Alberta Energy Regulator

Directive 020

Release date: September 5, 2023

Effective date: September 5, 2023

Replaces previous edition issued October 19, 2022

Well Abandonment

Contents

1 Introduction

1.1 Purpose of the Directive

Directive 020: Well Abandonment details the requirements for well abandonment, **zonal abandonment**, casing removal, and **plug backs** as required under section 3.013 of the *Oil and Gas Conservation Rules* and section 98 of the *Geothermal Resource Development Rules*.

The objective of a well abandonment is to cover all nonsaline groundwater (water with total dissolved solids less than 4000 milligrams per litre [mg/L]) and to isolate or cover all **porous zones**.

All open-hole and cased-hole abandonments must be conducted in accordance with the requirements in this directive.

1.2 AER Requirements

Following AER requirements is mandatory for the responsible duty holder as specified in legislation (e.g., licensee, operator, company, applicant, approval holder, or permit holder). The term "must" indicates a requirement, while terms such as "should," "recommends," and "expects" indicate a recommended practice. Information on compliance and enforcement can be found on the AER website.

In this directive, defined terms are set in **boldface** at first use, and the definitions are provided in appendix 1.

1.3 What's New in This Edition

Requirements were added to allow for **routine** abandonment of wells penetrating an oil sands zone. If a well penetrating an oil sands zone meets the conditions and requirements for low thermal potential set out in section 5.4.8, the licensee may abandon it using the section 5.3 requirements for wells that do not penetrate an oil sands zone.

1.4 Overview

When planning to abandon a well, a licensee has to determine whether the planned abandonment operation will be routine or nonroutine, as defined by this directive. A planned abandonment operation is **routine** if it meets all the requirements that apply to the well based on

- the type of well being abandoned,
- the well's geographic location,
- the impact of the well on any oil sands zones, and
- the absence of a wellbore problem.

Routine abandonments are any operations that comply with the requirements specified in this directive. Routine abandonment operations **do not** require AER approval before work is started. Nonroutine abandonments consist of any operations that vary from the requirements in this directive. Nonroutine abandonment operations **do** require AER approval before work is started.

The following are examples of **nonroutine** abandonment operations:

- abandonment of a well associated with a salt cavern
- abandonment of a well associated with an **in situ coal gasification** scheme
- abandonment of a well with a wellbore problem, including a fish-in-the-hole across two or more porous zones, a leaking plug, or a ghost hole across two or more porous zones
- reabandonment of a well
- **surface abandonment** of a well where cement does not cover all nonsaline groundwater zones
- use of cement plugs in a well in a manner that does not meet the requirements in this directive
- use of a bridge plug inside the surface casing
- use of any type of plugging device set more than 15 metres (m) above the completion interval or where there are multiple effective porous zones between the plugging device and the completed interval
- removal of uncemented casing from the well in a manner that does not meet the requirements stated in this directive

The preceding list of examples is not a comprehensive list of the types of nonroutine abandonments that may be used, nor all the possible situations that could be encountered in Alberta.

If the licensee has questions about an abandonment operation, contact the AER at WellOperations@aer.ca *before* beginning any work. If an emergency situation occurs after hours or on a weekend, contact the appropriate AER field centre.

1) The licensee must keep all test results and abandonment details for abandoned wells.

If a licence for an abandoned well is transferred, the new licensee assumes all responsibility for the control or further abandonment of the well and the responsibility for the costs of doing that work.

2 Requirements for Nonroutine Abandonment Requests and Notification/Reporting

2.1 Obtaining Approval for Nonroutine Abandonment Operations

2) The licensee must submit a nonroutine abandonment request using the designated information submission system. The Well Abandonment Variance Request form is available on the directive forms webpage.

3) In addition, the licensee must send an email to WellOperations@aer.ca that includes the nonroutine abandonment request, all supporting documentation, and the wellbore schematic.

The AER will review the request and may ask the licensee to provide additional information regarding the nonroutine abandonment operation.

The licensee will be notified once the request has been approved or denied.

4) The licensee may not begin abandonment operations until the AER approves the nonroutine abandonment request and must conduct its operations in accordance with the terms and conditions of the approval.

2.2 AER Notification

Notification is required prior to all well abandonment operations through the designated information submission system.

5) Notification of abandonments (including zonal abandonment) must be submitted to the AER no earlier than seven calendar days before beginning operations.

6) If an operation is demobilized and remobilized later, licensees must re-notify the AER as required by requirement 5.

Oil sands evaluation wells and test-hole wells drilled within the surface mineable area are exempt from the notification requirements.

2.3 AER Reporting Requirements

7) The licensee must report surface abandonments through the designated information submission system within 30 days of completing the operation.

A well licence abandonment submission *cannot* be made if there is a casing failure or a surface casing vent flow or gas migration report that is open or outstanding for the well licence.

8) The licensee must ensure the surface casing vent flow or gas migration reports and casing failure reports have a resolution entered and the reports are closed within the designated information submission system prior to the submission of the well licence abandonment information.

9) The licensee must submit plug logs to the AER in accordance with *Directive 080: Well Logging* within 30 days of the run date. See section 6.2 for details.

Industry is responsible to ensure that all work performed on a well is properly reported (see *Directive 059*: *Well Drilling and Completion Data Filing Requirements*).

3 Previously Abandoned Wells and Zones

3.1 Previously Abandoned Wells (Cut and Capped)

Wells that were abandoned to the standards in place prior to this edition of *Directive 020* are not required to be reabandoned to current standards. Exceptions to this are leaking wells and wells that are being re-entered.

3.2 Previous Zonal Abandonments

Active wells that have existing zonal abandonments and were compliant at the time of the zonal abandonment will not be required to be reabandoned to current standards. The exception to this is as follows.

10) For wells with existing zonal abandonments of **level-A intervals**, an additional cement plug must be circulated on top of the uppermost previously abandoned zone.

    a) This cement plug must be a minimum length of 30 vertical metres and have a minimum volume of 1 cubic metre (m^3).

    b) The base of this plug must be below the base of groundwater protection (BGWP).

11) If the uppermost previously abandoned zone's plug base is above the BGWP, the plug must be drilled out, and an additional cement plug must be circulated on top of the uppermost previously abandoned zone.

    a) This cement plug must be a minimum length of 30 vertical metres.

    b) All perforations above this point must be abandoned to the current base standard.

3.3 Leaking Wells / Lowering Casing Stubs

12) The current well licensee must submit a nonroutine abandonment request to WellOperations@aer.ca for approval (see section 2.1).

    a) The request must include the reason for the re-entry.

    b) The licensee must also notify the mineral rights owners and have an active surface lease agreement.

13) Approval from Alberta Energy is required if the mineral rights have reverted back to the Crown. Operations to re-enter the well for repair or lowering of the casing stub may proceed once the appropriate approvals are in place.

14) For wells and zones found to be leaking, the source of the leak must be identified and repaired in accordance with *Directive 087: Well Integrity Management*.

15) The leaking zone and all those above must be abandoned in accordance with *Directive 020*.

16) The well must be abandoned at surface immediately after confirmation that the repair has been successful.

17) The licensee must update the licence abandonment report using the designated information submission system as a reabandonment.

18) The licensee must follow the requirements of *Directive 056: Energy Development Applications and Schedules* when re-entering an abandoned well for the purpose of production or if it is not the current licensee of the well.

3.4 Re-entry Wells

19) Wells that are re-entered must be abandoned in accordance with this directive from the re-entry depth to surface.

If there are abandoned zones below the re-entry depth, the requirements for previous zonal abandonments in section 3.2 and leaking wells / lowering casing stubs in section 3.3 apply.

4 Open-Hole Abandonment Requirements

20) For the abandonment of an open-hole well, the licensee must set cement plugs of sufficient length and number to

    a) cover all nonsaline groundwater to the BGWP,

    b) cover all zones above the top of the **Mannville Group** (or equivalent; i.e., the Luscar or Blairmore Groups or Spirit River Formation), and

    c) isolate or cover all porous zones below the top of the Mannville Group (or equivalent).

To determine the BGWP depth for a well, refer to the Base of Groundwater Protection Query Tool available on the AER website under Systems and Tools. The elevations provided in the tool are subsea and will need to be converted to kelly bushing.

Porous zones are defined as

- carbonates with effective porosity greater than 1%,
- sandstones with effective porosity greater than 3%,
- a zone with offset production regardless of the porosity, or
- any zone with drillstem test formation fluid recoveries greater than 300 linear metres or gas volumes greater than 300 m^3.

21) For wells in which intermediate casing has been set but has not been cemented full length, the uncemented interval must be evaluated as follows:

   a) If nonsaline groundwater has not been covered by surface casing and the intermediate casing cement top is below the BGWP, **remedial cementing** must be conducted to isolate nonsaline groundwater intervals.

   b) If there are porous intervals not covered by the intermediate casing's primary cement, remedial cementing must be conducted to isolate the intervals.

   c) Following completion of the plugging program, the wellbore must be filled with **nonsaline water**.

4.1 Open-Hole Abandonment of Non-Oil Sands Wells

For wells outside an oil sands area (see figure 1), using fillers or additives in the cement used for plugs is acceptable for open-hole abandonments if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

22) All zones above the top of the Mannville Group (or equivalent) must be covered with a plug that is placed in one or more stages.

   a) For wells where the top of the Mannville Group (or equivalent) is at a depth less than 1500 m true vertical depth (TVD), this plug must extend a minimum of 15 vertical metres below the top of the Mannville Group (or equivalent).

   b) For wells where the top of the Mannville Group (or equivalent) is at a depth greater than 1500 m TVD, this plug must extend a minimum of 30 vertical metres below the top of the Mannville Group (or equivalent).

23) Licensees must use the logs from the well to determine the exact plug placement for wells drilled deeper than the top of the Mannville Group (or equivalent).

24) All plugs run at a depth less than 1500 m TVD must be a minimum length of 30 vertical metres and extend from a minimum of 15 vertical metres below to a minimum of 15 vertical metres above the zone being covered.

25) All plugs run at a depth greater than 1500 m TVD must be a minimum length of 60 vertical metres and extend from a minimum of 30 vertical metres below to a minimum of 30 vertical metres above the zone being covered.

A plug may extend over more than one zone.

26) Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

There is no maximum distance between plugs as long as the pressure from the zone being isolated does not exceed the fracture pressure of the interval left open above it.

27) The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

Examples of plugging programs are provided in

- figure 2, southern plains / foothills,
- figure 3, central plains,
- figure 4, northwest plains, and
- figure 5, northeast plains.

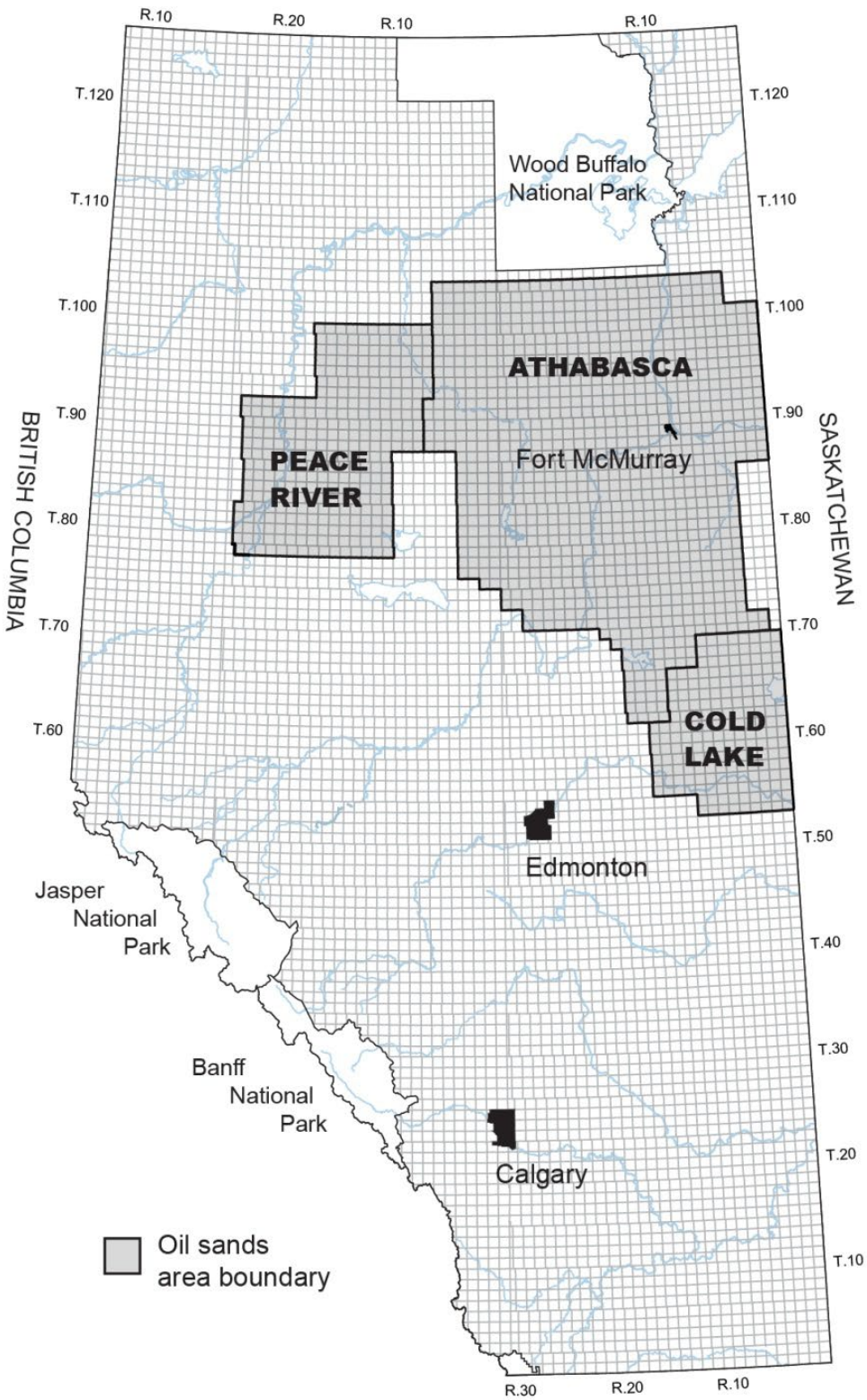

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Figure 1. Oil sands area boundary

