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MADE at the City of Calgary, in the  
Province of Alberta, on

24th day of August 2012.



ENERGY RESOURCES CONSERVATION BOARD

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

- 1) The Class III scheme of Shell Canada Limited (Approval Holder) in the **Radway Field and surrounding areas** (approval area) shown in Appendix A, for the disposal and sequestration of carbon dioxide (CO<sub>2</sub>) into the Basal Cambrian Sand Formation (BCS) as described in
  - a) Application No. 1670112,  
  
is approved, subject to the terms and conditions herein contained.
- 2) For the purposes of this approval, the injection fluid will contain a minimum of 95 per cent CO<sub>2</sub> by volume, at any time.
- 3) (1) The Approval Holder may commence or continue injection and disposal of CO<sub>2</sub> for the wells listed in this clause 3)(1) a) when the commitments of the current Measurement, Monitoring, and Verification (MMV) Plan for these wells are met, substantially in accordance with the scheme.
  - a) 00/08-19-059-20W4/0(2) The undrilled well(s), referred to in clause 3)(2) 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 once the *Directive 051* requirements have been submitted and approved.
  - a) 07-11-059-20W4  
15-01-059-21W4  
05-35-059-21W4  
10-06-060-20W4  
12-14-060-21W4  
15-16-060-21W4  
15-29-060-21W4
- 4) The minimum *Directive 065* application requirements for undrilled wells listed in clause 3)(2) a) must include:
  - a) geological interpretation of the BCS CO<sub>2</sub> disposal formation in the well(s), including:

- i) updated BCS gross sand thickness isopach map over the approval area
  - ii) updated BCS storage capacity map over the approval area
  - iii) updated interpreted and annotated log cross-section showing:
    - a. stratigraphic interpretation of the zone(s) of interest,
    - b. completions/treatments to the wellbore(s), with dates,
    - c. finished drilling date and Kelly bushing (KB) elevation and the scale of the log readings, and
    - d. tabulation of the interpreted net reservoir thickness, permeability and porosity for the well(s),
  - b) geological interpretation of the bounding formations, extending from the Precambrian to top of the Upper Lotsberg Salt, based on all information from the new well(s) including:
    - i) continuity and thickness of base and caprock (include all seals and baffles in the bounding formations),
    - ii) updated thickness and extent map of the Middle Cambrian Shale (MCS) over the approval area,
    - iii) updated thickness and extent maps of the Upper and Lower Lotsberg Salts in the approval area,
    - iv) lithology,
    - v) integrity of the base and caprock, and
    - vi) if fracturing is evident, explanation of how containment can be assured
  - c) bottomhole injection pressure, maximum sandface pressure, fracture propagation pressure, and formation fracture pressure for each of the well(s) in clause 3)(2) a).
  - d) BCS stabilized shut-in reservoir pressures in accordance with *Directive 040* requirements at the injection well(s) referred to in clause 3)(2) a), accompanied by pressure transient analyses (PTA), which may provide indication of fracture flow,
  - e) address the need to rerun the CO<sub>2</sub> plume and pressure front models after each well is drilled, and
  - f) evidence that the current MMV Plan commitments have been met.
- 5) The Approval Holder must conduct the CO<sub>2</sub> injection only through the well(s) referred to in clause 3)(1) a) in accordance with the following requirements and those of Table 1:
- a) the BCS Formation stabilized shut-in reservoir pressure in each injection well listed in clause 3)(1) a) must not exceed 26 000 kilopascals (gauge),
  - b) the Approval Holder must obtain stabilized shut-in reservoir pressures in accordance with *Directive 040* requirements after 2 years of injection at the well(s) referred to in clause 3)(1) a). Based on the results, additional tests may be required in order to better understand the plume movement,
  - c) a hydraulic isolation log must be run on the injection well(s) and deep monitoring wells in accordance with *Directive 051* after two years of injection. 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,
  - d) the cumulative injection volume for all approved scheme wells must not exceed 14 500 million cubic metres of CO<sub>2</sub> at standard conditions (15°C, 101.325 kPa), which is an equivalent mass of 27 million tonnes.

