



ENHANCED OIL RECOVERY

Approval No. 12832

MADE at the City of Calgary, in the
Province of Alberta, on
6th day of December 2018.



ALBERTA ENERGY REGULATOR

The Alberta Energy Regulator (AER) pursuant to the Oil and Gas Conservation Act, chapter O-6 of the Revised Statutes of Alberta, 2000, orders as follows:

- 1) The scheme of Enhance Energy Inc. (hereinafter called “the Operator”) for enhanced recovery of oil by miscible displacement using miscible fluid (CO₂) and/or water injection in that part of the **Clive D-3 A Pool** and containment of CO₂ within the Clive D-3 A and D-2 A Pools outlined in Appendix A of the approval (hereinafter called “the Approval Area”), as described in

- a) Application No. 1904282,

is approved, subject to the terms and conditions herein contained.

- 2) For the purpose of this approval, “miscible fluid” means a mixture that contains:

- a) no less than 0.95 mole fraction of carbon dioxide, with the remainder composed of hydrocarbon components and hydrogen sulphide, at any time.

- 3) (1) The Operator may commence or continue the miscible fluid and/or water injection in the wells listed in this clause 3, paragraph 1, subclause a, when the commitments of the Measurement, Monitoring, and Verification Plan for these wells are met, substantially in accordance with the scheme.

- a) No injection well(s) listed at this time:

Class II & III

The class of injection fluid is described in *Directive 051*.

- (2) The undrilled well(s), referred to in clause 3, paragraph 2, subclause a, may be eligible for approval to commence injection once an application that includes at a minimum the *Directive 065* requirements described in clause 4, and the *Directive 051* requirements have been submitted and approved:

- a) Bottomhole location(s) of undrilled injection well(s):

01-34-039-24W4

06-01-040-24W4

- 4) The *Directive 065* application for undrilled injection wells referred to in clause 3, paragraph 2, subclause a, must include, at a minimum, the following information, and should be submitted within twelve months of the date of this approval:

- a) evidence that the Measurement, Monitoring, and Verification Plan (hereinafter called the MMV Plan) as detailed in Application No. 1904282 has been approved by the Minister of Energy, and adhered to,
 - b) geological interpretations of the new well(s) within the Approval Area, which should include:
 - i) updated the Leduc, Ireton, Nisku and Calmar gross thickness isopach mapping over the Approval Area,
 - ii) updated the Calmar and Nisku anhydrite mapping over the Approval Area,
 - iii) acceptable porosity, resistivity and lithology logs, as described in Section 4.3.3 of *Directive 080: Well Logging* for the entire length of all injection wellbores. The logs must be submitted to the AER in accordance with Section 7.2 of *Directive 080*, and
 - iv) updated interpreted and annotated log cross-section showing:
 - (1) stratigraphic interpretation of the zone(s) of interest,
 - (2) completions/treatments to the wellbore(s), with dates,
 - (3) the unique well identifier of the well(s), finished drilling date and Kelly bushing elevation and the scale of the log readings, directional survey, and
 - (4) tabulation of the interpreted net reservoir thickness, permeability and porosity for the well(s).
 - c) bottomhole injection pressure, maximum sandface pressure, fracture propagation pressure, and formation fracture pressure for each of the well(s) referred to in clause 3, paragraph 2, subclause a,
 - d) evidence whether the Leduc and Nisku zones are in fluids/pressure communication, and
 - e) evidence that the most suitable surface and downhole casings, tubulars and equipment are employed in new wells drilled for injection/production and/or retrofits injection wells as detailed in Application No. 1904282.
- 5) The injection of the miscible fluid and/or water may commence in the well(s) referred to in clause 3, paragraph 1, subclause a, once the AER has confirmed in writing that *Directive 051* requirements have been met.
- 6) The Operator must conduct the miscible fluid and/or water injection into the well(s) referred to in clause 3, paragraph 1, subclause a, in accordance with the following requirements:
- a) stabilized reservoir pressures of the Clive D-3 A and D-2 A Pools in the Approval Area must be obtained annually, respectively, in accordance with *Directive 040* requirements, the test results must be submitted to the AER through the AER Digital Data Submission (DDS) System. Injection operations must be suspended in the well(s) referred to in clause 3, paragraph 1, subclause a, if the reservoir pressure exceeds 17 500 kilopascals (gauge),
 - b) no production may be taken from any wells within the Approval Area subject to active miscible fluid injection wherein the Leduc reservoir pressure is less than 13 000 kilopascals (gauge) unless the AER, upon application, otherwise permits,