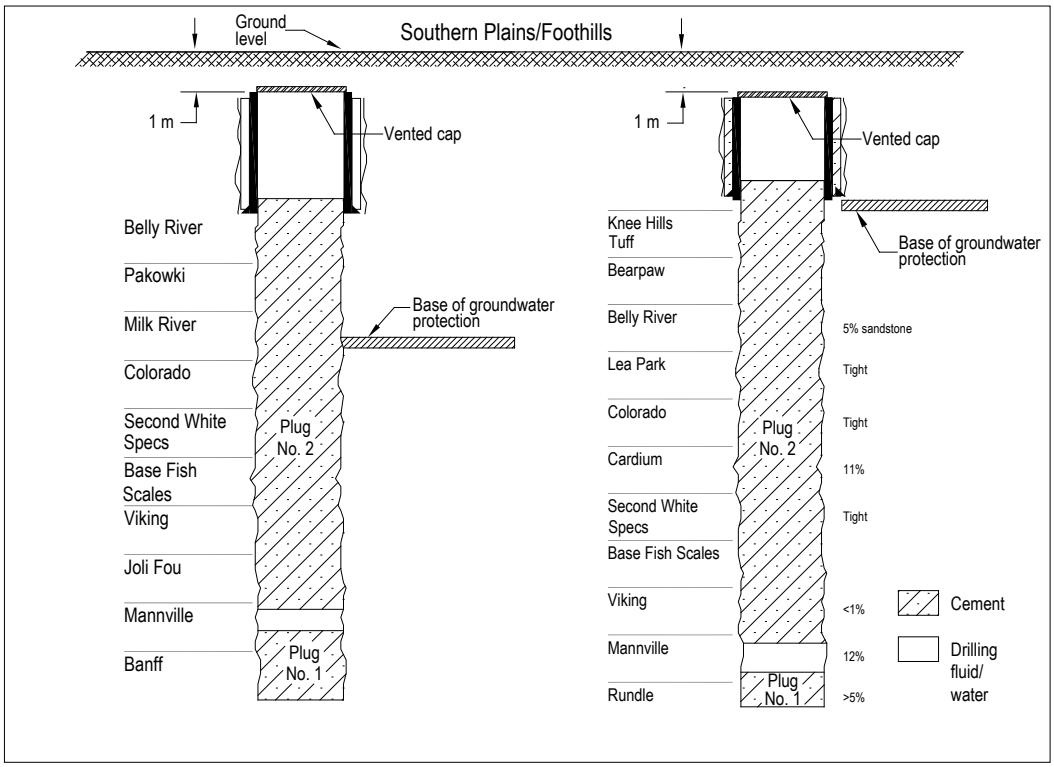

Figure 2. Plug placement examples for Southern Plains / Foothills

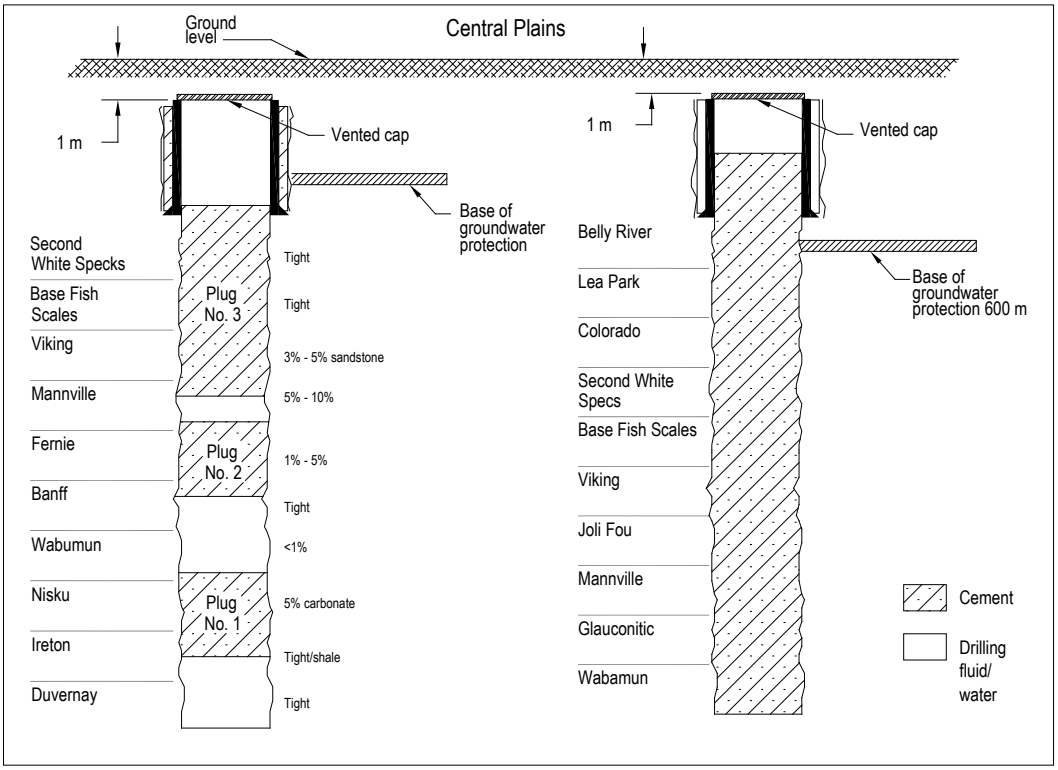

Figure 3. Plug placement examples for Central Plains

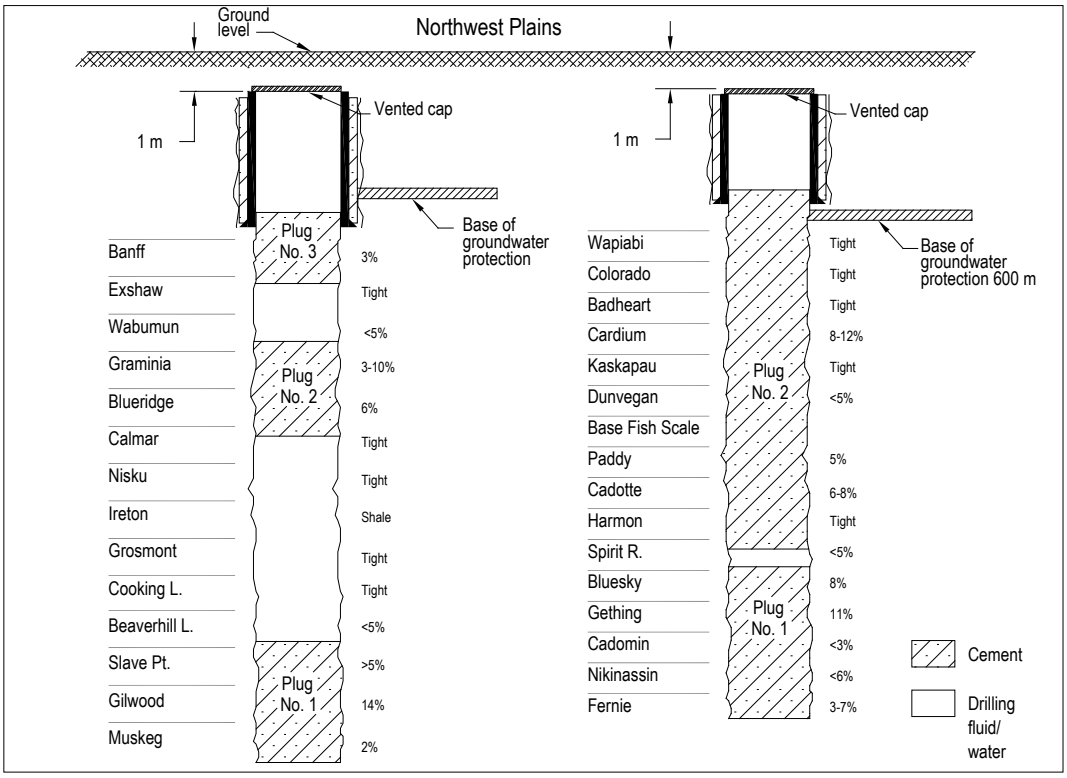

Figure 4. Plug placement examples for Northwest Plains

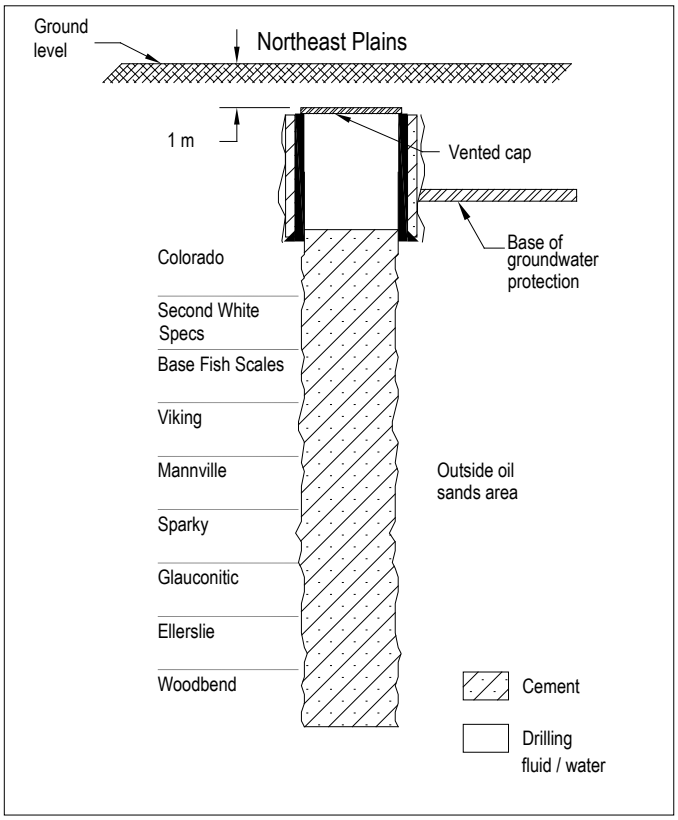

Figure 5. Plug placement example for Northeast Plains

4.2 Open-Hole Abandonment of Wells That Have Penetrated Oil Sands Zones

28) For wells that are in an oil sands area (see figure 1 and tables below) and have penetrated oil sands zones, **thermal cement** must be used for the entire length of the plug that is across the oil sands zones. Thermal cement is a blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at temperatures up to 360°C.

Cold Lake Oil Sands Area

Township	Ranges
053–054	01W4M to 09W4M
055–061	01W4M to 13W4M
062–066	01W4M to 11W4M
067–069	01W4M to 08W4M

Athabasca Oil Sands Area

Township	Ranges
062–066	12W4M to 15W4M
067–068	09W4M to 15W4M
069	09W4M to 16W4M
070	02W4M to 17W4M
071	02W4M to 24W4M
072	04W4M to 24W4M
073–074	04W4M to 26W4M
075	04W4M to 02W5M
076–085	04W4M to 04W5M
086–087	01W4M to 04W5M
088–092	01W4M to 07W5M
093–100	01W4M to 06W5M
101–103	04W4M to 06W5M

Peace River Oil Sands Area

Township	Ranges
78–82	11W5M to 25W5M
83–87	11W5M to 24W5M
88–92	08W4M to 24W5M
93–99	07W4M to 17W5M

4.3 Wells in the Cold Lake or Athabasca Oil Sands Areas

29) A thermal plug must be set from the well's total depth to a minimum of 15 vertical metres above the top of the Grand Rapids Formation.

