

# Wellbore Plugging and Abandonment Practices

API BULLETIN E3  
SECOND EDITION, APRIL 2018



AMERICAN PETROLEUM INSTITUTE

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## Foreword

This document, prepared by the API Subcommittee on Well Cements (SC10) provides guidance on environmentally sound practices for wellbores drilled for oil and gas exploration and production (E&P) operations. Guidance is provided to accomplish the following:

- permanently abandon wells;
- place wells on inactive status (temporary abandonment).

Permanent abandonment is performed when there is no further utility for a wellbore by sealing the wellbore against fluid migration.

Inactive well practices may be performed when a wellbore has future utility, such as for enhanced oil recovery projects or conversion to a disposal or storage well. This permits the operator to hold the well in a condition that facilitates restoring its utility.

The purpose of this document is to address wellbore plugging and abandonment practices. The primary goals are protection of usable quality ground water, and isolation of hydrocarbon bearing, or water injection intervals. Topics discussed include, cementing practices, cement plug placement and the use of mechanical barriers. This document does not address regulatory requirements.

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# Wellbore Plugging and Abandonment Practices

## 1 Considerations for Plugged and Abandoned Wells

### 1.1 General

This document provides guidance for the design, placement, and verification of cement plugs in wells that are to be temporarily or permanently abandoned. Wells that are temporarily abandoned have intent to re-enter in the future. The placement of barriers vary depending on whether the well is to be temporarily or permanently abandoned.

The information in this document is general in nature. Wellbore plugging and abandonment practices will vary with regulation, well type, and purpose. Sound engineering and operational practices should be applied to each plugging operation. Plug lengths are not considered in this document. Local regulations must be considered in the design as they may dictate the length of cement to be placed below or above specific intervals, or both.

### 1.2 Well Construction and Abandonment Practices

This document assumes that generally accepted well construction practices were followed during the installation of the cemented casings.

As specified in API 65-2, properly designed casing strings cemented in place provide multiple barriers during well operations. An example abandoned wellbore can be seen in Figure 1.

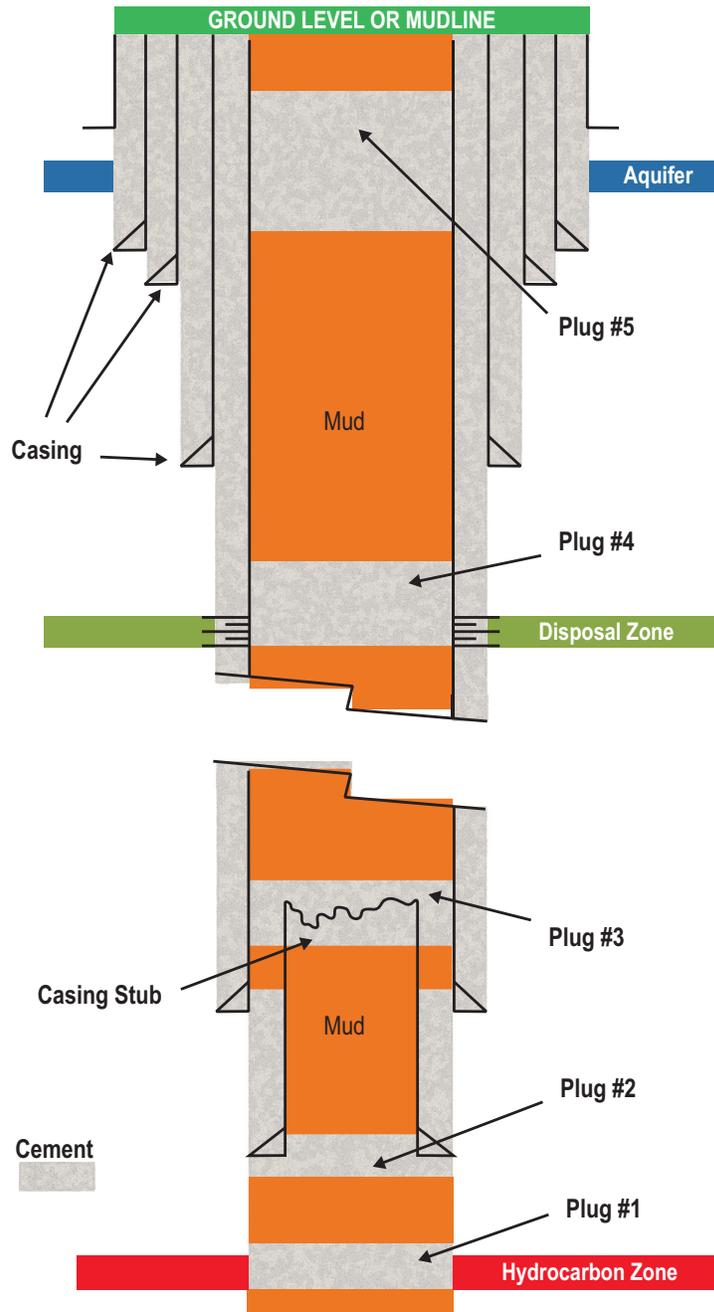
Abandonment barriers installed during wellbore plugging and abandonment operations may include:

- plug set across any exposed casing/liner shoe;
- plugs set in open hole;
- cement or mechanical plugs, or both, set above perforated intervals in cased hole;
- plugs set at points where casing has been removed;
- plugs set across liner tops;
- plugs set above and below usable quality water;
- plugs set above or below hydrocarbon bearing zones or other potential flow zones;
- plugs set at the surface or mudline.

## 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 65-2, *Isolating Potential Flow Zones During Well Construction*



- NOTE 1 Plug #1 may cover all open hole length in several cases.  
 NOTE 2 Plug #3 is commonly called a casing stub plug.  
 NOTE 3 Plug #5 is commonly called surface plug.

**Figure 1—Example Schematic of a Permanent Well Abandonment**

### 3 Terms, Definitions and Abbreviations

#### 3.1 Terms and Definitions

##### 3.1.1

**adequate cement**

Cement in annulus or as plugging material which has been verified as to location and quality.

##### 3.1.2

**barrier**

A component or practice that contributes to the total system reliability by preventing liquid or gas flow if properly installed.

##### 3.1.3

**cement**

For the purposes of this document, the term cement includes Portland cement, pozzolan blends, blast furnace slag blends, phosphate cement, hardening ceramics, resins, geo-polymers or other suitable qualified materials.

##### 3.1.4

**disposal zone**

A geological formation whose strata is isolated from overlying usable quality water by an impermeable layer into which fluids are injected for disposal.

##### 3.1.5

**Inside Blow Out Preventer****IBOP**

A tool used as a check valve inside the workstring.

##### 3.1.6

**plug**

A verifiable barrier element located within the wellbore which may be mechanical or cement.

##### 3.1.7

**usable quality ground water**

Subsurface water suitable for consumption by humans or animals with or without treatment.

##### 3.1.8

**workstring**

A generic term used to describe a tubular such as jointed tubing, coiled tubing or drill pipe used to convey a treatment or for well service activities.

#### 3.2 Abbreviations

For the purposes of this document, the following acronyms are used.

IBOP Inside Blow Out Preventer

P&A Wellbore plugging and abandonment

## **4 Wellbore Plugging and Abandonment Guidance**

### **4.1 General**

This section provides guidance on procedures for plugging and abandoning a well. The procedures involve setting cement plugs or other barriers at critical intervals to prevent the wellbore from becoming a conduit for fluid migration. The primary objectives of a well abandonment operation are protecting usable quality water and isolating potential flow zones. The plugging and abandonment procedures provided in this document focus on the following objectives:

- a) protecting usable quality water from contamination by formation fluid migration or surface water runoff;
- b) isolating potential flow zones (e.g. reservoir hydrocarbon zones, shallow gas, over-pressurized water zones) unless cross flow is deemed acceptable;
- c) protecting surface soils and waters;
- d) isolating injection/disposal zones (e.g. water, carbon dioxide, cuttings re-injection).

These objectives are accomplished by placing cement or mechanical plugs, or both, at selected intervals in the wellbore to prevent fluid movement. In a permanent abandonment, barriers should span the full cross section of the well at the desired isolation depths. An assessment of the cement in the annulus should be done to determine plug-setting depth(s).

Selection of plug depth shall consider formation fracture pressure to enable containment of anticipated pressures from below.

Operators shall consult appropriate regulatory requirements prior to commencing wellbore plugging and abandonment operations. Wellbore plugging and abandonment operations shall conform to regulatory requirements and shall incorporate prudent methods to maintain well control throughout the operation.

### **4.2 Static Equilibrium**

#### **4.2.1 General**

The wellbore should be static prior to cement plug placement. Fluid movement before the plug sets could affect the plug integrity. To be static, wellbore fluids should be the same density at all depths in the wellbore, and if there are perforated or open hole intervals, the wellbore fluid column should exceed formation pore pressure. The type and density of fluid left in the well between cement plugs may be stipulated by regulations.

#### **4.2.2 Abnormally Pressured/Lost Circulation Zones**

Abnormally pressured or lost circulation zones can prevent fluid equilibrium in the wellbore. Mechanical devices, such as bridge plugs, inflatable packers, or cement retainers may help to stabilize the well.

