Directive 086

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Reservoir Containment Application Requirements for Steam-Assisted Gravity Drainage Projects in the Shallow Athabasca Oil Sands Area

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Contents

1 Introduction

1.1 Purpose of This Directive

This directive provides application requirements (in addition to those already found in *Draft Directive 023: Oil Sands Project Applications*) for new scheme approvals and amendments to existing scheme approvals for steam-assisted gravity drainage (SAGD) projects within a specific area of shallow bitumen deposits. In this area, called the shallow area (figure 1) for the purpose of this directive, SAGD projects may be subject to higher operational risks due to the depth of the reservoir (150 metres or less) and the presence of complex geological settings that may impact caprock integrity and potentially result in a loss of reservoir containment of injected steam and heated reservoir fluids from the Wabiskaw-McMurray deposit.

These additional application requirements relate to assessment of caprock integrity for containment of injected steam and heated reservoir fluids within the target reservoir. The additional application requirements will help to assure the AER that operators have sufficient knowledge to take steps needed to manage subsurface risks and safely produce bitumen in this area. This directive does not deal with the wellbore aspects of fluid containment since these are addressed in *Directive 013: Suspension Requirements for Wells*, *Directive 020: Well Abandonment*, and *Directive 051: Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements*.

1.2 AER Requirements

AER requirements are those rules that the approval holder is required to follow. The term “must” indicates a requirement, while terms such as “recommends” and “expects” indicate a recommended practice. Each AER requirement is numbered.

1.3 What’s New in This Edition

As a result of the rescission of *Directive 023: Guidelines Respecting an Application for a Commercial Crude Bitumen Recovery and Upgrading Project* and *Directory 078: Regulatory Application Process for Modifications to Commercial In Situ Oil Sands Projects*, references in section 1.1 have been updated.

2 Definition

2.1 Shallow Area

For this directive, the AER has designated a region called the shallow area (figure 1). The shallow area is defined as the region where the net bitumen pay in the Wabiskaw-McMurray deposit is greater than zero and the base of the Lower Clearwater Shale is shallower than 150 m. Generally at 150 m depth or less in the shallow area, the Clearwater Formation may become subject to Quaternary erosion. Figures 2 and 3 provide two geological cross-sections that illustrate the regional stratigraphy across the shallow area.

2.2 Caprock

A caprock is defined as a succession of low-permeability and geomechanically strong strata that can effectively contain injected steam and heated reservoir fluids. In the northeast Athabasca Oil Sands Area, the overburden for the Wabiskaw-McMurray bitumen deposit typically consists of the Clearwater Formation, the Grand Rapids Formation, and Quaternary strata. In particular, a regionally persistent unit of the Cretaceous Clearwater Formation, known informally as the Lower Clearwater Shale, has been demonstrated by existing SAGD schemes to behave as a caprock. Locally, the caprock in the Clearwater Formation may have become partially to completely eroded, which may impact caprock integrity and increase the risk of a loss of reservoir containment.

3 Caprock Criteria for the Clearwater Formation

1) The applicant must demonstrate that the Clearwater caprock in the shallow area meets the following criteria:
    - be a minimum of 10 m thick;
    - be composed of clay-rich bedrock, with a gamma-ray value greater than 75 API units[1]; and
    - be laterally continuous across the project area.[2]

The Lower Clearwater shale is the deepest caprock overlying the Wabiskaw-McMurray deposit that meets the above criteria. Requests to calculate the maximum operating pressure at the base of other geological units will be considered by the AER at the project application stage provided one of the following conditions are met:

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[1] A 10 m thick caprock can include small amounts of tight streaks and organic-rich material with gamma-ray values less than 75 API units.

[2] Defined as the boundaries within which bitumen recovery may occur over the life of the project.

- the Lower Clearwater shale is present and meets the above criteria or
- the applicant demonstrates that an equivalent caprock is present that will contain injected steam and heated reservoir fluids as effectively as the Clearwater caprock that meets the above criteria.

Figures 2 and 3 provide two cross-sections that illustrate the regional stratigraphy across the shallow area.

4 Equivalent Caprocks

The Grand Rapids Formation and Quaternary strata have not been demonstrated to be effective caprocks in the shallow area. The AER is prepared to consider a demonstrated equivalent to the Clearwater caprock (i.e., one that effectively contains injected steam and heated reservoir fluids).