30) All zones above the top of the Mannville Group (or equivalent) must be covered with a plug that is placed in one or more stages.

For intervals that do not penetrate an oil sands zone, using fillers or additives in the cement is acceptable if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

31) Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

32) The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

Figure 6 is an example plugging program.

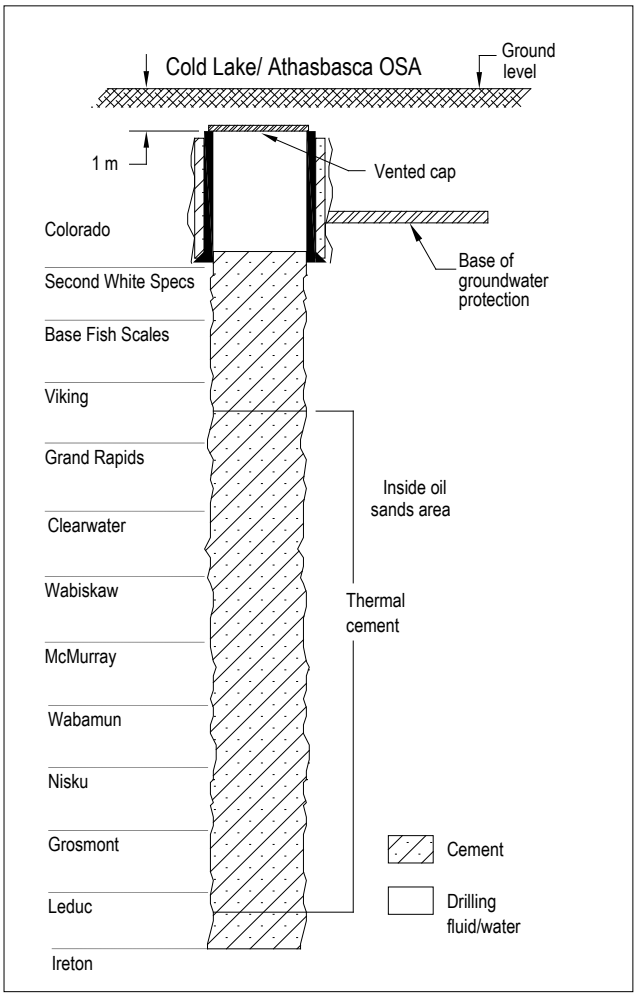

Figure 6. Plug placement example for the Cold Lake and Athabasca oil sands areas

4.4 Wells in the Peace River Oil Sands Area

33) All zones above the top of the Spirit River Group must be covered with a plug that is placed in one or more stages. This plug must extend a minimum of 15 vertical metres below the top of the Spirit River Group.

34) Licensees must use the logs from the well to determine the exact plug placement for coverage and/or isolation of porous zones below the top of the Spirit River Group.

For intervals that do not penetrate an oil sands zone, using fillers or additives in the cement is acceptable if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

35) A thermal plug must be set that extends from a minimum of 15 vertical metres below the base of any oil sands zone to a minimum of 15 vertical metres above the top of the oil sands zone.

36) All plugs run at a depth less than 1500 m TVD must be a minimum length of 30 vertical metres and extend from a minimum of 15 vertical metres below to a minimum of 15 vertical metres above the zone being covered.

37) All plugs run at a depth greater than 1500 m TVD must be a minimum length of 60 vertical metres and extend from a minimum of 30 vertical metres below to a minimum of 30 vertical metres above the zone being covered.

A plug may extend over more than one zone.

38) Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

There is no maximum distance between plugs as long as the pressure from the zone being isolated does not exceed the fracture pressure of the interval left open above it.

39) The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

Figure 7 is an example of a plugging program.

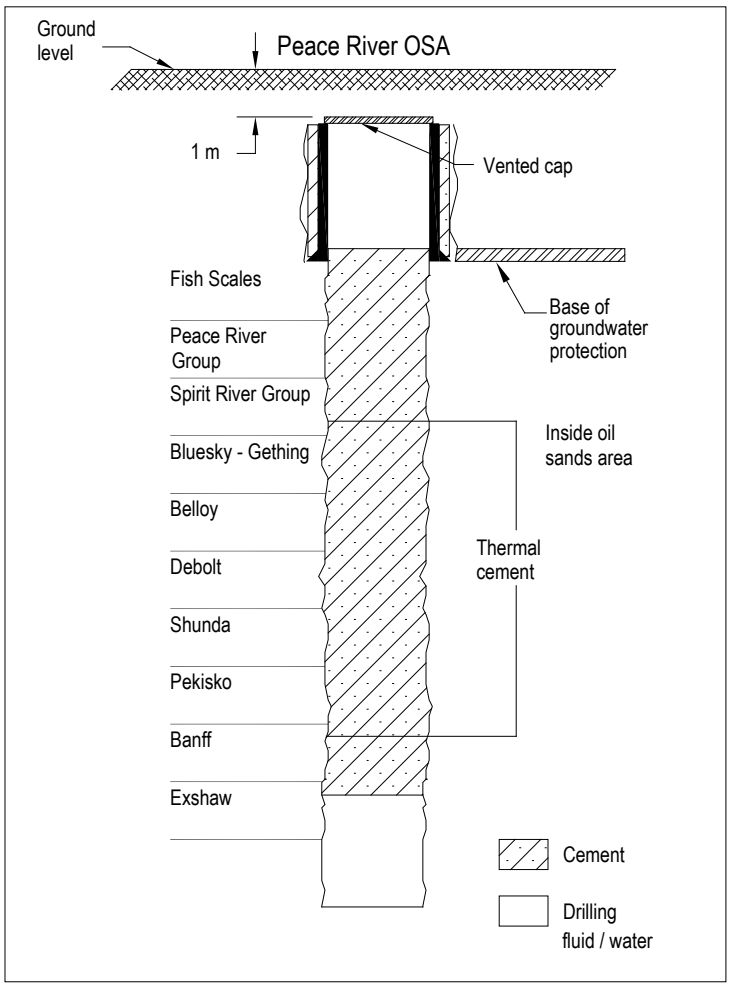

Figure 7. Plug placement example for the Peace River Oil Sands area

4.5 Confirming Plug Placement

40) The licensee must confirm the location of all plugs using one of the approved methods described in section 6.

The only time a plug location does not need to be confirmed is when

- one stage of a multistage plug is placed with no loss of circulation,
- continuous cement is run from total depth to surface in one or more stages with no loss of circulation, or
- the top plug is placed and run to surface.

Plugs that are too low, too high, or misplaced are unacceptable (see figure 8).

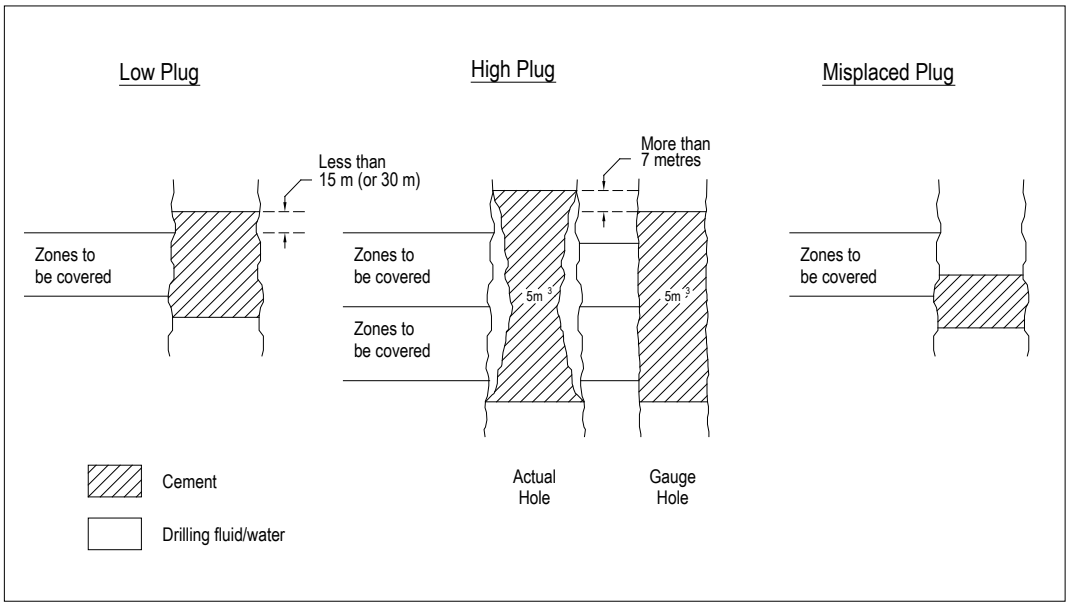

Figure 8. Examples of unacceptable plugs

Plug is too low:

- For zones at a depth less than 1500 m TVD, a low plug is any plug with a top less than 15 vertical metres above the zone it was intended to cover.
- For zones at a depth greater than 1500 m TVD, a low plug is any plug with a top less than 30 vertical metres above the zone it was intended to cover.

41) Low plugs must be built up and their locations confirmed.

Plug is too high: A plug that is more than 7 vertical metres above its theoretical top is considered "high." To calculate a plug's theoretical top, use the following formula:

Actual cement volume (m^3)/gauge hole volume (m^3/m) = x m

Drill pipe setting depth (m) – x m = theoretical top

42) High plugs must be circulated or drilled out. High plugs must be rerun and their locations confirmed.

Plug is misplaced: The plug was positioned in such a way that it did not cover the zones it was intended to cover.

43) Depending on its position, a misplaced plug may first need to be circulated or drilled out. Misplaced plugs must be rerun and their locations confirmed.

4.6 Oil Sands Evaluation Wells and Test-Hole Wells

Oil sands evaluation and test-hole wells (identified as "OV" and "TH" respectively on the licence's AER classification) have specific abandonment requirements. These wells are drilled for core samples only and are not intended to be completed.

44) Downhole abandonment operations on oil sands evaluation and test-hole wells in the surface mineable areas must be completed within 30 days after drilling has finished.

45) Downhole abandonment operations on oil sands evaluation and test-hole wells that are outside of the surface mineable areas must be completed prior to rig release.

46) Oil sands evaluation and test-hole wells that penetrate an oil sands zone and are within a designated oil sands area must be filled with thermal cement from the final total depth to the surface.

47) Test-hole wells drilled outside a designated oil sands area that do not penetrate an oil sands zone must be filled with cement with a final compressive strength of at least 3500 kPa after curing for 48 hours from the final total depth to the surface.

48) Any drop in cement due to pipe displacement must be replaced by an equivalent volume of nonsaline water. If the calculated and actual volumes required to fill the hole coincide, fluid level testing is not required.

49) Surface abandonment operations must be completed immediately after downhole operations.

50) Oil sands evaluation and test-hole well abandonments are considered routine and must be reported within 30 days of completing the surface abandonment.

5 Cased-Hole Abandonment Requirements

51) In a cased-hole abandonment, the licensee must do the following:

    a) Cover all nonsaline groundwater with cement.

    b) Abandon each completed pool separately unless the AER has identified the pool as one that may be abandoned with one or more other pools.

A list of subsurface geological strata and corresponding geographic locations for potential wells that may be abandoned in a commingled manner is available on the Directive 020 webpage. These wells may be abandoned routinely in accordance with the applicable requirements in this directive.

The abandonment program for a cased-hole well will depend on whether

- the well was completed,
- the well penetrated any oil sands zones, and
- the well has been completed in an interval classified as "level A."

For the purpose of this directive, level-A intervals are intervals that

- have been used for disposal of class Ia or Ib fluids,
- have been used for injection of acid gas,
- have been used only for injection in carbon dioxide enhanced oil recovery storage (**CO_2 EOR storage**) or only for **CO_2 sequestration** schemes as described in *Directive 065: Resources Applications for Oil and Gas Reservoirs*,
- have a hydrogen sulphide (H_2S) concentration in excess of 15%, or
- have been designated as critical sour.

This evaluation is done on a well (not a pool) basis.

52) Any high-risk offset wells within 100 m of a proposed CO_2 EOR storage or CO_2 sequestration injection well must be abandoned to the requirements prescribed for level-A abandonment prior to injection.

It is advisable to perform testing prior to beginning downhole abandonment operations to avoid having to re-enter the well to correct a wellbore problem. Refer to section 7.

5.1 Cement Evaluation

53) The licensee must review the existing cement behind the casing strings of a well before beginning abandonment operations.

