	Moderate sulfate resistance; Lower heat of hydration than Type I; cures in 24 hours
Portland Cement Type III	High early strength, but reduced curing time (12 hours). Higher heat of hydration than Type I
Portland Cement Type IV	Extended setting time, therefore seldom used; Lower heat of hydration than Types I and III
Portland Cement Type V	High sulfate resistance; cures in 6 hours

TABLE 4-13: SEALING MATERIALS	
ITEM	CHARACTERISTICS
Water	Drinking Water Quality; sometimes non-potable water with less than 2000 mg/l chloride and 1500 mg/l sulfate can be used
Neat Cement	Mixed at a ratio of one 94-pound sack of Portland cement (I or II) to 5-6 gallons of water. Additional water may be needed if additives such as bentonite, retardants, or accelerators, are used.
Sand-Cement	Mixed at a ratio of not more than 188 pounds of sand to one 94-pound sack of Portland cement (I or II) and 7 gallons of water. Additional water may be needed if additives such as bentonite, retardants, or accelerators, are used.
Concrete	Mixed at a ratio of at least six 94-pound sacks of Portland cement per cubic yard of aggregate, plus water. Concrete is most often used for large volume annular seals. Aggregates can decrease the permeability, reduce shrinkage, and reduce the heat of hydration. Aggregate size may be no more than 1/5 the radial thickness of the annular seal.
Bentonite	The only clay (in gel form) acceptable for annular seals. One gallon of water for every 2 pounds of bentonite sufficiently hydrates the clay, and takes between 30-60 minutes to set. Bentonite may not be used if the seal is required to have structural strength, or where it will dry out. In addition, it should not be used where roots will invade the seal, where there is flowing water, or where the rock is fractured.

Additives

With the approval of the enforcing agency, special additives may be used to accelerate or retard the curing time of the cement. Hydrated lime may be added up to 10% of the volume of cement to increase fluidity. Bentonite may be added up to 6% by weight of the cement used to reduce heat generation during setting and improve fluid properties.

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Dry additives need to be mixed with dry cement before adding water. The materials must be mixed thoroughly to prevent lumps. The mix ratios may change if additives are used; therefore the enforcing agency must approve any variations.

Seal Placement

- Obstructions shall be removed.
- Centralizers shall be used to maintain the 2-inch minimum radial thickness of the annular seal.
- Packers can be used to form a foundation for the sealing material.

Transition Seals

Bentonite transition seals, up to 5 feet long, or fine sand, less than 2 feet long, may be placed between the filter pack and the seal to prevent the seal material from entering the filter pack.

Bentonite in the form of granules or powder are placed above the water level, while coarser forms of bentonite are used in seals below the water level. Water is added at a ratio of approximately 1 gallon for every 2 pounds of bentonite.

Transition seals should be installed using a tremie pipe, taking care to mix the bentonite well to prevent bridging.

Timing and Method of Placement

The annular space shall be sealed within 14 days of the casing installation. The seal shall be placed in one continuous operation, unless the seal is greater than 100 feet long. In that case an initial seal no more than 10 feet long may be installed and allowed to set.

The emplacement method must prevent bridging, freefall or dilution of the sealing material, or separation of the aggregate from the sealing material. Freefall methods of sealing may be used only if the interval is dry and within 30 feet of the ground surface.

Ground water flow into the borehole needs to be restricted while placing the seal. It is important to verify that the volume of the material placed in the seal is at least equal to the volume being sealed.

Surface Construction Features (*Section 10*)

Openings into the top of the well shall be closed by water-tight plugs or caps. Vents shall terminate above the ground and above known flood levels, be screened, and have down-turned U bends. All wells must have access for measuring water levels.

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The following Table 4-14 summarizes required features when constructing a well:

Openings	Openings into the top of the well shall be closed by water-tight plugs or caps. Vents shall terminate above the ground and above known flood levels, be screened, and have down-turned U bends. All wells must have access for measuring water levels.
Pumps installed over the casing	A water-tight gasket shall be placed between the pump head and base, or between the pump base and the rim of the casing, or a well cap shall be installed.
Pumps mounted away from the well or submersible pumps	A well cap shall close the opening between the well casing and any pipes which enter the well.
Other	A watertight cover shall be installed at the top of the casing if the well is not completed right away.
Gaskets	A watertight seal or gasket shall be placed between the pump discharge head and the discharge line. If the discharge is below the ground surface, the gasket should be placed between the discharge pipe and discharge line.
Base	For small diameter domestic wells, a concrete base or pad shall be constructed around the top of the well casing, slope away from the well casing, extend at least 2 feet in all directions, and shall be at least 4 inches thick.
Pitless Adapters	Where freezing conditions exist, use a pitless adapter; there are additional requirements.
Well Pits or Vaults	Approval must be obtained from the enforcing agency.
Enclosure	Community water supply wells shall be locked.
Pump Blowoff	The pump blowoff or drain line shall be located above known flood levels and protected against backpressure.
Air Vents	Community water supply wells shall have a casing vent and air release vents.
Backflow Prevention	Pump discharge pipes that do not discharge to the atmosphere must have an automatic backflow device. Drinking water supply wells have additional specific requirements.