The AER will consider applications for small-scale pilot projects for limited duration to facilitate the demonstration of equivalent caprocks. Such applications will be reviewed on a case-by-case basis and must indicate how the operations can be performed safely. Applicants wanting to apply for larger-scale projects, after smaller-scale tests have been completed, would be required to address the appropriate upscaling of field tests.

5 Maximum Operating Pressure (MOP)

2) There are two mechanisms by which a caprock can fail: tensile and shear. To reduce the risk of caprock failure, applicants must determine a MOP that takes into account both failure mechanisms. To establish an appropriate and correlated accompanying maximum wellhead injection pressure, an application must be submitted in accordance with *Directive 051*.

5.1 Tensile Failure

3) Applicants must determine the MOP to avoid tensile failure by using the following formula:

$$\begin{aligned} MOP_{(bottomhole)}\ (\text{kPag}) = {} & \text{Safety factor of } 0.8 \times \\ & \text{Caprock fracture closure gradient (kPag/m)} \times \\ & \text{Depth at shallowest base of caprock (m TVD)}, \end{aligned}$$

where kPag is kilopascals gauge and m TVD is metres true vertical depth.

The lowest valid caprock fracture closure gradient obtained from representative micro fracture injection tests must be used. Surface topography must be considered in determining the depth at the shallowest base of the caprock. The MOP may be determined on a drainage pattern basis,[3]

[3] Drainage pattern refers to a configuration of production and injection wells placed within the reservoir that will be operated in a unified manner to recover bitumen from a localized area.

but in that case it must be supported by a technical assessment that addresses how the MOP will be managed when steam chambers in different drainage patterns coalesce.

5.2 Shear Failure

4) To address potential shear failure of the caprock leading to a loss of containment, applicants must conduct geomechanical modelling.

5.3 Short-term Exceedance of MOP

The AER is prepared to consider an exceedance of the MOP during certain operations, including start-ups and maintenance. For any proposed MOP exceedance lasting less than 48 hours and having an operating pressure below fracture closure pressure of caprock, the operator must get permission from the AER by emailing Directive086@aer.ca. Any other proposed MOP exceedances must be applied for through an amendment to the scheme approval and will be assessed on a case-by-case basis.

6 Risk Assessment and Management Plan

5) Applicants for SAGD projects within the shallow area must conduct and provide a risk assessment and management plan regarding reservoir containment. It is recommended that the assessment and plan follow the ISO 31000 international standard methodology.

7 Monitoring Program

6) Applicants for SAGD projects within the shallow area must provide a monitoring program that will determine whether operations are within the expected operating parameters. The monitoring technology, location, intervals, density, and frequency must take into account the operating strategy and associated risks.

7) Applicants must use the monitoring data obtained during operations to calibrate and update the geomechanical modelling that was initially done to assess shear failure of the caprock. If the updated modelling indicates that the MOP should be lower than the MOP initially approved, applicants must immediately inform the AER at Directive086@aer.ca. Otherwise applicants can use the *Directive 054* annual project performance review process to update the AER on the monitoring results and any updated modelling.

8 Information Requirements

8) The information in the subsections below must be submitted by the applicant to the AER, in addition to any other information required by the AER.

8.1 Geology

All isopach, structure, and depth maps must incorporate three-dimensional (3-D) seismic or other demonstrated equivalent imaging data, be annotated with well data, and be at a scale that shows the project area. Applications must also

- describe how the caprock meets the shallow area caprock criteria, supported by representative log cross-sections that illustrate the caprock thickness, formation tops, and 75 API unit cutoff on the gamma-ray log;
- if an equivalent caprock is being proposed, provide the information to support the conclusion that the caprock would effectively contain injected steam and heated reservoir fluids, including field tests of the caprock;
- describe the information used to delineate the caprock in the project area, supported by
  - a map showing the locations of evaluation wells, cored wells, and wells with fracture imaging logs; and
  - a map showing where 3-D seismic, two-dimensional (2-D) seismic, or other imaging data have been acquired;
- describe the geology of the caprock, supported by
  - the lithology and mineralogy of the caprock, including available particle size and mineralogical analysis;
  - structure maps of the caprock top and base;
  - a map of the depth to base of caprock in metres true vertical depth, incorporating surface topography; and
  - an isopach map of the caprock;
- acquire 3-D seismic or other demonstrated equivalent imaging data for the entire development area[4] and subsequently for any future expansions to the development area to identify geological features such as faults, incising channels, and localized subsidence features that may not be identified by evaluation wells or 2-D seismic data, and provide the following information:
  - a description of the 3-D seismic or other demonstrated equivalent imaging data acquisition parameters and the methods used to process the data;
  - representative depth-converted seismic or other demonstrated equivalent imaging sections tied to well logs that are annotated with formation tops;

[4] Defined as the boundaries within the project area that is approved for specific placement of drainage patterns for the recovery of bitumen.