5.1.1 Cement Top Determination

The cement top can be determined by available location log data, theoretical calculations, or a cement evaluation log. Confirmation of cement returns to surface in the drilling tour sheets during primary cementing is also acceptable for confirming cement coverage to surface.

54) A cement evaluation log must be run if

    a) theoretical calculations (using an excess of 20%) indicate that the cement top does not extend a minimum of 15 vertical metres above the uppermost porous intervals, or

    b) a surface casing vent flow or gas migration issue is present.

5.1.2 Identification of Porous Intervals

55) The licensee must identify porous zones to determine whether they are hydraulically isolated.

5.1.3 Remedial Cementing

56) For **protected intervals** that are not isolated from each other and for all porous zones that are not isolated from each other, the licensee must perforate or slot the casing to circulate cement to surface. If circulation of cement to surface is not possible, cement squeezes must be conducted, but intervals must be squeezed individually to ensure isolation.

Cement squeezing multiple intervals at the same time is considered nonroutine.

For remediation of surface casing vent flows or gas migration, or both, see *Directive 087*.

5.2 Use of Inhibitor

57) The casing must be filled with nonsaline water from the uppermost abandoned zone (below the BGWP) to surface.

58) Inhibitor must not be used inside the casing over intervals above the BGWP.

59) For intervals below the BGWP that are isolated from the BGWP by an approved zonal abandonment method, the casing must be filled with either noncorrosive fluid or nonsaline water.

5.3 Wells Not Penetrating Oil Sands Zones

Requirements for abandonment operations on cased-hole wells that do not penetrate oil sands zones are as follows. See section 5.4.8 regarding wells with low thermal potential that may qualify for abandonment following the requirements of section 5.3.

5.3.1 Noncompleted Wells

Noncompleted wells without liners do not require additional cement plugs to be run if the existing casing string is pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

60) Noncompleted wells must be filled with nonsaline water.

5.3.2 Wells With a Cemented Liner

61) The completed interval must be abandoned in accordance with the requirements set out in sections 5.3.5 and 5.3.6. Following abandonment of the completed intervals, the licensee must use one of the following options for abandoning a liner top in a well with a cemented liner.

Option 1 – Setting a Permanent Bridge Plug

62) For non-level-A intervals, the licensee must set a permanent bridge plug within 15 m above the liner top.

63) If the licensee is unable to set the bridge plug as required by requirement 62, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

   a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

   b) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

   c) The depth is below the BGWP.

64) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

65) The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Plug

66) A cement plug must be set across the liner top. This plug must extend from a minimum of 15 vertical metres below the liner top to a minimum of 15 vertical metres above the liner top.

67) The location of the plug must be confirmed by one of the approved methods described in section 6.

68) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

5.3.3 Wells With an Uncemented Liner

69) To abandon a well with an uncemented liner across more than one zone, the zones behind the liner must be evaluated for porosity, and cement squeezes must be conducted to ensure isolation between the porous zones.

70) Once the liner has been cemented, the requirements for abandonment of wells with a cemented liner in section 5.3.2 must be followed.

5.3.4 Wells With Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals

71) For non-level-A intervals, the licensee must use one of the following options for abandoning casing patches, casing failures (within one zone), and previously cement squeezed intervals (within one zone that have been drilled out).

a) For abandonment of previously cement squeezed intervals that have been drilled out and are over more than one zone, each zone must be isolated by one of the methods below.

b) For abandonment of casing failures that occur over more than one zone, a cement squeeze must be conducted as set out below in option 2.

72) Casing patches, casing failures, and previously cement squeezed intervals (that have been drilled out) that are over a level-A interval must be abandoned in accordance with section 5.3.5.1.

Option 1 – Setting a Permanent Bridge Plug

73) The licensee must set a permanent bridge plug within 15 m above the interval.

74) If the licensee is unable to set a bridge plug as required by requirement 73, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

b) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

c) The depth is below the BGWP.

75) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

76) The plug must be capped with either a minimum of 8 vertical metres of class “G” cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Plug / Squeezing Cement

77) A cement plug must be set that extends a minimum of 15 vertical metres below the bottom of the interval to a minimum 15 vertical metres above the top of the interval.

78) The location of the plug must be confirmed by one of the approved methods described in section 6.

79) The plug must be pressure tested to 7000 kPa for 10 minutes.

If the licensee elects to apply a squeeze pressure to the cement, the AER recommends following the criteria set out in option 2 of section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

5.3.5 Zonal Abandonment Within a Completed Well (Vertical/Deviated) or a Horizontal Well Completed in a Single Formation

5.3.5.1 Level-A Intervals

80) When abandoning level-A intervals within a completed well (vertical/deviated) or within a horizontal well completed with an open-hole interval that penetrates a single formation, the licensee must use one of the following options.

Option 1 – Setting a Cement Retainer

81) A cement retainer must be set in the following ways:

    a) In vertical/deviated wells, the retainer must be set within 15 m above the perforations or the single-zone open-hole section.

    b) In horizontal wells completed within a single formation, the retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

82) The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.

83) A cement squeeze must be conducted through the retainer in the following ways:

    a) In vertical/deviated wells, the minimum cement volume must equal the casing volume from the bottom of the retainer to the bottom perforation (or bottom of the open-hole section) plus 0.5 m^3.

    b) In horizontal wells completed within a single formation, the minimum cement volume must equal the casing volume from the bottom of the retainer to the measured total depth of the well plus 0.5 m^3.

84) The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.

85) The retainer must be capped with class “G” cement that is circulated in place and

    a) is a minimum of 30 vertical metres in length,

    b) has a minimum volume of 1 m^3, and

    c) additionally, in vertical/deviated wells *only*, the cement must extend a minimum of 30 vertical metres above the formation top.

86) In vertical/deviated wells *only*, if the retainer is drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

87) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.3.5.1.

Option 2 – Squeezing Cement

88) A cement squeeze must be conducted into the perforations or the single-zone open-hole section.

89) The plug must

    a) be circulated in place,

    b) have a minimum volume of 1 m^3, and

    c) in vertical/deviated wells, extend from a minimum of 15 vertical metres below the completion or total depth, whichever is shallower, to a minimum of 30 vertical metres above the formation top, or

    d) in horizontal wells completed within a single formation, extend from the formation top or from below the formation top to a minimum of 30 vertical metres above the formation top.

90) The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.

91) The location of the plug must be confirmed by one of the approved methods described in section 6.

92) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

93) For vertical/deviated wells *only*, if this plug is to be drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

94) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.3.5.1.

Option 3 – Setting a Permanent Bridge Plug

Abandonment of a level-A interval by this method requires approval from the AER.

95) The licensee must contact WellOperations@aer.ca for approval.

96) A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted in the nonroutine request. If zonal isolation is confirmed, approval may be granted to set a permanent bridge plug as follows:

    a) In a vertical/deviated well, within 15 m above the perforation or the single-zone open-hole section.

    b) In a horizontal well completed within a single formation, within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

97) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

98) The plug must be capped with class "G" cement that is circulated in place and

    a) is a minimum of 60 vertical metres in length,

    b) extends a minimum of 60 vertical metres above the formation top, and

    c) has a minimum volume of 1 m^3.

99) If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.3.5.2 Non-Level-A Intervals

100) The licensee must use one of the following options for abandoning non-level-A intervals within a completed well (vertical/deviated) or within a completed horizontal well with an open-hole interval that penetrates a single formation.

Option 1 – Setting a Permanent Bridge Plug

101) The licensee must do the following:

    a) In a vertical/deviated well, set a permanent bridge plug within 15 m above the perforation or the single-zone open-hole section.

    b) In a horizontal well completed within a single formation, set a permanent bridge plug within 15 vertical metres above top of the formation in which the horizontal zone is completed.

c) If the licensee is unable to set a bridge plug as required by (a) or (b) above, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

i) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

ii) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

iii) The depth is below the BGWP.

102) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

103) The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

104) If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Retainer

105) A cement retainer must be set in the following ways:

a) In a vertical/deviated well, a cement retainer must be set within 15 m above the perforations or the single-zone open-hole section.

b) In a horizontal well completed within a single formation, a cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

106) The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. A cement squeeze must be conducted through the retainer. The AER recommends following the criteria set out in option 1 of section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

107) The retainer must be capped with a minimum of 8 vertical metres of class "G" cement.

108) In vertical/deviated wells *only*, if the retainer is drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

109) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.3.4.

Option 3 – Setting a Plug in a Permanent Packer

This option is only available to vertical/deviated wells.

110) The licensee must set a permanent plug in a permanent packer within 15 m above the perforation or the single-zone open-hole section.

111) If the licensee is unable to set a permanent plug as required by requirement 110, then a permanent plug must be set in a permanent packer at a depth where all of the following conditions are met:

    a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

    b) The cement top behind the casing extends above the top of the formation in which the permanent plug and packer will be set.

    c) The depth is below the BGWP.

112) The plug and packer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

113) The plug and packer must be capped with either a minimum of 8 vertical metres of class “G” cement or a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

114) If more than one year has elapsed from the setting and pressure testing of the plug and packer prior to capping with cement, the plug and packer must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

Option 4 – Setting a Cement Plug / Squeezing Cement

115) The licensee must do the following:

    a) In vertical/deviated wells, a cement plug must be set across the perforations or the single-zone open-hole section. The plug must extend from a minimum of 15 vertical metres below the completed interval or the plug-back total depth, whichever is shallower, to a

minimum of 15 vertical metres above the top of the completed interval. It is acceptable to run a continuous cement plug across multiple completed zones.

b) In horizontal wells completed within a single formation, a cement squeeze must be conducted into the open-hole interval. The plug must extend from the formation top or from below the formation top to a minimum of 15 vertical metres above the formation top.

116) The location of the plug must be confirmed by one of the approved methods described in section 6.

117) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

If the licensee elects to apply a squeeze pressure to the cement, the AER recommends following the criteria set out in option 2 of section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

118) In vertical/deviated wells *only*, if the cement plug is to be drilled out, a cement squeeze must be conducted. Following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

119) At the time of well abandonment, the squeezed interval must be abandoned in accordance with section 5.3.4.

5.3.6 Completed Horizontal Wells Across Multiple Formations

120) For a horizontal open-hole interval that penetrates multiple formations, each porous formation must have a cement plug set in the open-hole section to either cover or isolate it from different porous formations.

a) A minimum 30-vertical-metre cement plug is required, extending from a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the porous formation.

121) The location of the plug must be confirmed by one of the approved methods described in section 6.

122) If *any* of the horizontal intervals is a level-A interval, the uppermost interval must be abandoned in accordance with section 5.3.5.1.

5.4 Wells Penetrating Oil Sands Zones

Requirements for abandonment operations on cased-hole wells within an oil sands area (see figure 1, shown previously) and that penetrate oil sands zones are as follows.

Licensees with wells that penetrate an oil sands zone and that meet the conditions for wells with low thermal potential set out in section 5.4.8 may choose to abandon the well using the requirements of section 5.3 or 5.4.

5.4.1 Thermal Cement

123) Thermal cement must be used when abandoning wellbores that penetrate oil sands zones. Thermal cement is a blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at temperatures up to 360°C.

5.4.2 Noncompleted Wells

124) The casing string must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

125) All noncompleted oil sands zones must have a thermal cement plug run across the oil sands formation.

   a) The plug must extend from a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the top of the formation. Plugs may be combined to form a single plug covering two or more uncompleted oil sands zones.

   b) The wellbore between plugs must be filled with nonsaline water.

126) The location of suspended cement plugs must be confirmed by one of the approved methods described in section 6. The location of cement plugs that are circulated in place from a bridge plug top or plug-back total depth do not need to be confirmed.

Noncompleted wells with liners must have the liner abandoned in accordance with sections 5.4.4 or 5.4.5.

5.4.3 Wells With a Cemented Liner

127) The completed interval must be abandoned in accordance with the requirements set out below for completed, open-hole, or horizontal intervals (see sections 5.4.5, 5.4.6, or 5.4.7). Following abandonment of the completed intervals, the licensee must use one of the following options for abandoning a liner top in a well with a cemented liner.

Option 1 – Setting a Permanent Bridge Plug

128) The licensee must set a permanent bridge plug within 15 m above the liner top.

129) If the licensee is unable to set the permanent bridge plug as required by requirement 128, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

   a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

   b) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

   c) The depth is below the BGWP.

130) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

131) The plug must be capped with a minimum of 8 vertical metres of thermal cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Plug

132) A thermal cement plug must be set across the liner top.

133) This plug must extend from a minimum of 15 vertical metres below the liner top to a minimum of 15 vertical metres above the liner top.

134) The location of the plug must be confirmed by one of the approved methods described in section 6.

135) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

5.4.4 Wells With an Uncemented Liner

136) To abandon a well with an uncemented liner across more than one zone, the zones behind the liner must be evaluated for porosity, and thermal cement squeezes must be conducted to ensure isolation between the porous zones.

137) Once the liner has been cemented, the requirements set out for abandonment of wells with a cemented liner (section 5.4.3) must be followed.

5.4.5 Wells with Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals

138) For non-level-A intervals, the licensee must use one of the following options for abandoning casing patches, casing failures within one zone, and previously cement squeezed intervals within one zone that have been drilled out:

a) For abandonment of previously cement squeezed intervals that have been drilled out and are over more than one zone, each zone must be isolated by one of the methods below.

b) For abandonment of casing failures that occur over more than one zone, a cement squeeze must be conducted as set out below in option 2.

139) Casing patches, casing failures, and previously cement squeezed intervals (that have been drilled out) that are over a level-A interval must be abandoned in accordance with section 5.4.6.1.

Option 1 – Setting a Permanent Bridge Plug

140) The licensee must set a permanent bridge plug within 15 m above the interval.

141) If the licensee is unable to set a permanent bridge plug as required by requirement 140, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

b) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

c) The depth is below the BGWP.

142) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

143) The plug must be capped with a minimum of 8 vertical metres of thermal cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Plug / Squeezing Cement

144) A thermal cement plug must be set that extends a minimum of 15 vertical metres below the bottom of the interval to a minimum 15 vertical metres above the top of the interval.

145) The location of the plug must be confirmed by one of the approved methods described in section 6.

146) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the AER recommends following the criteria set out in option 2 of section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

5.4.6 Zonal Abandonment Within a Completed Well (Vertical/Deviated) or a Completed Horizontal Well in a Single Formation

147) The licensee must review the well logs to determine which oil sands zones have been penetrated by the well.

148) Oil sands zones that have been penetrated but not completed must have a thermal cement plug run in accordance with section 5.4.2.

149) Each completed oil sands zone must be abandoned using one of the following options, depending on the interval type (level-A or not).

5.4.6.1 Level-A Intervals

150) The licensee must use one of the following options for abandoning level-A intervals within a completed vertical/deviated well or within a completed horizontal well with an open-hole interval that penetrates a single formation.

Option 1 – Setting a Cement Retainer

151) A cement retainer must be set in the following ways:

a) In vertical/deviated wells, a cement retainer must be set within 15 metres above the perforations or the single-zone open-hole section.

b) In horizontal wells completed within a single formation, a cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

152) The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.

153) A thermal cement squeeze must be conducted through the retainer in the following ways:

a) In vertical/deviated wells, the minimum cement volume must equal the casing volume from the bottom of the retainer to the bottom perforation (or bottom of the open-hole section) plus 0.5 m^3.

b) In horizontal wells completed within a single formation, the minimum cement volume must equal the casing volume from the bottom of the retainer to the measured total depth plus 0.5 m^3.

154) The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.

155) The retainer must be capped with thermal cement that is circulated in place and

a) is a minimum of 30 vertical metres in length,

b) has a minimum volume of 1 m^3, and

c) additionally, for vertical/deviated wells *only*, the cement must extend a minimum of 30 vertical metres above the formation top.

156) In vertical/deviated wells *only*, if the retainer is drilled out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

157) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.4.6.1.

Option 2 – Squeezing Cement

158) A thermal cement squeeze must be conducted into the perforations or the single-zone open-hole section.

159) The plug must

a) be circulated in place,

b) have a minimum volume of 1 m^3, and

c) in vertical/deviated wells, extend from a minimum of 15 vertical metres below the completion or total depth, whichever is shallower, to a minimum of 30 vertical metres above the formation top, or

d) in horizontal wells completed within a single formation, extend from the formation top or from below the formation top to a minimum of 30 vertical metres above the formation top.

160) The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.

161) The location of the plug must be confirmed by one of the approved methods described in section 6.

162) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

163) In vertical/deviated wells *only*, if this plug is to be drilled out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

164) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.4.6.1.

Option 3 – Setting a Permanent Bridge Plug

Abandonment of a level-A interval by this method requires approval from the AER.

165) The licensee must contact WellOperations@aer.ca for approval.

166) A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted with the nonroutine request. If zonal isolation is confirmed, approval may be granted to set a permanent bridge plug as follows:

   a) In a vertical/deviated well, within 15 metres above the perforation or the single-zone open-hole section.

   b) In a horizontal well completed within a single formation, within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

167) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

168) The plug must be capped with thermal cement that is circulated in place and

   a) is a minimum of 60 vertical metres in length,

   b) extends a minimum of 60 vertical metres above the formation top, and

   c) has a minimum volume of 1 m^3.

169) If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.4.6.2 Non-Level-A Intervals

170) The licensee must use one of the following options for abandoning non-level-A intervals within a completed vertical/deviated well or within a completed horizontal well with an open-hole interval that penetrates a single formation.

Option 1 – Setting a Permanent Bridge Plug

171) The licensee must do the following:

a) In vertical/deviated wells, set a permanent bridge plug within 15 m above the perforations or the single-zone open-hole section.

b) In horizontal wells completed within a single formation, set a permanent bridge plug within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

172) If the licensee is unable to set a permanent bridge plug as required by requirement 171, then a permanent bridge plug must be set at a depth where all of the following conditions are met:

i) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

ii) The cement top behind the casing extends above the top of the formation in which the bridge plug will be set.

iii) The depth is below the BGWP.

173) Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

174) The plug must be capped with a minimum of 8 vertical metres of thermal cement. The cement top must extend a minimum of 15 vertical metres above the formation top.

175) If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2 – Setting a Cement Retainer

176) A cement retainer must be set in the following ways:

a) In vertical/deviated wells, a cement retainer must be set within 15 metres above the perforations or the single-zone open-hole section.

b) In horizontal wells completed within a single formation, a cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

177) The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

178) A thermal cement squeeze must be conducted through the retainer.

179) The retainer must be capped with a minimum of 8 vertical metres of thermal cement.

   a) The cement top must extend a minimum of 15 vertical metres above the formation top. The AER recommends following the criteria set out in option 1 of section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

180) In vertical/deviated wells *only*, if this plug is to be drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

181) At the time of well abandonment, the squeezed intervals must be abandoned in accordance with section 5.4.5.

Option 3 – Setting a Plug in a Permanent Packer

This option is only available to vertical/deviated wells.

182) The licensee must set a permanent plug in a permanent packer within 15 metres above the perforations or the single-zone open-hole section.

183) If the licensee is unable to set a permanent plug as required by requirement 182, then a permanent plug must be set in a permanent packer at a depth where all of the following conditions are met:

   a) The depth is within the same formation as the completed interval or the next formation, provided no other effective porous zones are between the bridge plug setting depth and the completed interval.

   b) The cement top behind the casing extends above the top of the formation in which the permanent plug and packer will be set.

   c) The depth is below the BGWP.

184) The plug and packer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

185) The plug must be capped with a minimum of 8 vertical metres of thermal cement.

186) The cement top must extend a minimum of 15 vertical metres above the formation top.

187) If more than one year has elapsed from the setting and pressure testing of the plug and packer prior to capping with cement, the plug and packer must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

Option 4 – Setting a Cement Plug / Squeezing Cement

188) This option depends on whether the well is a vertical/deviated well or horizontal well completed within a single formation. The licensee must use the appropriate method:

a) In vertical/deviated wells, a thermal cement plug must be set across the perforations or the single-zone open-hole section. The plug must extend from a minimum of 15 vertical metres below the completed interval or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the top of the formation. It is acceptable to run a continuous thermal cement plug across multiple zones.

b) In horizontal wells completed within a single formation, a thermal cement squeeze must be conducted into the open-hole interval. The plug must extend from the formation top or from below the formation top to a minimum of 15 vertical metres above the formation top.

189) The location of the plug must be confirmed by one of the approved methods described in section 6.

190) The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

If the licensee elects to apply a squeeze pressure to the cement, the AER recommends following the criteria set out in option 2 of section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

191) In vertical/deviated wells *only*, if the cement plug is to be drilled out, a cement squeeze must be conducted.

a) Following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85% of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

192) At the time of well abandonment, the squeezed interval must be abandoned in accordance with section 5.4.6.1.

5.4.7 Completed Horizontal Wells Across Multiple Formations

193) For a horizontal open-hole interval that penetrates multiple formations, each porous formation must have a thermal cement plug set in the open-hole section to either cover or isolate it from different porous formations.

a) A minimum 30-vertical-metre thermal cement plug is required, extending from a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the porous formation.

b) The location of the plug must be confirmed by one of the approved methods described in section 6.

194) If *any* of the horizontal intervals is a level-A interval, the uppermost interval must be abandoned in accordance with section 5.4.6.1.

5.4.8 Wells Penetrating Oil Sands Zones with Low Thermal Potential

Wells penetrating an oil sands zone do not require thermal abandonment if one of the following conditions is satisfied:

- Condition 1: The well is in the Cold Lake area of low thermal development potential (see figure 9).
- Condition 2: A **qualified geoscientist** confirms low thermal development potential in accordance with the requirements in section 5.4.8.2 for a geological review.
- Condition 3: The AER approves a variance for nonthermal well abandonment within an oil sands area in accordance with the requirements in section 5.4.8.3.

Licensees with wells penetrating an oil sands zone meeting at least one of the conditions of a well with low thermal potential may follow either section 5.3 or 5.4 abandonment requirements.

195) The licensee must determine whether the well penetrating the oil sands zone meets any of the low thermal potential conditions before abandoning the well in accordance with the requirements in section 5.3 (i.e., nonthermal abandonment).

196) If the AER determines that the abandoned well did not meet any of the conditions for low thermal potential, the licensee must remediate the abandoned well to a thermal compatible state.

5.4.8.1 Low Thermal Potential Areas Within the Cold Lake Oil Sands Area (Condition 1)

The AER has identified areas within the Cold Lake oil sands area with low potential for thermal development (see figure 9). If the subject well is within the boundary for low thermal potential, the licensee may abandon the well using the requirements in section 5.3.

5.4.8.2 Conducting a Geological Review to Determine Low Thermal Potential (Condition 2)

Licensees may abandon wells using the requirements in section 5.3 (wells not penetrating oil sands) if a geological review determines that the subject well penetrating the oil sands zone has low thermal potential.

197) The licensee must use a qualified person authorized to practise geoscience, as defined by the *Engineering and Geoscience Professions Act*, to conduct the geological review.

198) The geological review must confirm that the subject well satisfies the following criteria for low thermal potential:

a) The well is outside a 1000 m radius from the edge of any project boundary for existing thermal operations and schemes.

b) The net pay thickness of any oil sands formations or members (see figure 10; refer to the Alberta Geological Survey table of formations for more details) in the subject well or any well within 1000 m is less than 7 m, and the oil (bitumen) saturation is less than 50% or equivalent to 6% weight per cent bitumen.

If the net pay thickness exceeds 7 m, the licensee can use completions and production history for any wells within 1000 m to show that the oil sands zones will be depleted by a method that does not involve thermal operations.

199) Licensees must maintain accurate records of any geological review conducted for the purpose of demonstrating that the subject well satisfies the AER's criteria for low thermal potential. Geological review records must be made available to the regulator on request.

5.4.8.3 Variance for Nonthermal Well Abandonment (Condition 3)

A licensee may request a variance to use nonthermal well abandonment for a well that penetrates and oil sands zone.

200) The licensee must submit a nonthermal abandonment request using the designated information submission system. The Variance for Nonthermal Well Abandonment Within Oil Sands Area form is available on the directive forms webpage.

201) In addition, the licensee must send an email to WellOperations@aer.ca that includes the nonroutine abandonment request, all supporting documentation, and the wellbore schematic.

The AER will review the request and may ask the licensee to provide additional information regarding the nonthermal abandonment operation.

The licensee will be notified once the request has been approved or denied.

202) The licensee may not begin abandonment operations until the AER approves the nonroutine abandonment request and must conduct its operations in accordance with the terms and conditions of the approval.