- e) no waste or other materials may be added to the injectant. The injectant must contain no less than 95 per cent of CO<sub>2</sub> by volume. The composition of the injection stream must be monitored by taking a representative sample of the injectant on a monthly basis,
  - f) continuously monitor the pressures of the tubing/casing annulus for the injection well(s), conduct annual packer isolation tests, which must be submitted electronically to the ERCB in accordance with the current MMV Plan, implement appropriate corrosion protection, and install and test the wellhead emergency shutdown valves prior to commencement of the CO<sub>2</sub> injection to ensure their proper operation. 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 [WellOperations@ercb.ca](mailto:WellOperations@ercb.ca),
  - g) immediately suspend injection operations if the injection facilitates the movement of fluids into any zone above the base of groundwater protection or any zone other than the BCS, and immediately inform [WellOperations@ercb.ca](mailto:WellOperations@ercb.ca),
  - h) immediately suspend injection operations if any injection equipment, monitoring equipment, or safety devices fail that could compromise the safe operation of the scheme,
  - i) immediately report any loss of containment, anomalies that indicate fracturing out of zone, or anomalous pressure changes occurring anywhere within the CO<sub>2</sub> disposal approval area to [ResourceCompliance@ercb.ca](mailto:ResourceCompliance@ercb.ca) and [WellOperations@ercb.ca](mailto:WellOperations@ercb.ca),
  - j) apply to remove the injection well from the list in clause 3)(1) a), before abandoning any well in the disposal project,
  - k) apply for and receive approval of its abandonment plan from the Well Operations Section, before abandoning any well in the disposal project, and
  - l) continue to monitor the injection and observation wells in accordance with the current MMV Plan, until the CO<sub>2</sub> disposal scheme is transferred to the Government of Alberta or when the subject approval is rescinded.
- 6) The Approval Holder must provide a written incident report within 90 days to [ResourceCompliance@ercb.ca](mailto:ResourceCompliance@ercb.ca) and [WellOperations@ercb.ca](mailto:WellOperations@ercb.ca) for an event that raises any immediate risk to public safety or environment including
- a) any anomalies that indicate fracturing out of zone,
  - b) any indications of loss of containment,
  - c) unexpected surface heave, and
  - d) appropriate mitigative measures taken.

If monitoring shows loss of containment or unexpected surface heave the approval holder is required to conduct and submit results of more comprehensive project modeling using site-specific parameters to re-evaluate the issue of deformations caused by pressure changes.

- 7) The Approval Holder is required to submit MMV plan updates as required by the ERCB; at a minimum updates are required at the critical milestones for commencement of injection, closure and post closure.

- 8) The Approval Holder must provide a complete pre baseline MMV plan by September 30, 2012, which includes a full set of baseline measurements to be taken during the pre-injection period and submitted to [ResourceCompliance@ercb.ca](mailto:ResourceCompliance@ercb.ca).
- 9) The Approval Holder must provide a special report by September 30, 2012, which includes the following;
  - a) a phased assessment of natural variability of the geochemistry of the water in the domestic water wells included in its baseline study, including the need for more frequent sampling during both the baseline data collection and early operational monitoring periods,
  - b) explanation of method for determining statistical significance of number of landowner water wells included in baseline data collection and analysis,
  - c) potential need for downhole microseismic arrays in other deep monitoring wells,
  - d) geomechanical testing of primary seal (MCS),
  - e) InSAR results to date and need for corner reflectors. If corner reflectors are deemed necessary the Approval Holder will be required to install the reflectors near each injection site at least 15 months prior to injection,
  - f) update on technologies to be used for monitoring changes in vegetation health due to surface leaks, and
  - g) evaluation and analysis of the need to add another deep monitoring well completed in the Winnipegosis formation at either the 15-16-060-21W4M or 15-29-060-21W4M locations.

The report must be submitted to [ResourceCompliance@ercb.ca](mailto:ResourceCompliance@ercb.ca).

- 10) The Approval Holder must provide annual status reports and presentations. The reports must be aligned to the most current MMV plan and submitted to [ResourceCompliance@ercb.ca](mailto:ResourceCompliance@ercb.ca). The report must be in metric units and include:
  - a) a summary of scheme operations including, but not limited to,
    - 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.
  - b) complete pressure analysis including but not limited to stabilized shut-in formation pressures and a discussion on how the pressure compares with the formation pressure expected for the cumulative volume of CO<sub>2</sub> injection, along with an updated estimate of what the actual cumulative injection volume will be at the maximum shut-in formation pressure specified in clause 5) a),
  - c) discussion of the overall performance of the scheme, including: how the formation pressure is changing over time; updated geological maps; and updated CO<sub>2</sub> plume extent and pressure distribution models, if needed. The updated models should be based on all new data obtained since the last model run including the cumulative CO<sub>2</sub> injected to the end of the reporting period.