- c) the injected gas stream shall contain no greater than 0.05 mole fraction of hydrogen sulphide at any time,
- d) a voidage replacement ratio must not exceed 1.0 on the basis of cumulative production and injection volumes following commencement of production,
- e) a minimum monthly voidage replacement ratio of 0.5 on a twelve month moving average basis must be maintained,
- f) the composition of the injectant (miscible fluid and/or re-injection gas stream) must be determined monthly,
- g) the Operator must monitor the Leduc producing well(s)'s producing gas-oil ratio in the Approval Area to determine when the miscible fluid breakthrough occurs,
- h) the Operator must obtain and analyze representative samples of the produced liquid and gas from production wells in the Approval Area to determine the breakthrough occurred,
- i) when breakthrough of the miscible fluid is indicated in any of the producing wells, the Operator must obtain and analyze representative samples from producers in the Approval Area every three months for the estimation of the breakthrough volume in the Approval Area,
- j) a hydraulic isolation log must be run on the injection well(s) referred to in clause 3, paragraph 1, subclause a, in accordance with *Directive 051* every five years. The need for further hydraulic isolation logging over the life of the injection well(s) will be determined through the annual reporting and presentation process,
- k) the Operator must continuously monitor the pressures of the tubing/casing annulus; conduct annual packer isolation tests for the injection well(s) referred to in clause 3, paragraph 1, subclause a, which must be submitted to the AER through the DDS system, and implement appropriate corrosion protection. If a leak, or potential leak, is detected in the tubing/casing annulus or packer in the injection well(s), the Operator must immediately inform the Resource Compliance Group in the AER Environment & Operational Performance Branch, and the AER Red Deer Field Centre,
- l) the Operator must immediately suspend injection operations if the injection facilitates the movement of injected fluids into any zone above the base of groundwater protection or any zone other than the Leduc and Nisku zones, and immediately inform the Resource Compliance Group in the AER Environment & Operational Performance Branch, and the AER Red Deer Field Centre,
- m) the Operator must immediately suspend injection operations if any injection equipment, monitoring equipment, or safety devices fail that could compromise the safe operation of the scheme,
- n) the Operator must immediately report any loss of containment, anomalies that indicate fracturing out of the Leduc and Nisku formations, or anomalous pressure changes occurring anywhere within the Clive D-3 A Pool to ResourceCompliance@aer.ca,