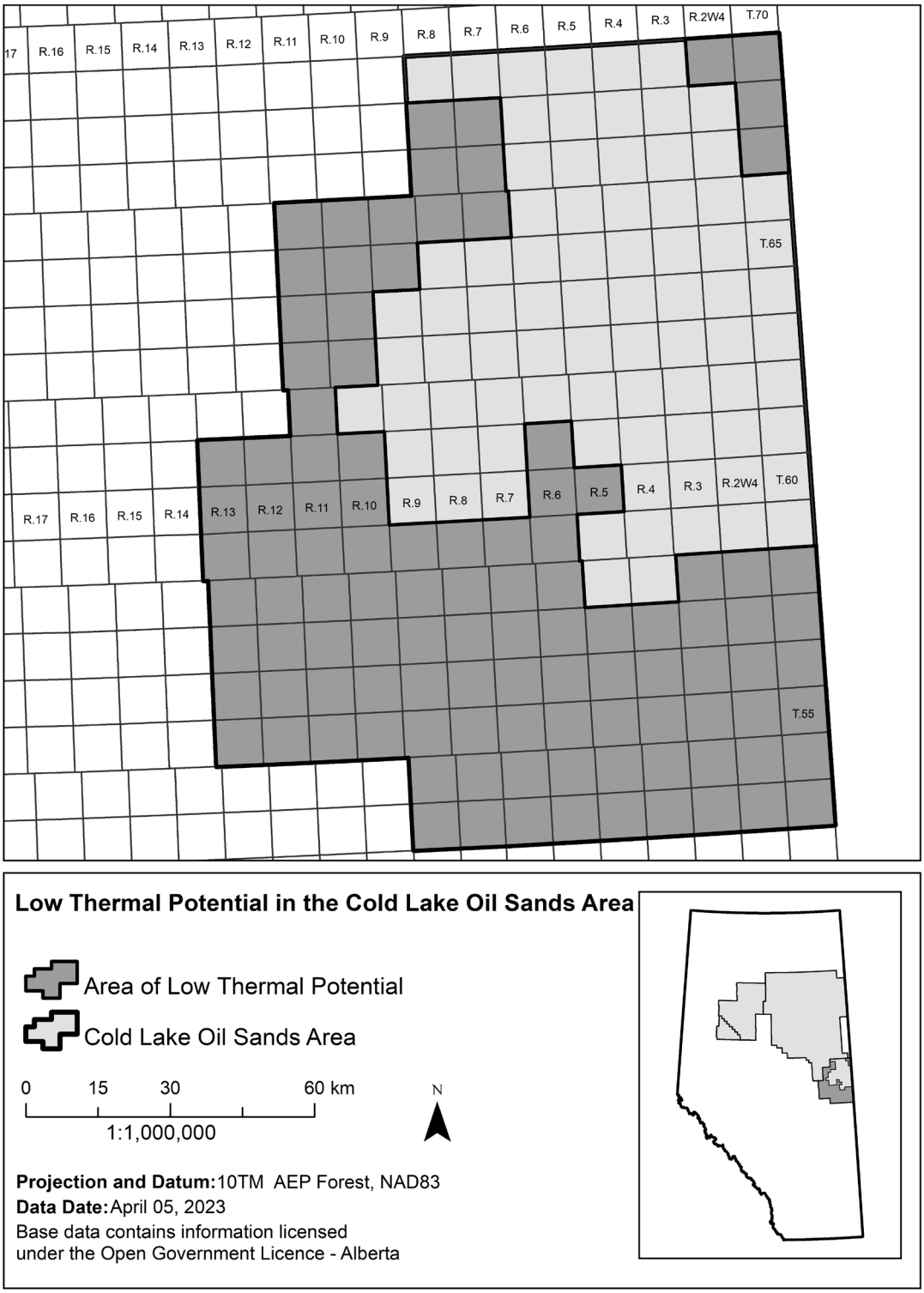

Figure 9. Map of low thermal potential areas within the Cold Lake oil sands area

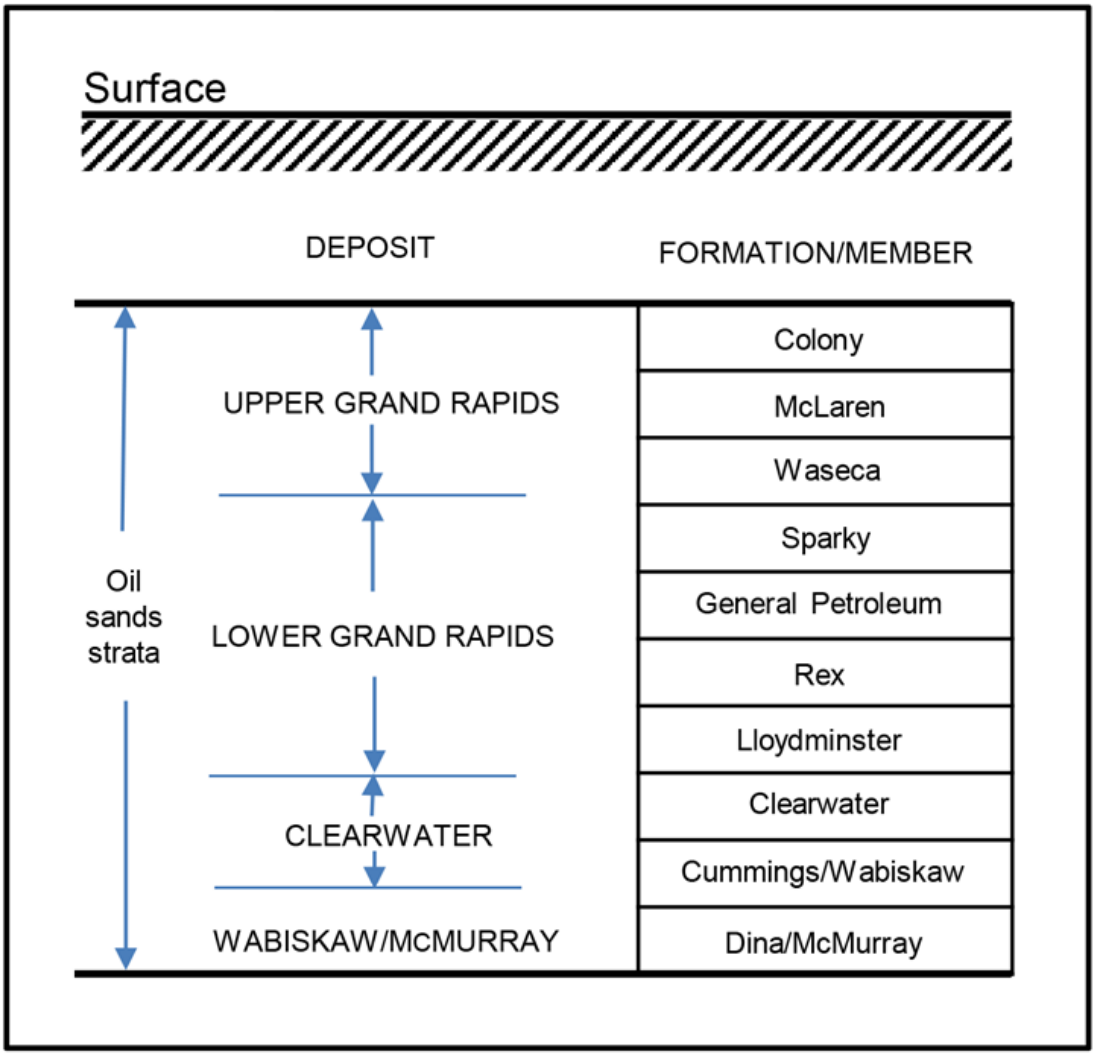

Figure 10. Stratigraphy of the Cold Lake area for geological review

5.5 Groundwater Protection

203) All nonsaline groundwater must be covered by cement. Groundwater protection must include the identification and isolation of the BGWP from hydrocarbon formations below, as well as the identification and isolation of all protected intervals that are above the BGWP.

To determine the BGWP depth for a well, refer to the Base of Groundwater Protection Query Tool available on the AER website under Systems and Tools. The elevations provided in the tool are subsea and will need to be converted to kelly bushing.

A protected interval is an interval above the BGWP and is defined as a lithology with greater than 3% porosity or a coal seam.

Protected intervals may be grouped (i.e., not isolated) if

- lithologies with greater than 3% porosity are not separated from each other by more than 10 m, and
- coal seams are not separated by more than 30 m of non-coal-bearing-strata or a sandstone (of any vertical extent) with greater than 3% porosity.

5.5.1 Remedial Cementing of Protected Intervals

204) The licensee must use one of the following options to cover or isolate all protected intervals.

Option 1 – Removing Casing and Setting a Cement Plug

205) Prior to pulling the casing, all downhole abandonment operations must be completed in accordance with this directive (or any nonroutine approval that may be in place).

If the casing is free below the BGWP, the licensee may cut and pull the casing. Casing removal schemes that meet the following requirements are routine. Any casing string other than the surface casing may be removed.

206) The cut point must be identified at or below the BGWP.

207) A permanent bridge plug must be set a minimum of 15 m below the intended cut point.

208) The bridge plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

209) The casing must be cut at the cut point identified.

210) Once the casing is cut and pulled, a cement plug must be set from the bridge plug to a minimum of 15 m above the surface casing shoe.

211) The cement plug must be located and pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

212) If the casing is unsuccessfully recovered, the licensee must notify WellOperations@aer.ca.

Option 2 – Perforating, Milling, or Slotting Casing

213) The licensee must perforate, mill, or slot the casing at the BGWP and attempt to establish circulation to the surface with nonsaline water. A maximum of 1 m^3 of acid may be used to establish circulation.

5.5.1.1 Circulation to Surface Is Successful

214) If circulation to surface is successful, the licensee must pump cement to surface by either setting a cement retainer above the perforations or the milled or slotted casing or by circulating cement to surface and leaving a cement plug across the perforations or the milled or slotted casing.

a) If a retainer is used, the cement retainer must be set within 15 m above the perforations or the milled or slotted casing.

i) The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

ii) Following pumping of cement, the retainer must be capped with a minimum of 8 vertical metres of class “G” cement.

b) If a retainer is not used, a bridge or wiper plug must be set as close as possible below the perforations or the milled or slotted casing.

i) The cement top inside the casing must be a minimum of 15 vertical metres above the perforations or the milled or slotted casing.

ii) The location of the plug must be confirmed by one of the approved methods described in section 6.

iii) The plug must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes.

5.5.1.2 Circulation to Surface Is Unsuccessful

215) If circulation to surface is unsuccessful, the licensee must attempt to establish a feed rate.

a) If a feed rate is established, cement squeezes must be conducted, without exceeding the formation fracture pressure, into the perforations or the milled or slotted casing for each interval to ensure isolation. Cement squeezing multiple intervals at the same time is considered as nonroutine.

i) If a retainer is used for the cement squeezes, the licensee must do the following:

- The cement retainer must be set within 15 m above the perforations or the milled or slotted casing.
- The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.
- The retainer must be capped with a minimum of 8 vertical metres of class “G” cement.

ii) If a retainer is not used for the cement squeezes, the licensee must do the following:

- A cement plug must extend from a minimum of 15 vertical metres below the perforations or the milled or slotted casing to a minimum of 15 vertical metres above the perforations or the milled or slotted casing.
- The location of the plug must be confirmed by one of the approved methods described in section 6.
- The plug must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes.

b) If the attempts to establish a feed rate are unsuccessful, after reasonable efforts have been made without exceeding the fracture pressure, the perforations must be abandoned in accordance with one of the options set out in section 5.3.5.2. Examples of "reasonable efforts" when dealing with low fluid injectivity rate include acidizing, swabbing, and surging or any operation to improve fluid injectivity to promote cement placement.

The licensee must then evaluate the wellbore to ensure that all protected intervals above the BGWP are isolated from each other.

5.5.2 Requesting a Groundwater Protection Waiver

216) The AER requires that all protected intervals be covered by cement.

In specific situations, the AER may consider industry requests to waive the requirement to cover protected intervals. Abandonment operations for which a groundwater waiver is requested are nonroutine.

A written assessment containing the required information must be completed by the licensee and submitted to the AER at WellOperations@aer.ca (see section 2.1).

217) The written assessment must include

a) the surface casing/conductor pipe depth,

b) the production casing cement tops and method of identification,

c) the BGWP, and

d) confirmation by a qualified log analyst of the absence of protected intervals between the cement top and the surface casing/conductor pipe setting depth.

218) A request for a groundwater protection waiver must be approved by the AER prior to beginning any work.

6 Confirming Location of Cement Plugs

6.1 Methods for Confirming Plug Locations

There are four AER-approved methods for confirming the location of plugs. Method 1 is the preferred method. If methods 2, 3, or 4 are used, care must be taken to ensure that the cement plug is not "strung out."

Method 1 – Confirmation of Plug Location with Drill Pipe

This method uses a strap tally—measuring and counting joints of drill pipe—and subsequent tally adjustments to determine the drill pipe setting depth for each plug and the location of the plug top.

219) The location of the plug top must not be confirmed until after 8 hours from the time the plug was run or after surface samples have set.

220) The minimum force with which plugs must be located is 1800 decanewtons or string weight, whichever is less.

The use of slick line or wireline is *not* an approved method of locating the plug top.