### **4.3 Abandonment/Plugging Planning**

#### **4.3.1 Cement Volumes**

A cement plug is a key element in accomplishing the objectives of abandonment operations as specified in 4.1. The volume of cement slurry used for a particular plug is calculated from the desired plug length, the hole diameter, and appropriate allowances for cement contamination. Note that some cement plug lengths may be specified by regulation. Cement plugs may be placed using a workstring or a dump bailer.

### **4.3.2 Cement Design**

Portland cement is commonly used for abandonment, but other sealing materials may be suitable. The selection of a cement composition for wellbore plugging and abandonment operations depends on the well depth, formation temperatures, properties, wellbore fluid properties and should be designed for each application.

## **4.4 Wellbore Plugging and Abandonment Methods**

### **4.4.1 Plug-placement Methods**

The balanced plug method is commonly used. This method involves pumping the cement slurry through a workstring until all fluids in the workstring and the annulus are hydrostatically balanced. Fluid spacers are used both ahead of and behind the slurry to minimize cement contamination by the wellbore fluids. Fluid spacers help improve bonding. After the plug has been placed with hydrostatically balanced fluid columns, the workstring is slowly pulled out of the plug to some distance above the top of the plug. Knowing the characteristics of the wellbore fluids is important in placing a cement plug. The wellbore must be in a static state prior to and subsequent to plug placement. Movement of well fluids before the cement plug sets will affect plug quality and location.

Additional plug-placement methods include pump-and-pull, IBOP, and sacrificial workstring releasing tools.

### **4.4.2 Cement Squeeze Methods**

The cement squeeze method involves pumping a cement slurry to the desired interval to be isolated, usually through a workstring. Sufficient hydraulic pressure is then applied to the slurry to facilitate movement to the target area. The cement squeeze method is often used in isolating completion intervals. There are multiple squeeze placement methods for use. Cement may be squeezed through a cement retainer or retrievable packer set in the casing to contain the squeeze pressure below the tool.

Alternatively the bradenhead squeeze method, in which the squeeze pressure is controlled at the wellhead, may be used. Casing integrity should be considered before applying the bradenhead squeeze method.

Consideration should be given to the casing size versus tool size to ensure effective washing of the perforated interval to allow effective cement placement.

### **4.4.3 Mechanical Plugging Methods**

Mechanical isolation tools such as bridge plugs, retainers, inflatable packers, permanent packers, etc. can be effectively used in casing to isolate sections of the wellbore. These devices may be set at prescribed depths by wireline, tubing, workstring, or drill pipe. Although the mechanical plug provides a sealing mechanism in the wellbore, cement plugs are typically placed on top of the mechanical plug to form a barrier.

### **4.4.4 Coiled Tubing Method**

This method allows placement of cement plugs without rig intervention. Primary advantages include accurate volume and depth control. It is also highly effective in executing the pump-and-pull method of cement placement.

“Perf and wash” operation can be run before cement placement.

### **4.4.5 Through Tubing Method**

This method uses the existing completion string in the well as the work string to enable the placement of cement. A section of the tubing remains in the plug after cement placement.

#### 4.4.6 Dump Bailer Method

The wireline or slickline conveyed dump bailer is typically used to deliver a small volume of cement slurry to the desired location and is opened on impact or electronically triggered. The method's advantage is that the depth of the cement plug is accurately controlled. The primary disadvantage is the limited volume of cement slurry that can be transported in the dump bailer per run. This method is typically used to spot cement above a mechanical barrier such as a bridge plug.

### 5 Plug Placement Guidance

The following sections provide guidance for various abandonment scenarios.

#### 5.1 Open Hole Completion

The purpose of isolating an open hole completion is to prevent communication of wellbore fluids between zones or to the surface.

Methods used to place open hole abandonment plugs may include displacement, squeeze, dump bailer, coiled tubing and may include running through tubing open hole inflatable packers. See Figures 2 and 3.