  - structure and isopach maps of the Prairie Evaporite Formation (where well control exists), Paleozoic Era, Wabiskaw Member, and Clearwater Formation; and
  - isopach maps of any gas accumulations below the caprock;
  - a description of any geological features in the project area, supported by
    - a map that illustrates the location of these features,
    - a discussion of the strata containing these features,
    - a discussion of the impacts of these features on the caprock, and
    - an explanation of how the proposed development strategy mitigates the possible impacts of these features on caprock integrity over the life of the project (e.g., setbacks and operational strategies);
- acquire representative caprock core and fracture imaging logs for wells with caprock core for the development area and subsequently for any future expansions to the development area and provide a description of the caprock fracture occurrence, supported by
  - depth-corrected photos for all caprock core and
  - a comparison of fractures identified in core and fracture imaging logs, with examples from each; and
- describe the continuity, thickness, porosity, and permeability of all porous intervals between the bitumen reservoir top and caprock base, supported by data from representative wells and isopach maps of the intervals.

8.2 Hydrogeology

In order to assess the caprock integrity, where aquifers are present above and below the caprock within the development area and subsequently for any future expansions to the development area, the AER requires applicants to acquire hydrogeological data to determine whether the caprock hydraulically isolates the reservoir from aquifers above the caprock.

Aquifers to be assessed may include water sands in contact with the bitumen reservoir (i.e., top or bottom water), aquifers between the reservoir top and base of the caprock, and the deepest overlying aquifers (including any identified bedrock and incising channel aquifers). At a minimum, the deepest suitable aquifer overlying the caprock and the shallowest suitable aquifer underlying the caprock must be assessed. The following information must be provided:

- a map with the locations of observation wells, aquifer tests, drillstem tests, and sampling locations;
- lithologs with completion details for each observation well or test hole;

- isopach and structure maps for each aquifer;
- potentiometric surface maps in metres of freshwater equivalent head above sea level;
- plots of representative pressure head measurements versus depth and representative pressure head measurements versus elevation with comparisons to hydrostatic pressure and an assessment of hydraulic communication between aquifers; and
- representative laboratory analyses of groundwater from each aquifer and an interpretation of water chemistry differences between aquifers.

8.3 Geomechanics

- Acquire a minimum of one representative caprock micro fracture injection test (or demonstrated equivalent) for every four sections of proposed development area to inform an application review and calibration of geomechanical modelling. Before steaming, an applicant must increase the representative caprock micro fracture injection test density to a minimum of one for every two sections of development area that includes drainage patterns. The approved MOP may be reduced based on new test results before steaming. Should an applicant identify an area of geological features such as faults, incising channels, and localized subsidence features that may compromise the caprock integrity, the AER will require the applicant to have representative tests in the vicinity of these features.
- Provide the following information for all micro fracture injection tests conducted:
  - the raw test data;
  - a discussion of the operational procedures used to conduct the tests;
  - the test intervals in metres true vertical depth;
  - an interpretation and analysis of the test results, supported by
    - the estimated fracture closure gradient for the reservoir and caprock,
    - a description and justification of the analysis techniques and interpretation, and
    - the identification of any unexpected or unusual test results and a discussion of possible causes;
  - the criteria used to determine the locations of the tests; and
  - a discussion of any geological features that could affect the test results.
- With respect to potential tensile failure of the caprock, provide the details of the pressure calculated from the MOP formula, including
  - the basis for the caprock fracture closure gradient used in the calculation;

   - a discussion of the depth used for the shallowest base of the caprock; and
   - if the MOP is to be determined on a drainage pattern basis rather than on a project basis, a technical assessment of how the MOP will be managed when steam chambers in different drainage patterns coalesce.
- With respect to potential shear failure of the caprock, provide the details of the geomechanical modelling, including
   - the input data files used for the modelling and the source of the data;
   - the name and version of the modelling software used;
   - a discussion of the methodology used in the modelling (e.g., boundary conditions, material failure criteria, rock constitutive model, material properties, coupling of the geomechanical model to the reservoir model);
   - a discussion of the results predicted by the modelling, including the pressure at which shear failure of the caprock leads to a loss of containment and how the results support the proposed operating pressure;
   - an assessment of the sensitivity of the results from the modelling to the input parameters and a discussion of the uncertainties in the predicted results; and
   - a discussion of the frequency at which the modelling will be updated with the results of the project's monitoring program.