221) The licensee must include the following details in the tour report:

a) cement type, mass (tonnes), and slurry volume (in cubic metres) for each plug

b) drill pipe, tubing, or coil tubing setting depth (strap tally and tally adjustments must be shown on the tour reports to support the reported pipe/tubing setting depth)

c) force (in decanewtons) with which the plug top was felt

d) plug top depth (strap tally and tally adjustments must be included to support the reported plug top location)

e) date and time that the location of each plug was confirmed

Method 2 – Direct Density Plug Logging

This method uses a radioactive source and a detector run on wireline.

222) Tool calibration must be performed at least once per job. The resulting log must show fluid density, fluid gradient, or cement percentage.

223) The difference between the cement density and the density of the drilling fluid must be at least 300 kilograms per cubic metre (kg/m^3) (or 2.9 kPa/m).

224) A minimum of 25 m of plug must be logged to accurately determine the plug top. The position of the plug top is interpreted as a suitable intermediate point between drilling fluid and cement slurry density, commonly 1600 kg/m^3 (or 15.7 kPa/m).

225) A plug log must be produced for this method and submitted to the AER in accordance with *Directive 080*. A calibration time and results must be included on the log.

Method 3 – Hydrostatic Pressure Plug Logging

This method uses a pressure transducer run on wireline. As the tool travels, the difference between pressure readings produces a fluid gradient, which may then be converted to fluid density.

226) The tool must be run continuously and must be calibrated in accordance with section 11.110 of the *Oil and Gas Conservation Rules* or section 84 of the *Geothermal Resource Development Rules*, whichever is applicable. The resulting log must show fluid density, fluid gradient, or cement percentage.

227) The difference between the cement density and the density of the drilling fluid must be at least 300 kg/m^3 (or 2.9 kPa/m).

228) A minimum of 25 m of plug must be logged to accurately determine the plug top. The position of the plug top is interpreted as a suitable intermediate point between drilling fluid and cement slurry density, commonly 1600 kg/m^3 (or 15.7 kPa/m).

229) A plug log must be produced for this method and submitted to the AER in accordance with *Directive 080*. The serial number, range, and date of last calibration of the gauges must be shown on the plug log.

Method 4 – Radioactive Tracer Logging

This method uses a radioactive tracer introduced into the lead slurry. The location of the plug top is confirmed by detection of the tracer with a gamma-ray-logging tool. Since the radioactive logging method is locating the radioactive tracer, adequate precautions should be taken to properly mix the tracer with the cement to prevent channelling of the cement during pumping and displacement. The AER recommends that spacer fluid be used before the cement to prevent channelling.

230) The resulting log must show the location of the tracer, which is then interpreted as the plug top.

231) A plug log must be produced for this method and submitted to the AER in accordance with *Directive 080*.

6.2 Plug Log Submission Requirements

232) Plug logs generated for methods 2, 3, and 4 must be submitted within 30 days of completing downhole abandonment operations.

233) The licensee must ensure that all of the following reporting requirements for open-hole abandonments are met. Although some of the information required is obtained from third parties on the well site (e.g., the slurry volume), the licensee must ensure that the information is accurate.

234) The requirements for plug logs are as follows:

a) A gamma ray or other type of suitable log that can be correlated to the open-hole log suite must be run for depth-control purposes.

b) The base gamma-ray log must be traced onto the plug log and depth corrections made as necessary, or the licensee must include remarks on the plug log for all gamma-ray deflections that were visually correlated, as well as any depth corrections made.

235) A collar locator must be run in conjunction with tally adjustments to determine the drill pipe setting depth for each plug. In the absence of a collar locator, strap tally and tally adjustments must be used.

236) The drill pipe must be pulled above the top of the plug prior to confirming its location with a logging tool.

237) If the plug logging method fails to clearly indicate the plug top, the licensee must confirm the location of the plug top with drill pipe according to method 1.

238) The licensee must submit the following information with the plug log:

a) mud density and bit size

b) interval to be cemented

c) drill pipe setting depth (strap tally and adjustments used in conjunction with the collar locator must be included to support the drill pipe setting depth)

d) mass in tonnes and volume in cubic metres of cement that was run during placement of the plug (this includes the calculated volume plus any excess run)

e) type/class of cement used, including any additives and the average slurry density

f) volume of displacement fluid used

g) plug placement time and logging time

h) interval logged

i) depth at which the cement top was logged

j) quality of cement samples (this is a visual analysis usually conducted by the cementing company and consists of time required for samples to set at surface)

k) a trace of the base correlation log shown on the plug log or remarks for all gamma-ray deflections that were visually correlated and any depth corrections made

7 Testing and Inspection Requirements

239) Before beginning any surface abandonment operation, the licensee must perform certain required tests on the well, as detailed below.

It is advisable to perform the gas migration (GM) and surface casing vent flow (SCVF) tests prior to beginning downhole abandonment operations to avoid having to re-enter the well to correct a wellbore problem. If testing indicates GM, SCVF, or leaking plugs, the source of the leak must be identified and repaired prior to surface abandonment.

7.1 Gas Migration Testing for Open- and Cased-Hole Wells

7.1.1 Gas Migration Test Area

240) GM testing must be conducted on

a) **cased-hole well abandonments** where the well does not have a surface casing vent assembly, and

b) all wells in the required GM test areas (Townships 45–52, Ranges 1–9, W4M and Townships 53–62, Ranges 4–17, W4M; see figure 11).

To reduce the chance of re-entering a well for repair, the AER recommends that all wells be tested for GM prior to abandonment. See appendix 3 of *Directive 087* for suggested procedures of GM testing.

7.1.2 Notification of Gas Migration

241) If a GM problem is detected, the licensee must notify the AER through the designated information submission system within 30 days of detection. See *Directive 087* for definitions of serious and nonserious GM.

242) If GM is discovered *after* surface abandonment has been completed on a well, the licensee must notify the AER through the designated information submission system within 30 days of detection.

243) The licensee is required to repair the GM and must obtain a nonroutine abandonment approval prior to re-entering and reabandoning the well.

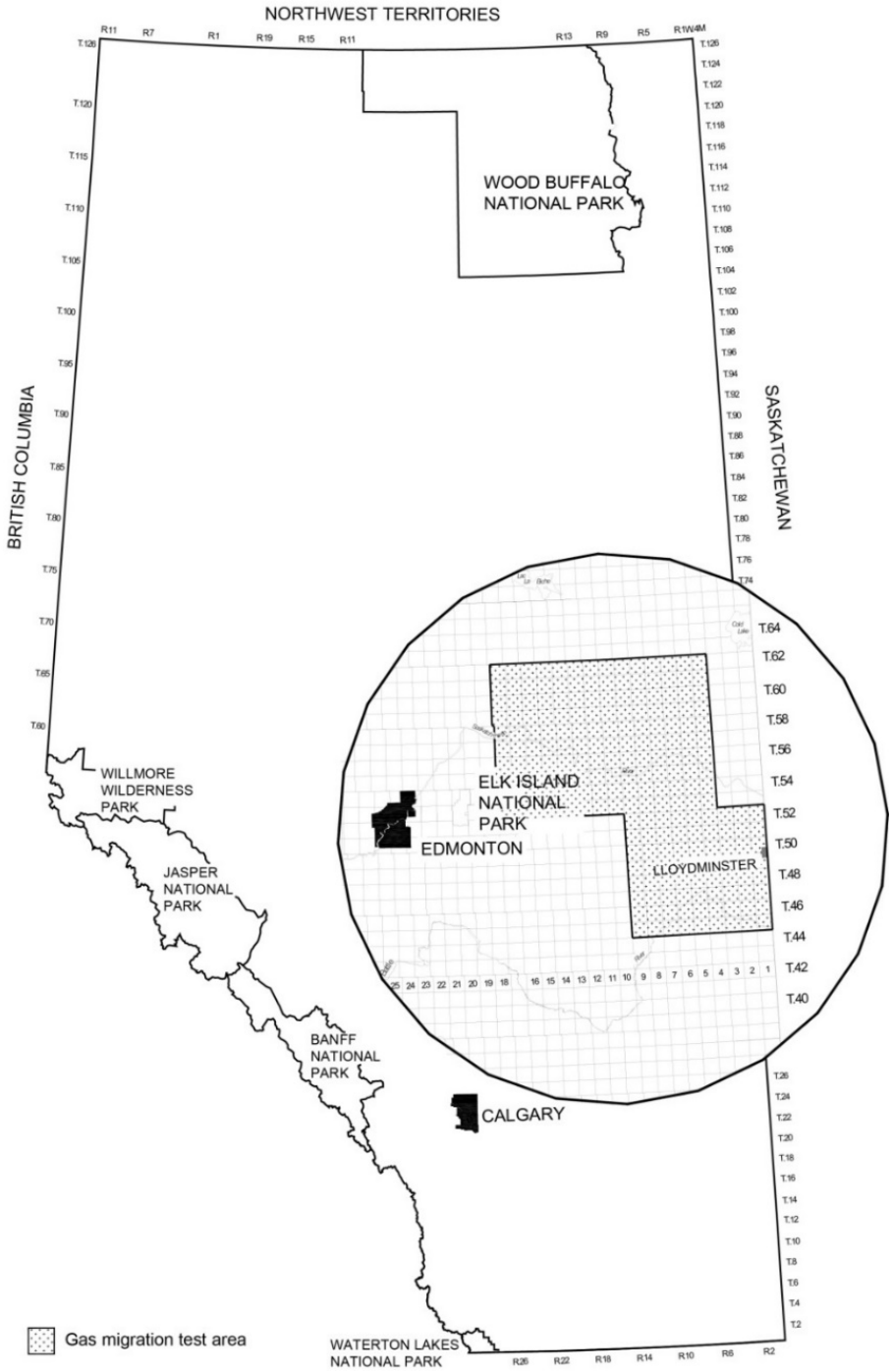

Figure 11. Required GM test areas

7.2 Fluid Level Test for Open-Hole Wells

244) Prior to conducting a surface abandonment, the licensee must conduct a **fluid level test** to determine whether there are any leaking plugs.

a) The fluid level test must be performed a minimum of 5 days after downhole abandonment operations have been completed.

b) To perform the test, the licensee must visually inspect the well to ensure that the fluid level inside the casing is static and no gas bubbles are present.

245) In the event of a leaking plug, the licensee must prepare a reabandonment program and submit a nonroutine abandonment request via the designated information submission system within 30 days of discovery of the leaking plug.

Fluid level testing is not required for oil sands evaluation and test-hole wells where the fluid required to fill the hole coincided with the calculated pipe displacement volume (see section 4.6).

246) If a well is in the designated site inspection region (Townships 7–14, Ranges 12–17, W4M and Townships 15–18, Ranges 10–13, W4M; see figure 12), the licensee must wait until the well passes an AER site inspection before cutting and capping the well. To schedule a site inspection, the licensee must contact the Medicine Hat Field Centre at 403-527-3385 within 24 hours after conducting downhole abandonment operations. The licensee must provide the well location, company contact name, and phone number.

247) Until the well has been inspected, the surface casing must be left open, with fluid visible, and protected from freezing. AER staff will visually inspect the well for leaking plugs and communicate the results to the licensee.

7.3 Surface Casing Vent Flow Test for Cased-Hole Wells

248) Prior to conducting a surface abandonment, the licensee must conduct a surface casing vent flow test to determine whether gas, liquid, or any combination of substances is escaping from the casing vent assembly.

249) A bubble test must be conducted with a hose 2.5 cm below the water surface for a minimum of 10 minutes. If any bubbles are present during the 10-minute test, the well has a vent flow.

See appendix 2 of *Directive 087* for suggested procedures of SCVF testing.