- o) the Operator must apply to remove the injection well(s) from the list in clause 3, paragraph 1, subclause a, before abandoning any injection well in the Approval Area, and
 - p) the Operator must apply for and receive approval of its abandonment plan from the Closure & Liability (Oil & Gas) Group in the AER Closure and Liability Branch before abandoning any well within the Approval Area.
- 7) The Operator must include the 00/10-35-039-24W4/0 and 00/14-35-039-24W4/3 wells completed in the Leduc zone, the 02/02-35-039-24W4/2, 00/16-02-040-24W4/0, 00/01-02-040-24W4/2, and 00/12-01-040-24W4/2 wells completed in the Nisku zone as deep monitoring wells, and must implement monitoring programs in accordance with the following requirements:
- a) stabilized formation pressures in the 00/10-35-039-24W4/0 well and/or the 00/14-35-039-24W4/3 well must be obtained annually in accordance with *Directive 040* requirements to monitor pressure development inside the Leduc formation, the test results must be submitted to the AER through the DDS System,
 - b) stabilized formation pressures in the 00/16-02-040-24W4/0 and 02/02-35-039-24W4/2 wells, and either the 00/01-02-040-24W4/2 well or the 00/12-01-040-24W4/2 well must be obtained annually in accordance with *Directive 040* requirements to monitor pressure development inside the Nisku formation, the test results must be submitted to the AER through the DDS System,
 - c) the Operator must complete annual isotope analysis ($\delta^{13}\text{C}$ & ^{14}C) on the producing fluids from the Nisku formation. The frequency isotope analysis will be re-evaluated after two years of commencement of the miscible fluid injection into the Approval Area,
 - d) the Operator must collect gas samples bi-annually, for chemical compositional analysis to detect CO_2 levels in these deep monitoring wells. The frequency sampling collections and analysis will be re-evaluated after two years of commencement of the miscible fluid injection into the Approval Area,
 - e) the Operator must update the reservoir simulations in the Approval Area annually. The frequency simulation update will be re-evaluated after two years of commencement of the miscible fluid injection into the Approval Area,
 - f) the Operator must immediately inform the Resource Compliance Group in the AER Environment & Operational Performance Branch if the injection facilitates the movement of fluids into the Nisku zone, which is observed in any deep monitoring wells, while continuing to monitor the movement of fluids within the Nisku zone and taking direction from the AER to continue, suspend, or reverse the injection thereupon based of the monitoring results, and
 - g) the Operator must fulfil the MMV Plan and/or subsequent amendments to the MMV Plan for the injection operations and deep monitoring wells, until the subject CO_2 injection scheme is rescinded.
- 8) Prior to commencement of the miscible fluid and/or water injection in the well(s) listed in clause 3, paragraph 1, subclause a, the Operator must provide a complete baseline data and

analysis report to ResourceCompliance@aer.ca by November 30, 2019, which includes the following:

- a) baseline data and analysis of carbon isotope signature ($\delta^{13}\text{C}$ & ^{14}C) contained within different sources, such as source CO_2 , CO_2 in producing gas from existing Leduc and Nisku formations, specifically from the deep monitoring wells listed in clause 7, and from coal bed methane (CBM) wells (as per the MMV Plan), CO_2 in soil gas and in headspace gas from domestic water wells (as per the MMV Plan),
 - b) baseline water chemistry data for produced water from the Leduc and Nisku formations, groundwater wells as per the MMV Plan, and existing baseline chemistry data from aquifers overlying the Leduc and Nisku formations,
 - c) baseline seismic data to indicate that no faults transect the seals in the Approval Area,
 - d) any baseline measurements to be taken during the pre-injection CO_2 period,
 - e) complete reservoir pressure analysis that includes initial and current Leduc and Nisku formation pressures, a discussion on how the pressures in the reservoirs are expected by the injection of CO_2 , and what the safe pressure levels are for the Leduc reservoir,
 - f) history match for the Leduc oil reservoir in the Approval Area prior to the CO_2 injection and CO_2 enhanced oil recovery (EOR) performance prediction,
 - g) the Operator must commit to perform, document, and submit to ResourceCompliance@aer.ca a risk assessment of all of the Leduc and/or Nisku wells, including abandoned, suspended or active, in the Approval Area to assess the possibility of leakage based on the vintage of the wells, diagnostic tools run and abandonment practice applied (including porous zone isolation). Wellbores found to have medium and high risks as detailed in the MMV Plan should be mitigated prior to the expected time of CO_2 reaching the locations, and
 - h) discussion of the need for changes to the MMV Plan.
- 9) The Operator must submit annual progress reports and make presentations on the CO_2 EOR scheme to the Resource Compliance Group in the AER Environment & Operational Performance Branch, with the first to occur after one year commencement of the miscible fluid injection. These reports and presentations shall include the following information in metric units:
- a) a summary of the scheme operations including:
 - i) any new project wells drilled in the reporting period,
 - ii) any workovers/treatments done on the injection and monitoring wells including the reasons for and results of the workovers/treatments,
 - iii) changes in injection equipment and operations,
 - iv) identification of problems, remedial action taken, and impacts on scheme performance, and