Disinfection (Section 11)

Domestic wells shall be disinfected, usually with 2 tablets of calcium hypochlorite per cubic foot, when the gravel in the annular space is being placed.

Casing (Section 12)

Steel, plastic, and concrete pipe casing are the three major types of casing used, and the technical specifications references are given in this section of the Well Standards.

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Sealing Off Strata (Section 13)

Strata that has poor quality water shall be sealed off at least 10 feet above and below. In subsidence areas, the integrity of the annular seal must be maintained by allowing the casing to move vertically without collapsing.

Well Development (Section 14)

Acceptable methods of well development include:

- Overpumping
- Surging using plungers
- Surging with compressed air
- Backwashing or surging by alternately starting and stopping the pump
- Jetting with water
- Introducing chemicals into the well
- Combinations of the above
- Sometimes hydrofracturing or setting explosive charges

Water Quality Sampling (Section 15)

Regulations for reporting water quality sampling results of community water supply wells and specific industrial wells are contained in *CCR Title 22, Social Security, Chapter 15, Domestic Water Quality and Monitoring*. Sampling results are sent to the California Department of Public Health, Division of Drinking Water and Environmental Management.

Special Provisions for Large Diameter Shallow Wells (Section 16)

Shallow wells (less than 50 feet deep) are not recommended for drinking water sources because they are easily contaminated, so these wells shall be at least 250 feet from any underground sewage disposal facility.

Destruction of Wells (Section 20)

It is important to destroy wells properly to protect the ground water and eliminate the physical hazard.

Definition of Abandoned Well (Section 21)

A well is considered abandoned if it has not been used for one year, unless the owner has demonstrated the intention to use the well again by meeting the following requirements:

1. The well does not impair the ground water or well water quality.
2. The well is provided with a cover.
3. The well is marked and easily visible.
4. The area around the well is kept clear of brush and debris.

Requirements for Destroying Wells (Section 23)

Before the well is destroyed, the well condition should be investigated, cleaned if necessary, and obstructions and debris removed. The casing should be perforated or removed. The enforcing agency must be notified if contaminants are known or suspected to be in a well, and their approval received before the well is destroyed.

The requirements for destroying wells depends on the conditions that are encountered. Table 4-15 summarizes the various requirements.

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TABLE 4-15: REQUIREMENTS FOR DESTROYING WELLS	
CONDITION	REQUIREMENTS
Wells in unconsolidated material in unconfined ground water	The upper 20 feet of the well shall be sealed and the rest of the well filled with fill or sealing material.
Wells penetrating several aquifers	The upper 20 feet of the well shall be sealed with "impervious material"(defined below). The well shall be sealed to prevent intermixing of formation water. Seals shall be placed opposite confining layers and extended at least 10 feet above and below. Formations containing deleterious waters and their confining units shall be sealed and extended at least 10 feet above and below.
Wells penetrating fractured rock	Near-surface fractured formations shall be sealed with neat cement, sand-cement grout, or concrete. At depth, alternate layers of coarse stone and cement grout or concrete may be used.
Wells in non fractured consolidated formations	The upper 20 feet shall be filled with impervious material; the remainder of the well may be filled with clay.
Wells in Local Conditions	The enforcing agency may require certain specific formations to be sealed off.

Placement of Material

- Filled from the bottom up
- Continuous pour for neat cement grout, sand-cement grout, or concrete.
- Prevent bridging, free fall, dilution or aggregate separation
- Under conditions of high head or gravel-packed wells, the casing shall be perforated opposite the area to be sealed and the sealant forced into the gravel or surrounding formation. Pressure must be maintained long enough to allow the cement mixture to set.
- Verify that the volume of material filling the well is at least equal to the volume of the well.

Acceptable Materials

Impervious materials include: neat cement, sand-cement grout, concrete, or bentonite; "well-proportioned" mixes of silt, sand and clay; and native soil with an intrinsic permeability value of < 10 feet/year.

Acceptable filler materials include clay, silt, sand, gravel, crushed stone, native soil, mixtures, and impervious materials.

Wells in Urban Areas

A hole 5 feet deep shall be excavated around the well casing, and the well casing removed to that depth. The seal used in the upper portion of the well shall spill over the top of the casing and borehole to form a cap. The excavation shall then be backfilled with native soil.

Appendix B gives suggested methods for sealing the annular space and strata with poor water quality. *Appendix C* suggests procedures for disinfecting wells, and *Appendix D* pertains to sampling for water quality.

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WATER QUALITY STANDARDS

Domestic Water Quality

The U.S. Environmental Protection Agency (EPA) has developed standards to protect the quality of drinking water provided by public water systems. These standards, known as National Primary Drinking Water Regulations, protect water quality by limiting the concentrations of contaminants that may be present. Maximum Contaminant Levels (MCL) are established based on health criteria and are enforceable standards. Contaminants are grouped into these categories: inorganic and organic chemicals, radionuclides, disinfectants, disinfectant byproducts and microorganisms.