8.4 Risk Assessment

Provide the details of the risk assessment and risk management plan regarding reservoir containment, including

- any assumptions used in the assessment;
- a description of the potential pathways by which reservoir containment could be lost and identify the potential receptors;
- an assessment of the likelihood of occurrence and consequence of loss of reservoir containment by each of the potential pathways;
- a discussion of how the risks would be mitigated;
- a discussion of the uncertainties associated with the assumptions made in the risk assessment and management plan; and
- a discussion of why the assessed level of risk and management plan are considered to be acceptable to allow the project to proceed.

8.5 Monitoring Program

Provide the details of the proposed monitoring program, including

- the type, location, intervals, and frequency of monitoring and data collection;
- a discussion of how operations will be monitored to ensure compliance with the proposed MOP, including the details of how the bottomhole pressure will be determined; and
- a discussion of how operations will be monitored to determine whether the integrity of the caprock has been compromised; this discussion should include the criteria that will be used to characterize events that may compromise caprock integrity (such as detecting deviations from expected/predicted operating conditions) and the field operating protocols for responding to such events.

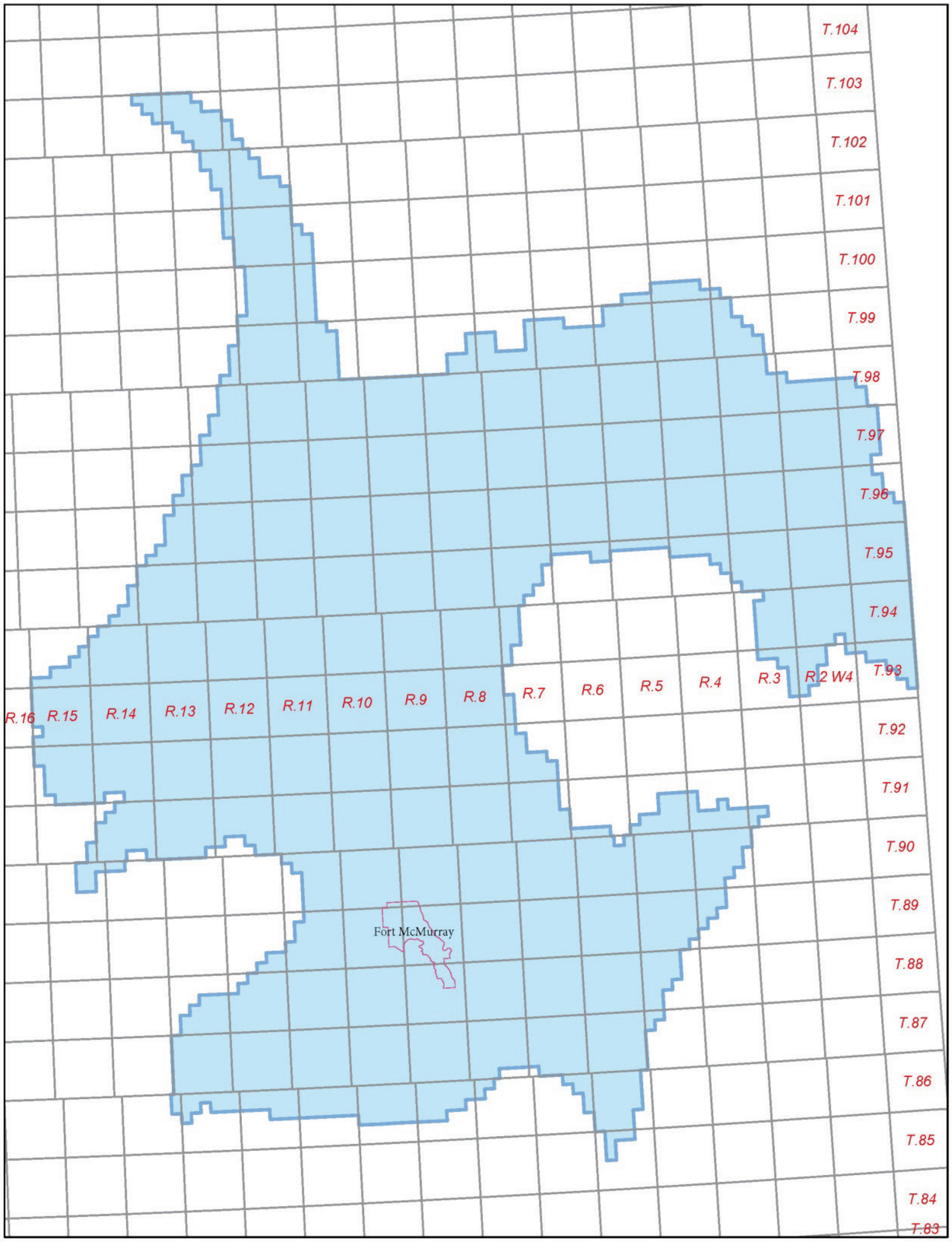

Figure 1. Shallow area

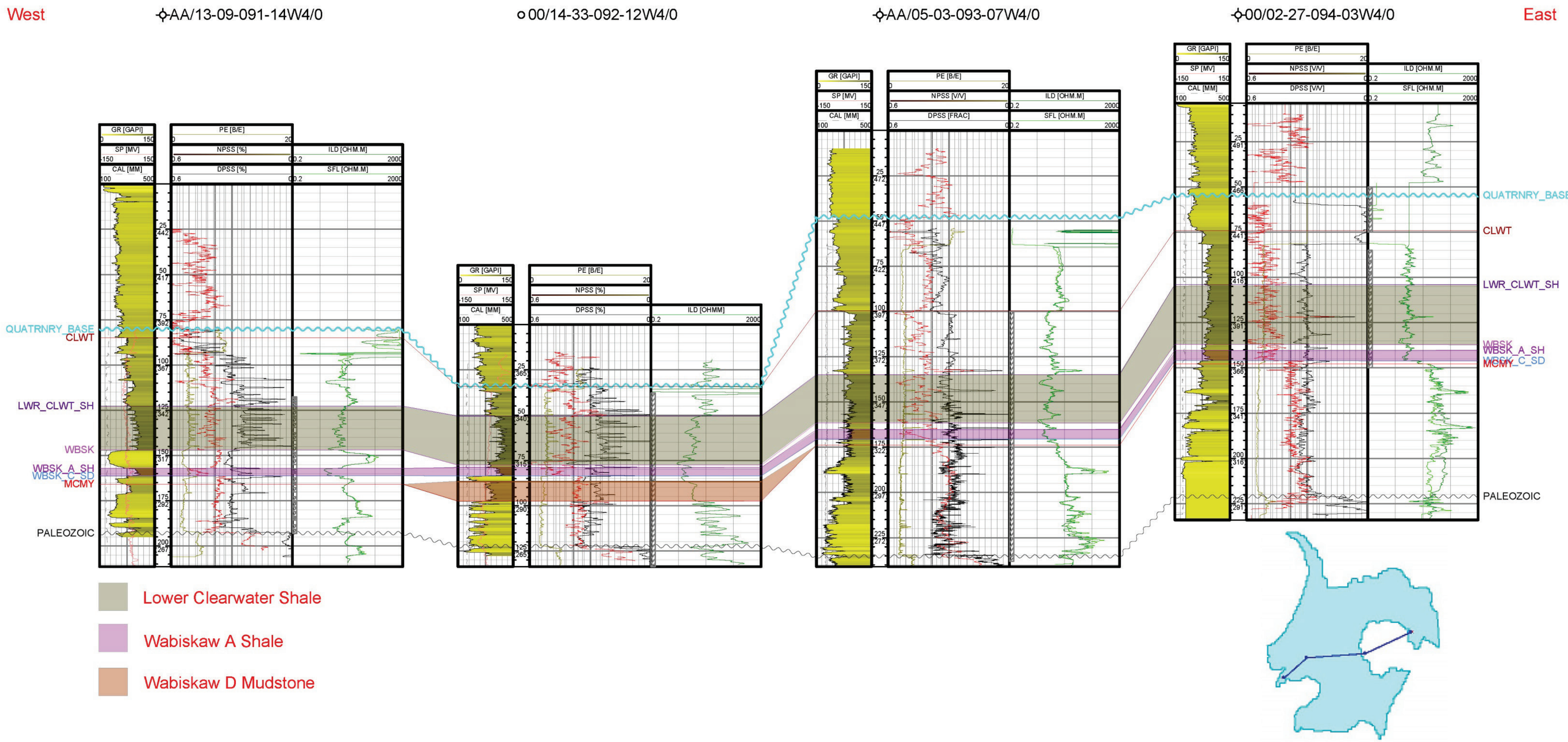

Figure 2. **West–east stratigraphic cross-section for the shallow area**

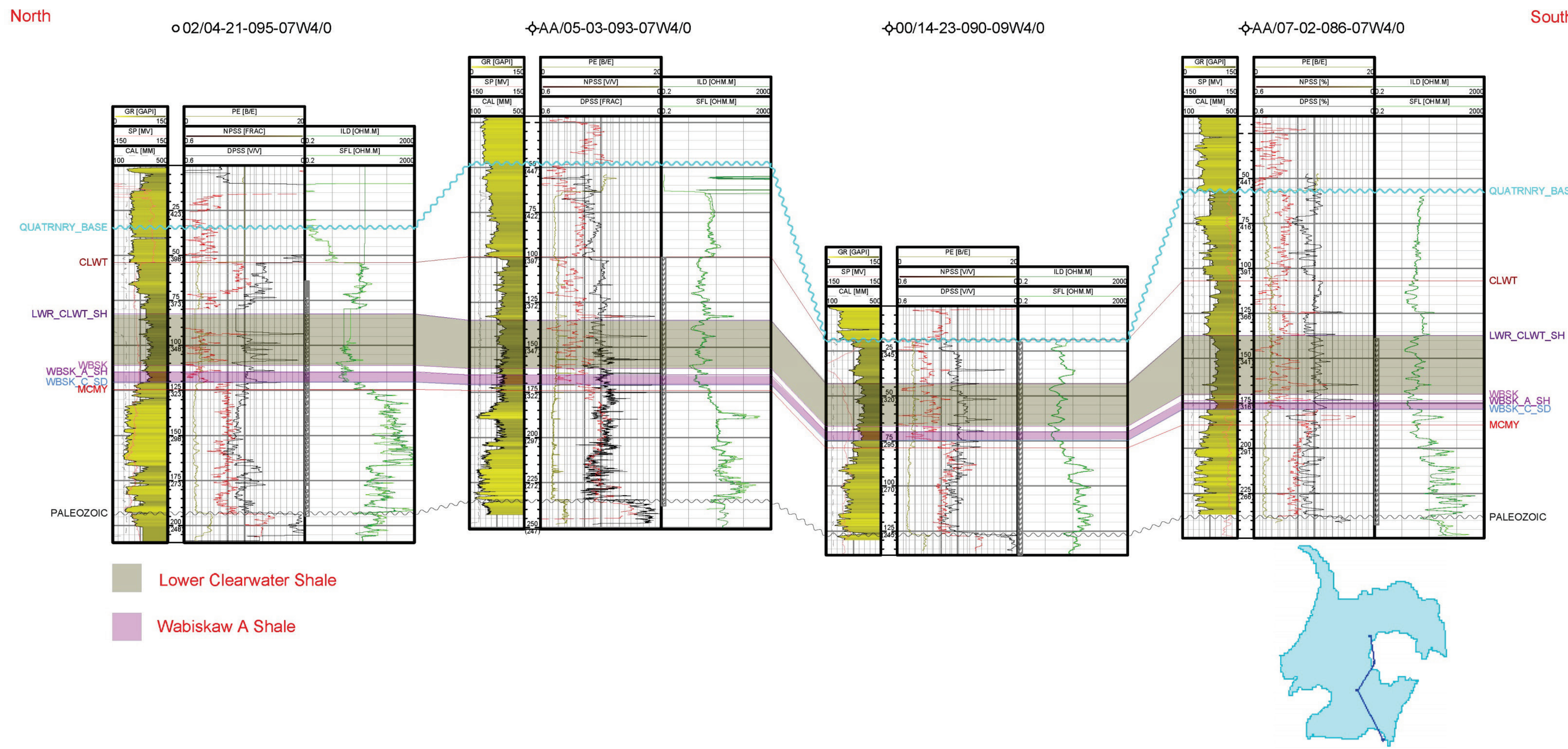

Figure 3. North–south stratigraphic cross-section for the shallow area