- v) a table of analysis data including baseline values and testing results. The table must include the unique well indicators, sample dates, test dates and results for all soil, CBM, water and deep monitoring wells, and wells for vent flowing tests.
- b) a full discussion of the pressures of the Leduc and Nisku formations, including stabilized shut-in formation pressures and on how the pressure compares with the formation pressure expected for the cumulative volume of the CO₂ injected, along with an updated estimate of what the actual cumulative injection volume will be at the maximum shut-in formation pressure specified in clause 6, subclause a,
- c) a discussion of the overall performance of the scheme, including the incremental oil recovery and the volume of incremental oil produced as a result of the miscible fluid injection, how the reservoir pressure is changing over time; updated geological maps; and updated CO₂ plume extent and pressure distribution models, if needed. The updated geological maps should be based on all new data obtained since the commencement of the injection to the end of the reporting period,
- d) a discussion on how an increase pressure due to the miscible fluid injection could have an adverse effect on hydraulic fracturing of the target formation or caprock, and the displacement of brine upward out of the target formation via a conduit such as fracture or fault, and wellbores within the area of influence. In addition, a list of all wells that penetrated the injection target formation surrounding the injection well where the pressure increase could also have an adverse effect,
- e) results and evaluation of all monitoring done during the reporting period including but not limited to: pressure surveys, corrosion protection, fluid analyses, logs and any other data collected that would help in determining the success of the scheme,
- f) a table showing the following data for each month of the reporting period:
 - i) a representative composition for the injected fluids,
 - ii) a representative composition for the re-injection streams,
 - iii) mole fraction of the CO₂ and impurities in the injection stream,
 - iv) standard volume of the CO₂ injected,
 - v) cumulative volume of the CO₂ injected at standard conditions following the commencement of the scheme
 - vi) CO₂ stream formation volume factor,
 - vii) volume of the CO₂ injected at reservoir conditions,
 - viii) cumulative volume of the CO₂ injected at reservoir conditions following the commencement of the scheme,
 - ix) hours on injection,
 - x) the net amount of the CO₂ injected in the reservoir, in reservoir cubic meters and in standard cubic meters, the difference between total CO₂ injected into and that produced from the scheme,
 - xi) maximum daily injection rate at standard conditions,
 - xii) average daily injection rate at standard conditions,
 - xiii) maximum wellhead injection pressure and corresponding wellhead injection temperature,
 - xiv) average wellhead injection pressure and corresponding average wellhead injection temperature,
 - xv) estimated or measured average reservoir pressure in the target formation, and

xvi) estimated average bottomhole injection pressure.*

* Include a discussion in detail on how the hydrostatic head of the miscible fluid in the wellbore, friction losses in the tubing, and pressure losses in the reservoir are accounted for in the determination of the average reservoir pressure.

- g) a plot showing ongoing monthly injection volumes and the maximum wellhead injection pressure versus time. The plot must display the scheme on an ongoing basis and not just for the reporting period,
 - h) a table showing the calculated net tonnes of the CO₂ injected in reservoir and in standard conditions, which is a difference between the miscible fluid injected into and that produced from the scheme:
 - i) on a monthly basis for the reporting period, and
 - ii) on an annual basis since the commencement of injection.
 - i) a table and plot of the calculated voidage replacement ratios both on a monthly and cumulative basis from the start of scheme operations, and
 - j) verification that all conditions of this approval have been met during the reporting period. All non-compliance events should be summarized, and should be voluntarily self-disclosed as soon as they occur to the Resource Compliance in the AER Environment & Operational Performance Branch.
- 10) All non-abandoned wells that are completed in the Leduc and/or Nisku zones and within the Approval Area must be abandoned by a Level A method in accordance with *Directive 020* upon completion of the CO₂ injection operations. The abandonment program must be submitted to the Closure & Liability (Oil & Gas) Group in the AER Closure and Liability Branch and approved by the AER.
- 11) All suspended wells that are completed in the Leduc and/or Nisku zones and within the Approval Area must meet the High Risk Type 2 suspension requirements of *Directive 013* once commencement of the CO₂ injection into the Approval Area.
- 12) The Operator is required to submit the MMV Plan updates at critical milestones, such as commencement of the miscible fluid injection, two years after commencement of the miscible fluid injection, closure and post closure of the miscible fluid injection. Specifically, the Operator must submit a closure and a post closure MMV Plan.
- 13) The AER may at any time vary these terms and conditions or may suspend or revoke this approval if, in its opinion, circumstances so warrant.

END OF DOCUMENT