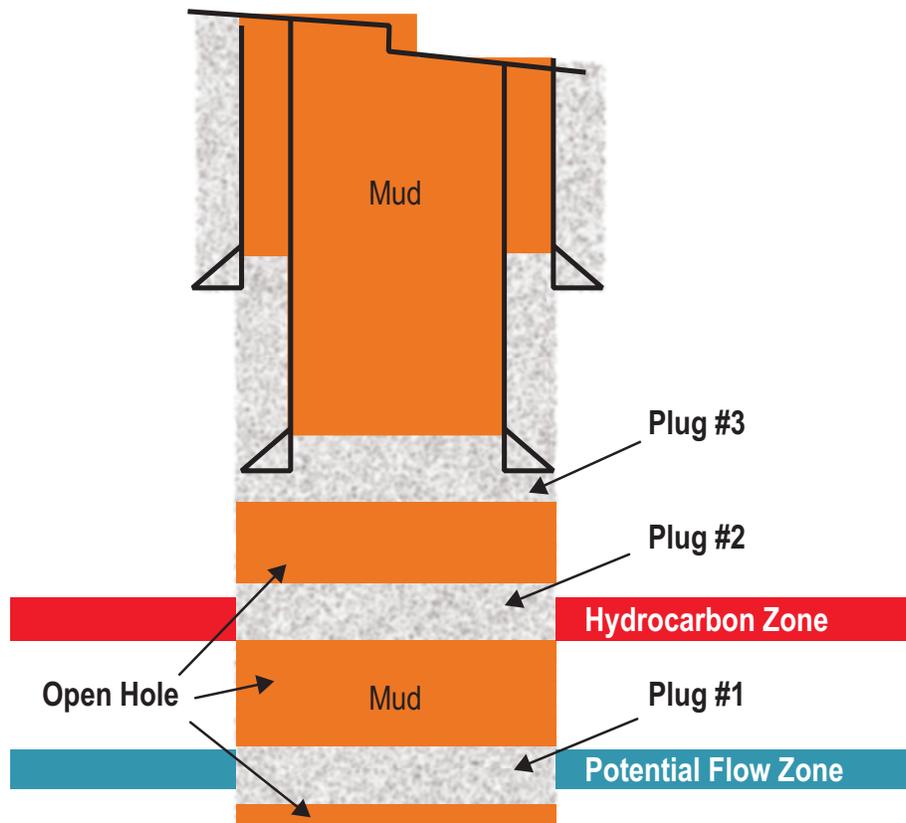


Figure 2—Open Hole Abandonment by Open Hole Balanced Plugs

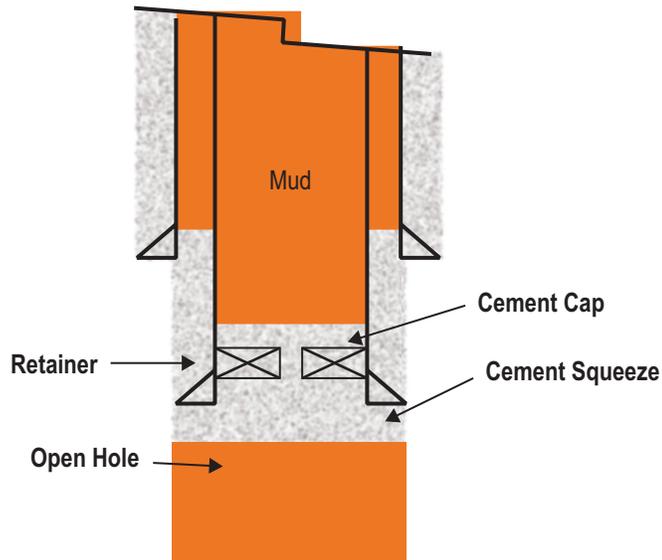


Figure 3—Open Hole Abandonment with a Cement Retainer Set at Casing Shoe

## 5.2 Cased Hole Abandonment

The purpose of cased hole abandonment is to prevent communication of wellbore fluids between zones or to the surface.

Cased hole abandonments typically involve squeeze cementing or a balanced plug, or both, to seal potential flow zone pathways such as perforations, as well as placing cement plugs in the cased wellbore. See Figures 4 and 5.

