Reference Document:
Remediating Onshore Oil and Gas Wells

- A petroleum well that has reached the end of its productive life must be carefully remediated to prevent the leaking of fluids and gases to protect future generations.
- Effective remediation isolates oil and gas producing zones from aquifers, and remediates the surface for alternative uses, such as agriculture, to meet the relevant regulatory standards.
- Initial well design and construction prevents unwanted fluid movements behind casing.
- Mechanical and cement plugs, and heavy, clay-rich fluids are used to prevent unwanted fluid movement within remediated wells.
- Well conditions and aquifer locations are considered in locating plugs so that they meet regulatory and environmental requirements.
- Research by the US Ground Water Protection Council has found that the rates of well integrity failure are very low – between 0.01 and 0.03 per cent.

1. Introduction

An oil or gas well is a technically advanced bore hole that reaches hundreds to thousands of meters beneath the earth’s surface to tap petroleum resources. Typical water wells for agriculture or domestic use are less than 100 meters deep. In Australia, oil and gas wells are typically 2,000 to 4,000 meters deep, although some may be as shallow as 300 meters. These are not particularly challenging depths for the oil and gas industry, as wells deeper than 10,000 meters are becoming more common in some countries.

When a well has reached the end of its operating life, which may extend for several decades, it must be properly remediated. Effective well remediation ensures that subsurface rock layers – including oil and gas reservoirs, as well as any aquifers penetrated by the well – remain isolated from each other over time. The objective is to have no significant fluid or gas flows in or around a well.

2. Well design

There are several international standards that guide best practice in well construction.

Before drilling begins, the well is carefully designed to address challenges such as safety, pressure, corrosion, high temperatures and fluid flows that could erode its steel casing over time. The design also takes into account maintenance programs that will be conducted over the life of the well, which is usually decades-long. This means that when a well is considered for remediation, it is already a thoroughly maintained system that is effective in preventing unwanted fluid flows.

Remediation further enhances the well integrity by placing anti-corrosive fluids and mechanical and/or cement plugs in the wellbore to prevent communication between subsurface rock layers, including aquifers and petroleum reservoirs.
3. Well remediation process

The industry term is term for remediation is ‘plugged and abandoned’. Across Australia, the steps to remediate a well are clearly defined by the relevant regulators. For example, in Queensland the steps are outlined by the Petroleum Regulation 2004. Generally, regulations require that a well must be abandoned in accordance with good industry practice, to the extent that this practice is consistent with the regulations. This ensures that as industry technologies and practices improve, they will be incorporated to improve the well remediation process.

Well remediation usually involves using a drilling rig or a smaller workover rig to remove any equipment inside the well – such as subsurface pumps and pipe tubing. This ensures that the well is unobstructed so that isolation plugs can be properly installed.

Well remediation designs:
- place dense fluid or cement plugs above and/or across the oil or gas sections to isolate the zone of production;
- place mechanical and cement plugs to isolate oil and gas intervals from aquifers;
- cut off wells to a depth that will remediate the surface location and not impede alternative uses (e.g. agricultural or commercial).

Cement plugs are important in most well remediations. The first cement plug (used to shut off water) was installed in 1903. Modern cementing practices have been developed since the 1920s. Some jurisdictions have regulated to include the use of bentonite, a clay, in plugging shallow wells (less than 1,200m deep). Bentonite can reseal some fissures and cracks that may appear over time.

3.1 Well remediation regulations and general requirements

Petroleum regulations vary in detail from state to state, but generally ensure that well remediation must use non-corrosive fluids, and plugs that are ‘fit-for-purpose’ based on industry standards.

**Fluid choice enhances remediation:** To maintain the structural integrity of the well, the fluid used in the well must be non-corrosive or made non-corrosive through the use of inhibitors. It must also be dense enough to prevent gas entering the well. Operators often recycle the fluid used for drilling a well. This fluid controls pressures in the well, while also being viscous and rich in solids and clays such as bentonite that can bridge areas where leaks or long-term corrosion may develop.

**Cement plugs are fully tested:** Cement plugging materials must be tested to ensure compliance with strength requirements as dictated by regulations or based on ‘best practice’. The cement in any plug will have undergone both manufacturer and service-company testing. Before being pumped each cement blend will again be tested at the service company’s laboratory.

**Engineering calculations ensure proper placement of cement plugs:** Placing cement plugs involves pumping cement into the well and monitoring volumes until the level reaches the correct location. After allowing time for the cement to set, the rig will lower pipe into the well on to the top of the plug to ensure the plug is where it was intended to be and that it is strong enough to withstand the downhole pressures. If it is not at the prescribed depth, another plug will often be placed on top of the first. This process can be repeated several times until the plug is at the desired depth.

**Depleted zones receive special attention:** As produced oil or gas zones are generally depleted, there is a risk that aquifers may drain into these under-pressured and permeable zones. In remediating wells, completion engineers consider reservoir conditions and confer with geologists and reservoir engineers. Operating companies usually require other experienced engineers or managers to confirm the remediated well has been isolated in accordance with environmental governance procedures.

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3.2 The remediation process

Wells drilled in Australia can vary widely depending on depth. Remediation processes for these wells may vary from state to state and by operator, but generally they include some key steps.

Shallow wells (less than 1,200m) are usually simpler in design (see Figure 1 below).

1. **Prepare and test the well:** The first step is to ensure the well is mechanically sound to commence well remediation. A small drilling or workover rig is used to remove any pumps or downhole equipment in the wells. Pipe tubing is run into the well to ensure that the well is unobstructed and suitable for the remediation procedure.

![Figure 1: Typical CSG well](image)

2. **Isolate the producing zones:**
   Because of depletion or under-pressure, often a well will not support a column of fluid to surface.
   In such cases, a dense fluid is placed over the existing producing zone in order to properly ‘balance’ the pressure differences. (Figure 2)

![Figure 2: The well bore is cleared, dense fluid is placed in the well, and a mechanical plug set above the producing zone](image)
3. **Plugging**

Mechanical plug: A mechanical plug is set above the producing zone.
Cement plug: The well is then filled with cement above the mechanical plug (Fig. 3)

![Figure 3: Well is cemented from mechanical plug to surface](image)

4. **Remediate surface structures**: The well head is removed and the surface location remediated. For example, in onshore wells in Queensland, the casing is cut off 1.5 metres below ground level and capped with a steel plate with a marker tape about 20 cm above the top of the casing (Figure. 4).

![Figure 4: Well is cut off about 1.5 metres below ground level and properly marked](image)
For deeper wells (more than 1,200m), the principles are similar, but the complexity of the well construction means more steps are required, and greater care is needed to control the higher pressures and temperatures.

These deeper wells are not usually filled entirely with cement. Instead multiple and alternating layers of cement and dense fluids, usually with clays like bentonite added, are used to control pressures. A variety of mechanical plugs are also used for the various sizes and depths of casing and pipe tubing in the well. While this is more complex than for shallow wells, it has the same purpose of preventing unwanted fluid flows and isolating aquifers for future generations.

3.3 Surface Site Remediation

After plugging and marking the well site, the surface can be remediated with soil treatments or replanting to assure that past practices, such as agriculture, can resume.

In Queensland, for example, a plaque placed on the nearest fence, building or other permanent structure must including the following information:

- the well or bore’s identifying name;
- the total depth in metres of the well or bore;
- the date on which the well or bore was abandoned; and
- the distance and direction to the well or bore from the plaque.

A well that has been properly remediated is very different to a producing well which needs regular measurement and monitoring. A remediated well is designed to be safe and to ensure that it poses no material threat to safety and the environment for future generations.