California has adopted the EPA standards and a few of its own. Recently the state adopted its own perchlorate standard, and has changed the arsenic standard to conform with the EPA. Selected inorganic contaminants and the comparison between California and EPA MCL standards are shown below in Table 4-16.

CONTAMINANT	MAXIMUM CONTAMINANT LEVEL (US EPA)	HEALTH EFFECTS	MAXIMUM CONTAMINANT LEVEL (CALIFORNIA)
Arsenic (As)	0.010 mg/l as of 1/23/06	Circulation, skin damage, cancer	0.010 mg/l as of 11/28/08
Cadmium (Cd)	0.005 mg/l	Kidney damage	0.005 mg/l
Fluoride (F)	4.0 mg/l	Bone disease	2 mg/l
Lead (Pb)	0.015 mg/l action level	Developmental delays, attention disorders, kidney problems	0.015 mg/l action level
Mercury (Hg)	0.002 mg/l	Kidney damage	0.002 mg/l
Nitrate	10 mg/l (as N)	Infants susceptible to methemoglobinemia (blue-baby syndrome)	45 mg/l (as NO ₃)
Nitrite (as N)	1.0 mg/l		1.0 mg/l
Perchlorate	----	Thyroid damage and cancer	0.006 mg/l
Selenium (Se)	0.05 mg/l	Hair or fingernail loss, circulatory problems	0.05 mg/l
Thallium (Tl)	0.002 mg/l	Hair loss; blood, kidney, intestine or liver problems	0.002 mg/l

⁴² U.S. EPA Office of Ground Water and Drinking Water, July 2002, www.epa.gov/safewater/mcl.html; California Department of Public Health, 2009, www.cdph.ca.gov.

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Many of the Volatile Organic Compounds (VOCs) regulated by the U.S. EPA have a lower MCL in California. Table 4-17 lists the most common organic compounds contaminating California aquifers⁴³ along with the BTEX gasoline components, and compares the MCL with the EPA standard.

CONTAMINANT	MCL (US EPA)	HEALTH EFFECTS	MCL (CALIFORNIA)
Benzene (B)	0.005 mg/l	Anemia, increased cancer risk	0.001 mg/l
Carbon tetrachloride	0.005 mg/l	Liver problems, increased risk of cancer	0.0005 mg/l
1,2-Dichloroethane (1,2-DCA)	0.005	Cancer	0.0005
Dichloromethane (DCM)	0.005 mg/l	Liver damage, cancer	0.005 mg/l
Ethylbenzene (E)	0.7 mg/l	Liver, kidney, central nervous system and eye damage	0.3 mg/l
Methyl-tert-butyl-ether (MTBE)	---	Potential human carcinogen at high doses	0.013 mg/l
Tetrachloroethylene (PCE, PERC)	0.005 mg/l	Liver problems, increased risk of cancer	0.005 mg/l
Toluene (T)	1 mg/l	Nervous disorders, and liver and kidney damage	0.15 mg/l
Trichloroethylene (TCE)	0.005 mg/l	Liver problems, increased risk of cancer	0.005 mg/l
Vinyl chloride	0.002 mg/l	Increased risk of cancer	0.0005 mg/l
Xylene (X)	10 mg/l	Central nervous system, liver, and kidney damage	1.750 mg/l

Total coliform bacteria is used as indicator of the presence of other potentially harmful bacteria, such as *E. coli*, though it is not considered a health threat in itself. *Escherichia coli* (*E. coli* O157:H7) is a bacteria strain that creates a powerful toxin and causes severe illness, including hemolytic uremic syndrome (kidney failure). It comes from human and animal fecal waste that contaminates both food and water.

⁴³ Compilation from California Department of Water Resources, 2003, California's Groundwater, Bulletin 118, <http://www.groundwater.water.ca.gov/bulletin118/index.cfm>.

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Turbidity is used as a water quality indicator because it is often associated with disease-causing viruses, parasites, and bacteria. Total Dissolved Solids (TDS) also indicates water quality. The higher the TDS, the higher the dissolved ions in the water. The secondary MCL value for TDS is 500 mg/l.

Synthetic Organic Compounds (SOCs) are also found in many California wells exceeding the MCLs as indicated in California Department of Water Resources Bulletin 118, Update 2003. Table 4-18 shows the most common SOCs recorded.

CONTAMINANT	MCL (U.S. EPA)	HEALTH EFFECTS	MCL (CALIFORNIA)
Dibromochloropropane (DBCP)	0.0002 mg/l	Kidney damage, testicle atrophy, cancer	0.0002 mg/l
Di(2-ethylhexyl)phthalate (DEHP)	0.006 mg/l	Damage to liver and testes, reproductive effects, cancer	0.004 mg/l
Ethylene Dibromide (EDB)	0.00005 mg/l	Damage to the respiratory system, nervous system, liver, heart, and kidneys; cancer	0.00005 mg/l
Heptachlor	0.0004 mg/l	Extensive liver damage, cancer	0.00001 mg/l
2,3,7,8-TCDD (Dioxin)	0.00000003 mg/l	Reduced fertility to birth defects, increased cancer risk	3×10^{-8} mg/l