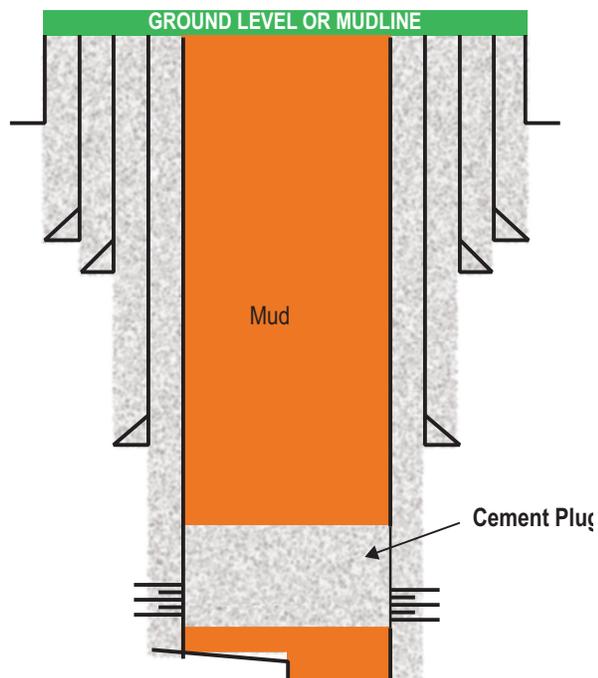


Figure 4—Cased Hole Abandonment with a Perforation Squeeze and a Balanced Plug

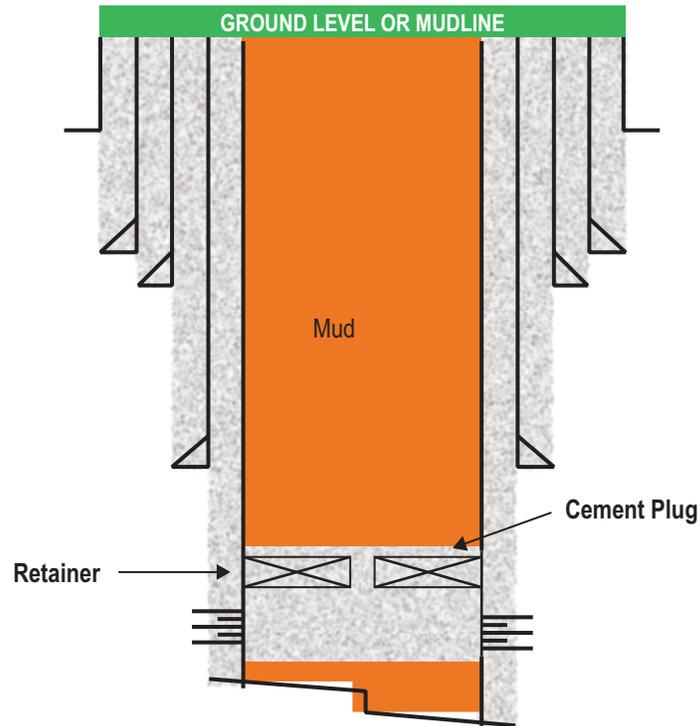


Figure 5—Cased Hole Abandonment with a Cement Retainer

### 5.3 Casing Shoe

The abandonment operations performed at the casing shoe provide a barrier to isolate the open hole below the casing shoe from the upper sections of the wellbore.

Methods used to abandon a casing shoe may include displacement (balanced plug), squeeze, coiled tubing, mechanical plugging methods and dump bailer. See Figures 6 and 7.

