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GAS WELL CLOSURE, ABANDONMENT AND REHABILITATION GUIDELINES

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1. PURPOSE OF THIS DOCUMENT

This document aims to provide guidance during the preparation for well closure, sealing and abandonment of a gas production/exploration well, focussing on the following aspects:

1. Determining the most suitable and appropriate closure, sealing and rehabilitation strategy with specific focus on:
    - Technical aspects pertaining to plugging mechanisms/techniques in order to ensure the most suitable and appropriate well specific closure, sealing and rehabilitation strategy is implemented - with specific focus on the plugging methods to ensure no vertical gas and/or fluid movements within the well;
    - Specifications of plugging material and equipment to ensure compliance with well abandonment standards (e.g., Best Practice Standards etc.);
    - Ensuring the landscape is safe, stable and non-polluting over the long-term, and that the post closure land use aligns with the surrounding land use and does not affect the sustained utilization thereof;
    - Mechanisms and tests that would be implemented to ensure cement bonding is structurally sound;
    - Mechanisms and tests that could be implemented for *future long-term monitoring* to ensure well plugging and sealing is structurally sound
2. Preparation of a consolidated site-specific closure, sealing and rehabilitation plan and project cost-breakdown.

2. WELL CLOSURE AND ABANDONMENT REQUIREMENTS AS PER THE EMPR

2.1 Well Objectives

Driven by the closure targets, the following well closure and rehabilitation objectives applies:

1. Well closure must represent legislative frameworks and requirements as stipulated by:
    - Industry Best Practice standards and guidelines; and
2. The gas well sealing, and closure plan must be aimed at preventing groundwater and natural gas reservoir fluids from migrating within or laterally through a well over time, by isolating all porous formations and freshwater aquifers.
3. Reflect the local environment - ecosystem rehabilitation of impacted areas, including natural fauna and flora, hydrology and hydrogeology;
4. Ensure than the final landscape is safe, stable and non-polluting over the long term, and that post closure land-use does not affect the sustained utilization thereof.

2.2 Closure Objectives

The surface area of the well to be abandoned and sealed, must be clear of obstructions and equipment and the well must be cemented for the full length and diameter of the well to surface.

Landform, erosion control and re-vegetation is an important part of the rehabilitation process. Landform and land use are closely interrelated, and the landform should be returned as closely as possible to the original landform. This requires the following:

- Remove any discard or waste materials from the well sites and dispose at a suitably licenced waste disposal facility;
- Shape, level and de-compact the final landscape after removing all of the project infrastructure, where necessary dress with topsoil and, where necessary, vegetate with indigenous species.

As is the nature of natural gas exploration, wells not yielding viable gas will be plugged and rehabilitated. The basic aim is to render wells permanently safe and remove all surface signs of exploration activity. All efforts should be taken to ensure the surface area is returned as close as possible to its pre-exploration condition.

The following factors must be taken into account when designing the well closure strategy:

- Final condition and design of the well;
- Height of the cement in the annulus outside the casing;
- Any permeable formations outside the casing that must be covered in cement;
- Any cemented casing overlaps;
- The need for abandonment plugs to cover the full diameter of the wellbore;
- The type of fluid in the annuli above the cement;
- Consideration of the difficulties of injecting cement into the annulus;
- Future monitoring of the well plug integrity;
- The depth below surface at which casings must be cut; and
- Any related seismic activity risks.

There are various alternative closure and post closure options available. The identification and consideration of the most suitable alternatives are driven by, inter alia the following considerations:

- The ability of the selected alternative to adequately meet the specified closure vision and objectives;
- The efficiency, viability, and practicality of the selected alternative; and
- The alignment with the local environmental and socio-economic context and associated opportunities and constraints.

The table below presents options and alternatives referenced in the EMP related to the process of abandoning and closure of a well site. The preferred options mentioned in the table below, are subject to input from the Contractor and Well Specialist who are required to advise on suitable options related to well-specific conditions.

Table 1: Recommended well closure techniques

Exploration activity	Aspect	Options	Comment
Exploration wells	Casing	Retain	Subject to pre-closure inspection of casing integrity by well engineer. The retention of well casings is strongly dependent on the nature of the geological strata and location of aquifers and other porous/permeable zones. The presence of these zones may also be a hindrance to the removal of a casing string.
	Plugging extent	Entire well length	Best Practice Guidelines requires well to be cemented for the full length and diameter of the wellbore to surface.
	Plugging material	API Standard	The cement to be used must comply with the requirements of the relevant API standards and Best Practice Guidelines, or alternative standards as agreed with the PASA and as approved by a well engineer.
	Plugging technique	Squeeze	The displacement method minimizes the contamination of the cement by being able to displace fluid within the well – thus allowing for a more stable well plug.
	Well surface infrastructure	Complete removal	Best Practice Guidelines requires that the surface areas of a decommissioning well must be clear of obstructions and equipment. In order to allow hindered land use of the well area, it is suggested that all surface infrastructures be removed. In addition, the well be capped at +- 1m below the ground level with the requirement for marking its location and representing its position on the Title/SG diagram.

It is anticipated that the closure options listed in the table above is in line with industry Best Practice Guidelines.