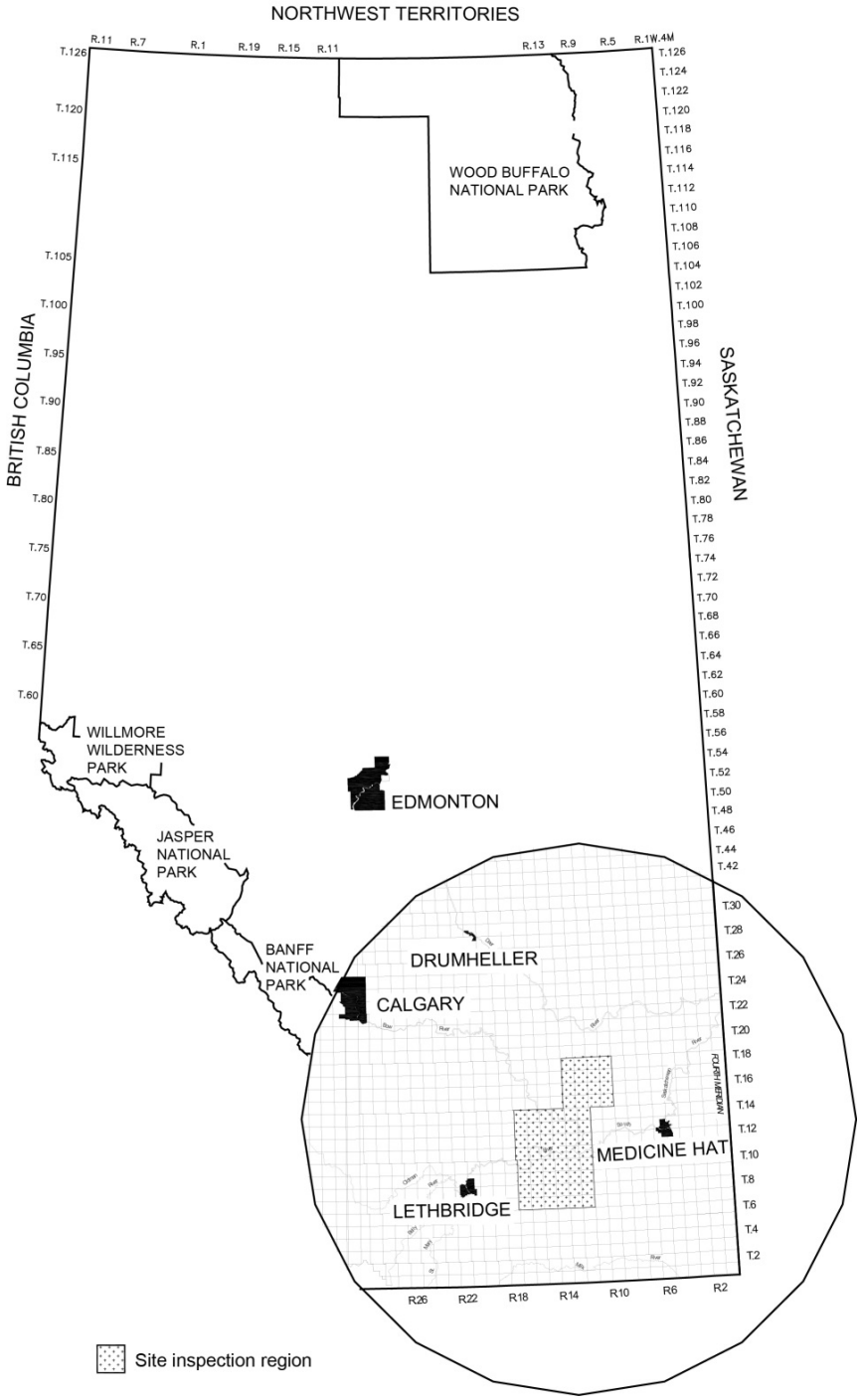

Figure 12. Site inspection region

7.3.1 Rate Determination

If bubbles were present during the bubble test, a SCVF rate test must be conducted. This test should be continued until a stabilized rate is obtained.

250) The licensee must use either a positive displacement gas meter or an orifice well tester to measure vented gas volumes.

7.3.2 Determination of Stabilized Shut-in Surface Casing Pressure

251) If bubbles were present during the bubble test, the SCV must be shut in until a stabilized pressure is obtained. The pressure is considered stabilized if the change in pressure is less than 2 kPa/hr over a six-hour period.

7.3.3 Determination of Serious or Nonserious Vent Flow

252) The licensee must determine if the vent flow is serious or nonserious in accordance with the criteria set out in *Directive 087*.

7.3.4 Notification of SCVF

253) Where an SCVF test (such as a bubble test) indicates that a leak may be present, and a vent flow is confirmed, the licensee must notify the AER via the designated information submission system within 30 days of detection and repair in accordance with *Directive 087*.

8 Surface Abandonment

Surface abandonment involves cutting the casing strings and capping the well.

254) The licensee must not begin surface abandonment until the required testing (see section 7) has been performed and the test results indicate the absence of any wellbore problem.

255) Surface abandonment must be completed within 12 months after downhole abandonment operations.

256) If the well is being abandoned due to an order of the AER, the licensee must begin surface abandonment as directed.

257) The licensee must inform all affected parties, including the landowner and occupant, of a planned surface abandonment before beginning any work.

258) Surface abandonment must be reported through the designated information submission system within 30 days of completing the operation.

259) Surface equipment, cement pads, debris, and produced liquids associated with the well licence must be removed within 12 months of the cutting and capping operation.

260) The licensee must retain records of the removal and cleanup activities and make this available to the AER upon request.

261) The casing strings must be cut at a minimum of 1 m below the final contour elevation, with the following exceptions:

a) If the well is in an area with special farming practices, such as deep tillage, drainage works, or peat lands, or is within 15 km of an urban development, casing strings must be cut at a minimum of 2 m below final contour elevation.

b) If the well is in an area where surface mining will be conducted,

i) a cement plug must be circulated from the uppermost abandonment plug to 15 m below the intended strip mining depth, and

ii) above the strip mining depth, the casing must be cut at intervals agreed on by the mining operator.

262) Surface, intermediate, and production casing strings must be capped at the surface with a steel plate fastened and installed to prevent any potential pressure buildup within the casing and restrict access to the casing strings at surface.

The “wedding cake” style cut and cap is now permitted.

263) The licensee must retain the record of the capping and venting procedure used in the well file for the life of the well. The documentation must be made available to the AER on request. Typical cased-hole abandonment schematics are shown in figure 13 and figure 14.

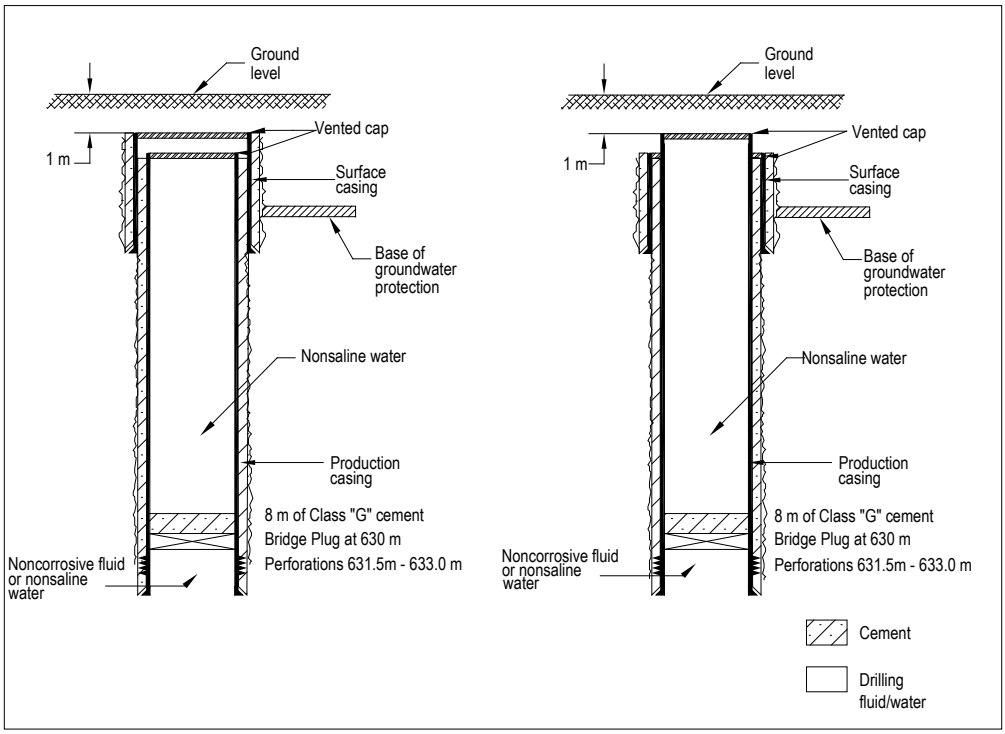

Figure 13. Examples of cased-hole abandonment for non-level-A intervals

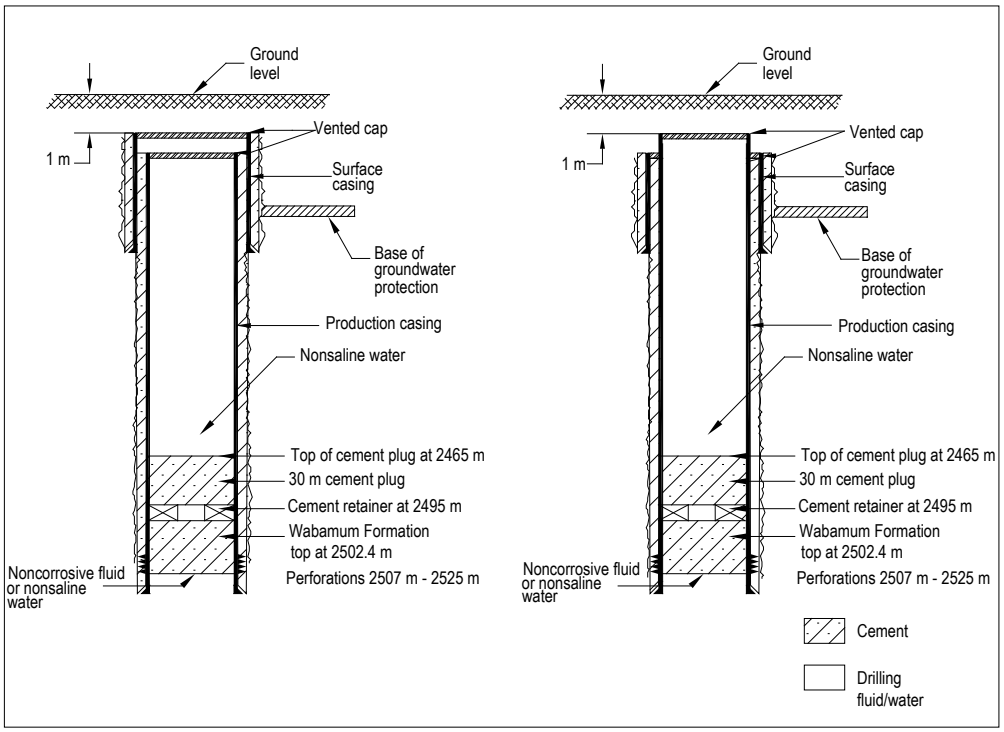

Figure 14. Examples of cased-hole abandonment for level-A intervals

Appendix 1 Definitions

CO_2 EOR storage scheme	An area approved for enhanced oil recovery and net geological storage of CO_2 as described in *Directive 065*.
CO_2 sequestration scheme	Wells approved for the permanent geological storage of CO_2 as described in *Directive 065*.
cased-hole well abandonments	The downhole abandonment of a completed or cased well.
in situ coal gasification (or liquification)	The intentional thermal or chemical conversion of coal into synthetic coal gas or liquid in an underground seam.
level-A interval	Level-A intervals are intervals that • have been used for disposal of class Ia or Ib fluids, • have been used for injection of acid gas, • have been used only for injection of CO_2 EOR storage or only for CO_2 sequestration schemes as described in *Directive 065*, • have an H_2S concentration in excess of 15%, or • have been designated as critical sour. This evaluation is done on a well (not a pool) basis.
Mannville Group (or equivalent)	The comparable geological formation to the Mannville, such as the Luscar or Blairmore Groups or Spirit River Formation.
noncompleted well	A well that has not been perforated and has no open-hole section.
nonsaline water	Water that has total dissolved solids less than or equal to 4000 milligrams per litre.
open-hole well (abandonment)	The downhole abandonment of an open-hole well after drilling is complete but before the rig is released.
plug back	The downhole abandonment of a portion of an open-hole well.
porous zone	A zone that • has carbonates with effective porosity greater than 1%, • has sandstones with effective porosity greater than 3%, • has offset production, regardless of the porosity, or • has drillstem test formation fluid recoveries greater than 300 linear metres or gas volumes greater than 300 cubic metres.
protected interval	A lithology with greater than 3% porosity or a coal seam.
qualified geoscientist	A person authorized to practise geoscience as defined by the *Engineering and Geoscience Professions Act*.

remedial cementing	Cementing operations performed to repair problems with primary cementing or to treat conditions arising after the wellbore has been constructed.
surface abandonment	The cutting of casing strings and capping of the well.
thermal cement	A cement blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at a temperature of 360°C.
“wedding cake” style cut and cap	A method of capping a well that has the production casing string extending beyond the intermediate or surface casing. If the well has intermediate casing, the intermediate casing would extend beyond the surface casing. All the casing strings are capped in a manner that will prevent the buildup of pressure inside any of the casing strings.
zonal abandonment	The abandonment of a single pool completion within a cased hole or the downhole abandonment of an open-hole interval in a cased hole.