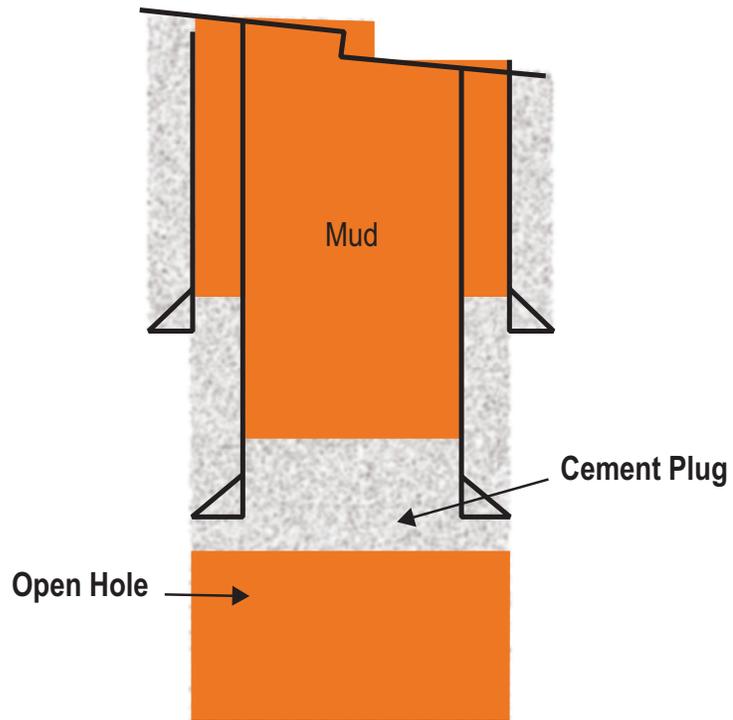


Figure 6—Casing Shoe Balanced Cement Plug

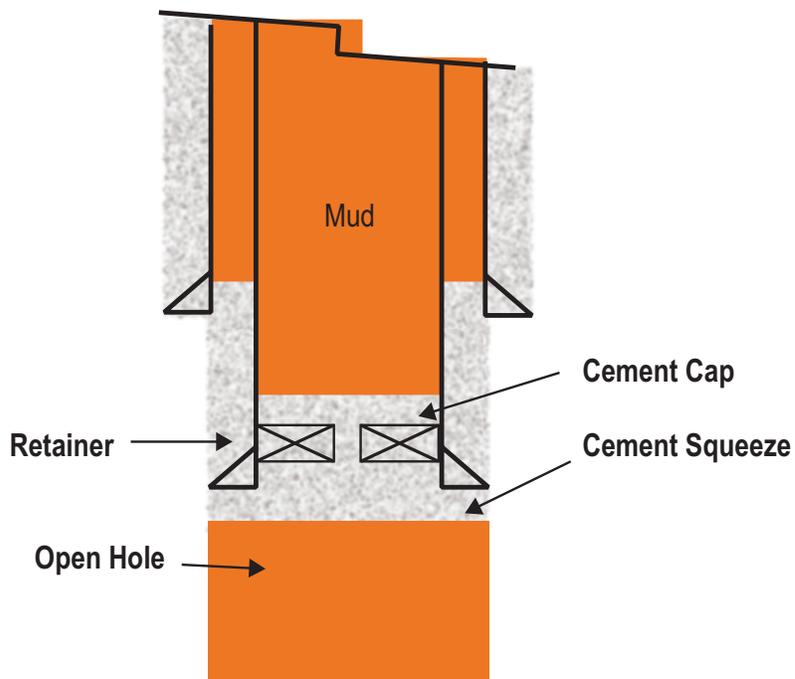
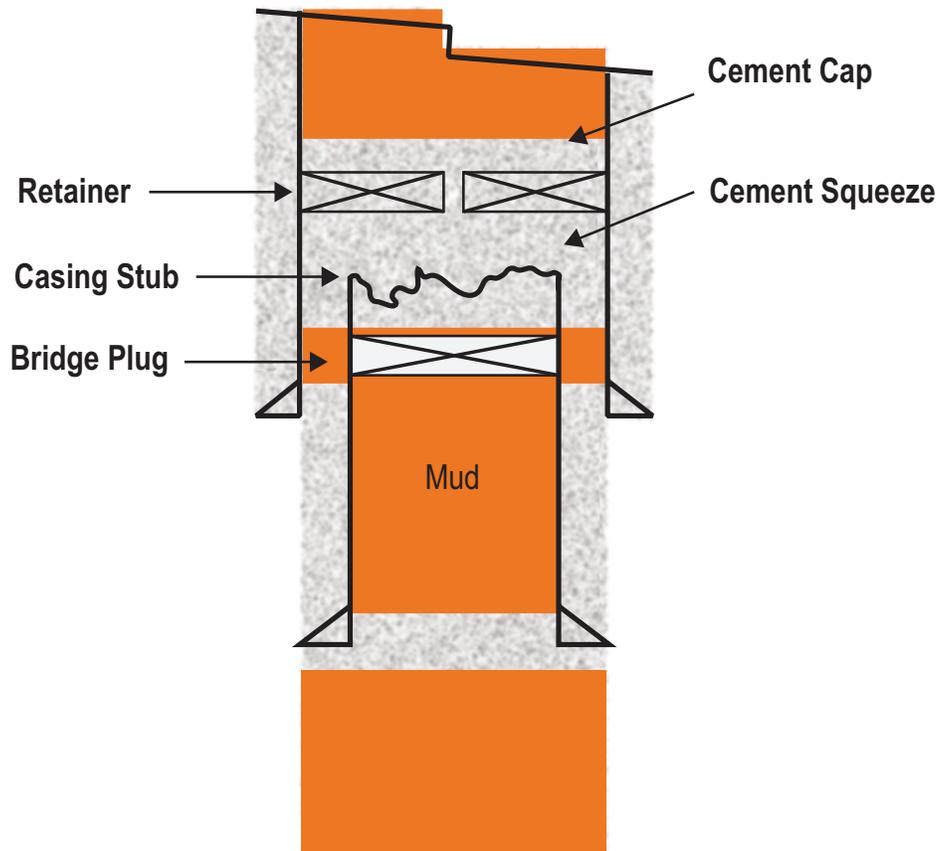


Figure 7—Casing Shoe Squeeze Cement Plug with Cement Retainer

## 5.4 Casing Stub or Liner Top

It may be required to place a plug across a casing stub or liner top in order to provide a barrier to isolate the sections of the wellbore below the casing stub or liner top from the upper sections of the wellbore.

Methods used to abandon a casing stub or liner top may include displacement (balanced plug), squeeze, coiled tubing, mechanical plugging methods and dump bailer. Adequate cement must also be present to isolate the cross section of the well. See Figures 8 and 9.



NOTE A bridge plug may or may not be feasible for this type of abandonment.