3. WELL CLOSURE, SEALING AND REHABILITATION ACTIONS

The anticipated closure actions can be summarised as follows:

1. Phase 1: Preparation for closure
2. Phase 2: Well Closure and Sealing
3. Phase 3: Earth Works and Surface Rehabilitation
4. Phase 4: Reporting

The tables below provide a summary of the closure actions/requirements for each phase.

PHASE 1: PREPARATION FOR CLOSURE

A licence holder may only suspend a production well on obtaining the approval of the designated agency (PASA). In this regard, a well that is no longer active or producing, or for which the approved suspension period has passed, must be plugged/sealed and rehabilitated in accordance with a PASA approved closure, sealing and rehabilitation plan.

The following tasks should be undertaken prior to well closure and rehabilitation:

Table 2: Summary of tasks to be undertaken prior to well closure and rehabilitation

Actions	Requirements
1. The well must be cleared of obstructions prior to abandonment	• Removal of surface infrastructure ○ Tetra4 will advise on storage facilities to store removed infrastructure

2. Assess well condition through downhole logging	• Conduct **Calliper logging** to identify and investigate potential blockages/cavities within well.
	  ○ This information is crucial for the planning of cementation and volumetric requirements
	• **Cement Bond Logging** to investigate the current integrity of the casing and cementation
	  ○ Determine whether top-up cementation work will be required (specifically across sections with “no cement bond” or “poor cement bond” results are noted).

3. Preparation of a site-specific closure, sealing and rehabilitation plan	• Contractor to determine the most suitable and appropriate closure, sealing and rehabilitation strategy with specific focus on the plugging method to ensure no vertical gas and/or fluid movements within the well.
	• Contractor to prepare a consolidated site-specifi closre/sealing plan – to be submitted to Tetra4 for approval.
	• The identification and consideration of the most suitable alternatives must be driven by the following considerations:
	  ○ The ability of the selected alternative to adequately meet the specified closure vision and objectives;
	  ○ The efficiency, viability, and practicality of the selected alternativs; and

	○ The alignment with the local environmental and socio-economic context and associated opportunities and constraints

PHASE 2: WELL CLOSURE AND SEALING

The table below provides a summary of tasks to be undertaken during well closure and sealing.

Table 3: Tasks should be undertaken during well closure and sealing

Actions	Requirements
4. Isolate all potential hydrocarbon/water bearing formations through the placement of cement plugs	• Develop cement formulation for cementing the entire well annulus. • Develop cement formulation to top-up "no bond" or "poor bond" cemented sections between casing and formation walls – ensure cement seals and does not disperse into porous formations. • Cement formulations and volumetric calculations to be approved by well engineer/cement specialist
5. Well Cementation	• Contractor must ensure cement mixture seals the entire well length along the well annulus. Cement plugs must be stacked along the full length and diameter of the well to surface (open hole section above the packer as well as the upper casing) to ensure efficient redundancy. • All plugs must be tagged to ensure successful placement. • Cementation extent: ○ From end of hole (bottom of well) to surface. • Cementation technique: ○ **Squeeze technique** - this displacement method minimizes the contamination of the cement by being able to displace fluid within the well, thus allowing for a more stable well plug. Contractor must also make use of wiper plugs for cement displacement. • Contractor to conduct cement top-ups along the annulus and existing cemented sections showing "no bond" or "poor bond" from logging results. • A surface / shallow cement plug (+/ 50m below ground Level) must be set, and the well casing must be cut and capped 1 m below ground level to remove the wellhead and all casing above this point
6. Cementation integrity testing	• Integrity of the plugs must be confirmed by setting weight down on the upper most plug (using the drill string) as well as a differential pressure test for 4 hours at determined pressure with less than 10% bleed over the period. Pressure test data to be captured in 15-minute intervals for the entire 4-hour testing period.

PHASE 3: EARTH WORKS AND SURFACE REHABILITATION

The table below provides a summary of tasks to be undertaken during earth works and surface rehabilitation

Table 4: Tasks should be undertaken earth works and surface rehabilitation

Actions	Requirements
7. Earth Works and Surface Rehabilitation	• The well casing must be cut and capped 1 m below ground level to remove the wellhead and all casing above this point; • Placement of a "surface tag" in order to ensure monitoring can continue once the casing is cut and the area revegetated. • Surface area to be rehabilitated is ±40 m^2 (well dependant – Tetra4 to confirm rehabilitation size) • Earth works and surface rehabilitation must include: o Earthworks to shape and profile the area in order to conform to the surrounding area; o Re-instate natural drainage lines; o Re-vegetate surface areas with an *Eragrostis teff* or local pioneer specie seed mix • Rehabilitation must reflect the local environment - ecosystem rehabilitation of impacted areas, including natural fauna and flora, hydrology and hydrogeology • Contractor must ensure that than the final landscape is safe, stable and non-polluting over the long term, and that post closure land-use does not affect the sustained utilization

PHASE 4: REPORTING

The table below provides a summary of reporting requirements after well closure, sealing and rehabilitation.

Table 5: Summary of reporting requirements

Actions	Requirements
9.	• Contractor to prepare a comprehensive project report containing the following: o Calliper and CBL logging results; o Cement formulations and Material Safety Datahseets of all additives; o Cementation methodology and photographs; o Recorded pressure test data; o Well tagging photographs and coordinates; o Surface rehabilitation photographs.