**Figure 8—Casing Stub Abandonment**

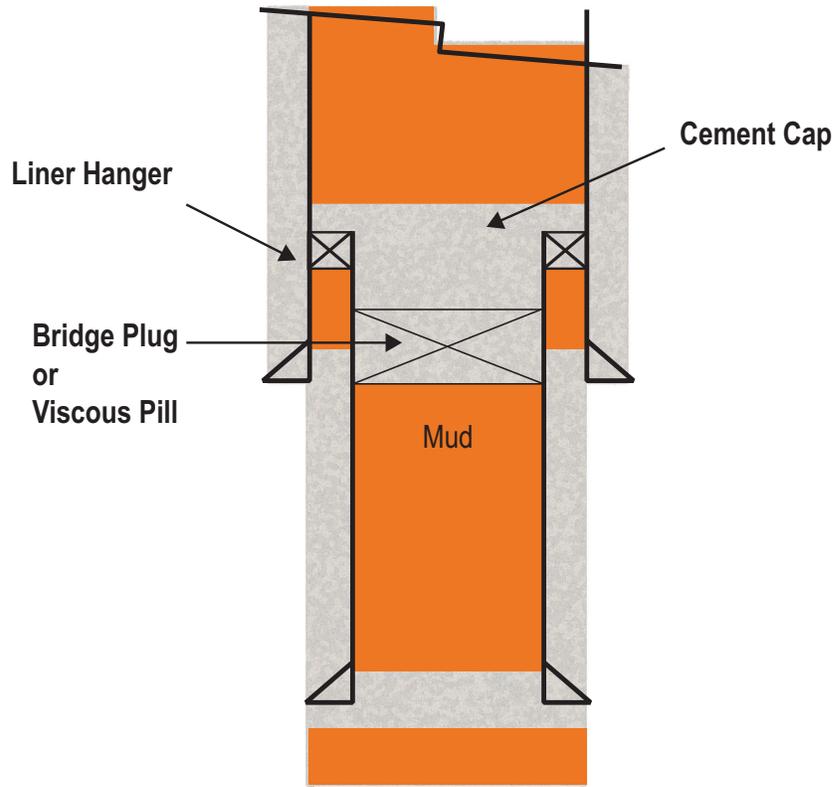


Figure 9—Liner Top Abandonment

## 5.5 Usable Quality Water

Cement plug(s) are typically placed across the usable quality water zones to completely isolate from wellbore contact above and below it. These plugs augment the primary cement present in the casing-open hole annulus in order to provide a barrier which spans the entire cross section of the well.

Methods used to isolate usable quality water may include displacement, coiled tubing and mechanical plugging methods. See Figure 10.

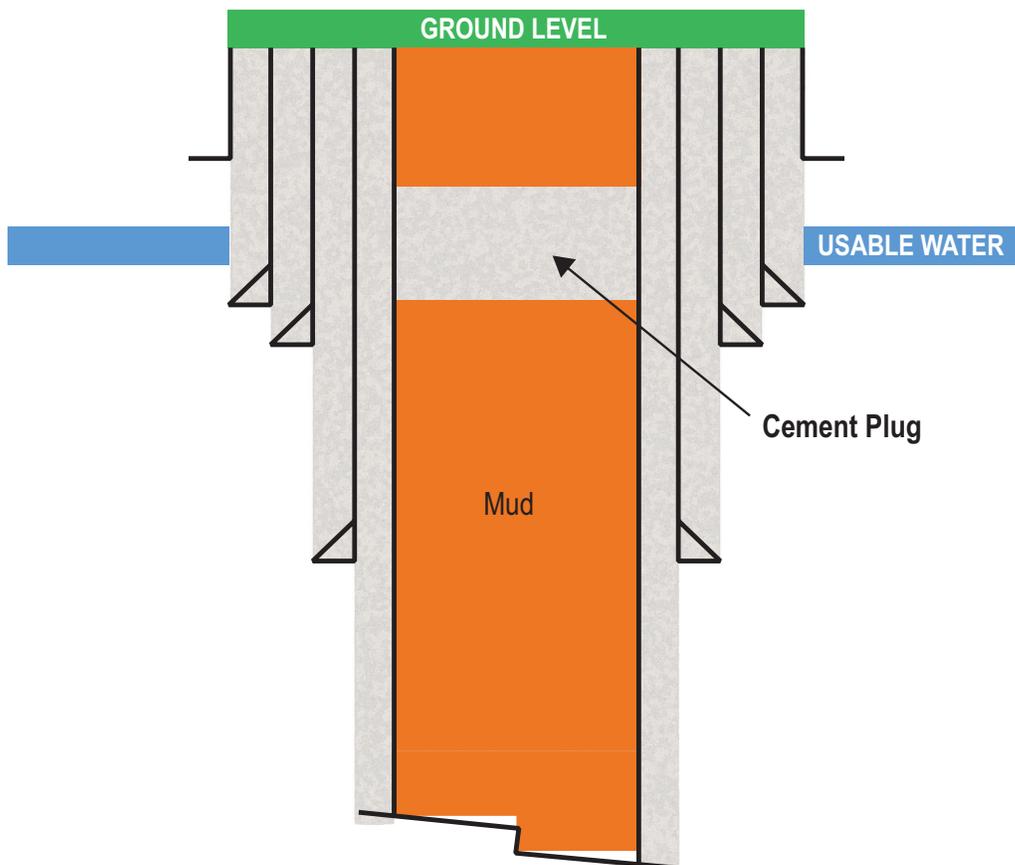


Figure 10—Balanced Cement Plug Inside Casing in Front of a Usable Water Zone

## 5.6 Surface Plug

The plug placed at the surface of the well protects the well from unintended access. It also prevents surface water runoff from entering the well possibly affecting usable quality water. Regulations usually require cement returns to surface on the surface casing's primary cement job to mitigate this concern. Coupled with the surface plug, this provides cement across the entire cross section of the wellbore. Placement is typically by the balanced plug displacement method. Usually surface plugs are not considered barriers to prevent flow from the lower sections of the well. See Figure 11.

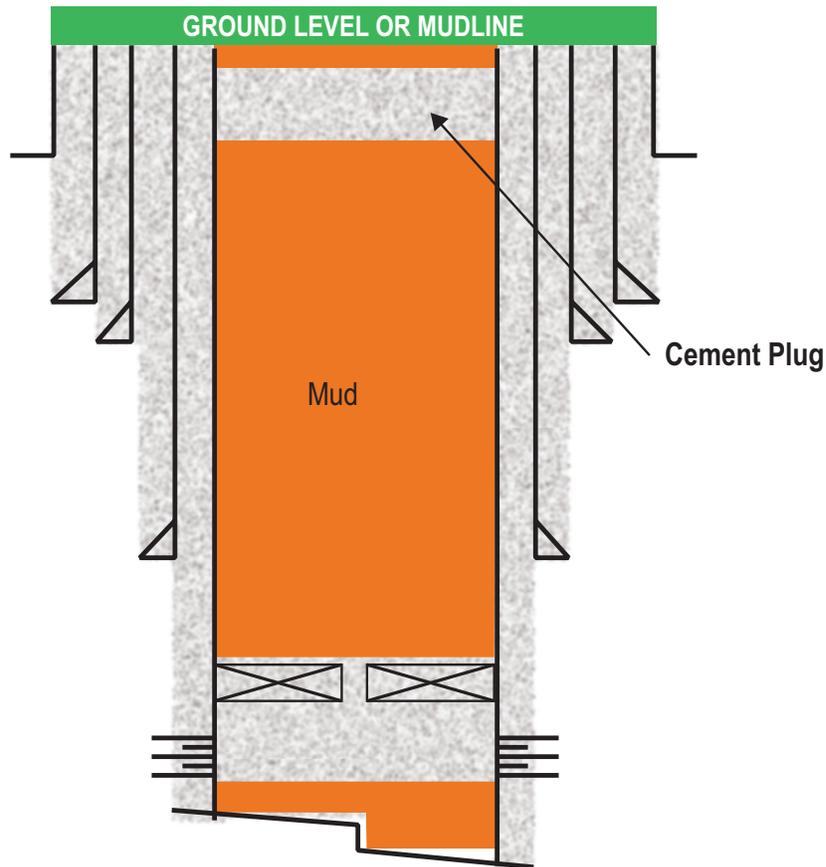


Figure 11—Well Abandonment with Surface Plug

## 6 Plug Placement Verification

### 6.1 General

Plug placement may require verification during wellbore plugging and abandonment operations to ensure the plug has been placed as designed. There are several methods used to verify plug placement, and selection of the verification method will depend on the purpose of the plug and the regulatory environment. Plug verification should be attempted only if wellbore conditions will permit such an operation to be conducted safely.

### 6.2 Weight Testing

#### 6.2.1 General

Applying weight to a plug, also called tagging the plug, is a common method of verifying plug depth and confirming the plug will withstand the applied force. However, the ability of the plug to provide a pressure seal is not confirmed with this method. A key advantage of weight testing plugs is the method does not expose the wellbore to pressure. The plug can be weight tested with a workstring. Wireline tools can be used to verify the depth of the top of the plug but cannot be used for weight testing.

### **6.2.2 Weight Testing Methods**

For weight testing to be effective, the cement must have sufficient compressive strength to support mechanical contact by work string or wireline tools. The wellbore and the wellbore fluids must be in a condition such that the weight test is conducted safely.

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