- d) a summary of MMV Plan activities, performance and results in the reporting period, including, but not limited to:
  - i) a report on any event that exceeded the approved operating requirements or triggered MMV activities,
  - ii) comparison of measured performance to predictions,
  - iii) summary of operations and maintenance activities conducted,
  - iv) details of any performance or MMV Plan issues that require attention,
  - v) pressure surveys, corrosion protection, fluid analyses, logs and any other data collected that would help in determining the success of the scheme, and
  - vi) discussion of the need for changes to the MMV plan.
- e) a table for all wells listed in clause 3)(1) a), showing the following injection data for each month of the reporting period:
  - i) mole fraction of the CO<sub>2</sub> and impurities in the injection stream,
  - ii) volume of the CO<sub>2</sub> injected at standard conditions,
  - iii) formation volume factor of the injected CO<sub>2</sub> stream,
  - iv) cumulative volume of the injected CO<sub>2</sub> at standard conditions following the commencement of the scheme,
  - v) volume of the CO<sub>2</sub> injected at reservoir conditions,
  - vi) hours on injection,
  - vii) maximum daily injection rate at standard conditions,
  - viii) average daily injection rate at standard conditions,
  - ix) maximum wellhead injection pressure (MWHIP) and corresponding wellhead injection temperature,
  - x) average wellhead injection pressure, corresponding average wellhead injection temperature,
  - xi) maximum bottom hole injection pressure (MBHIP) at the top of injection interval and the corresponding bottom hole injection temperature, and
  - xii) average bottom hole injection pressure at the top of injection interval and the corresponding average bottom hole injection temperature.
- f) a table showing the volumes of injected CO<sub>2</sub> on a monthly and cumulative basis,
- g) Hall Plots of constant average reservoir pressure where unexplained anomalous injection rate and pressure data could indicate fracturing.
- h) a plot showing the following daily average data at standard conditions versus time since the commencement of CO<sub>2</sub> injection:
  - i) daily CO<sub>2</sub> injection rate,
  - ii) wellhead and bottom hole injection pressure, and
  - iii) estimated or measured average reservoir pressure in the target formation.
- i) the potential need for installing additional monitoring wells in the Winnipegosis and BCS towards the periphery of the pressure build up zone in the BCS later in the project life,

- j) evaluate the need for additional deep monitoring wells adjacent to the four legacy wells in the approval area. Based on the information provided the ERCB may require the Approval Holder to drill one or more such deep monitoring wells, and
  - k) discussion of stakeholder engagement activities in the reporting period.
- 11) The Approval Holder must provide its first annual status report by January 31, 2013. The report must include all the relevant requirements listed in clause 10). This report must also provide a summary of construction and implementation activities, as well as updates, conclusions, and reviews of
- a) the feasibility of using 07-11-059-20W4M and 05-35-059-21W4M injection wells as BCS monitoring wells prior to commencement of injection,
  - b) detailed feasibility of technical, operational, cost and public safety considerations of adding mercaptans,
  - c) the initial baseline fall-off test analyses of 00/08-19-059-20W4/0 and any other drilled injection wells, and
  - d) any testing results in relation to construction and implementation activities.
- 12) The Approval Holder must provide a special report by January 31, 2013, on the suitability of the InSAR baseline data for pressure front and geomechanical modeling and analysis.
- 13) The Approval Holder must provide a special report by January 31, 2014, on the feasibility of using an artificial tracer for CO<sub>2</sub> injection, including conclusions and action plan, and provide a discussion of alternatives.
- 14) The Approval Holder must provide its second annual status report by January 31, 2014. The report must include all the relevant requirements listed in clause 10). As well, this report must include updates, conclusions, and reviews of:
- a) geology update from new injection wells,
  - b) initial injection well drilling and testing, and need for additional injection wells, and
  - c) any testing results in relation to construction and implementation activities.
- 15) The Approval Holder must provide its third annual status report by January 31, 2015. The report must include all the requirements listed in clause 10). Furthermore, this report must also include update, conclusions, and review of:
- a) baseline data and analysis of biogenic flux of CO<sub>2</sub> in different soil types throughout the approval area,
  - b) geology update from new injection wells,
  - c) initial injection well drilling and testing, and need for additional injection wells,
  - d) any testing results in relation to construction and implementation activities, and
  - e) the MMV Plan.
- 16) The Approval Holder must provide a special report by July 31, 2015. This report must include the efficacy of the InSAR program. Installation of GPS instruments may be required if the quality of InSAR data is too low for effective monitoring.

- 17) The Approval Holder must provide ongoing annual reports beginning March 31, 2016 through to March 31, 2040. The report must include all the requirements listed in clause 10). The Approval Holder must provide a report and presentation of general performance of prior calendar year, identification of operations problems, and discussion of the need for MMV changes. Include updates, conclusions and review of:
- a) need for additional deep monitoring wells adjacent to the four legacy wells in the approval area,
  - b) results from well testing including data from annual hydraulic isolation logging,
  - c) need for further hydraulic isolation logging beyond the first five years of injection,
  - d) projected timing for additional 3D surface seismic surveys,
  - e) required frequency of time-lapse seismic surveys,
  - f) update of CO<sub>2</sub> plume and pressure front models including the results of the prescribed reservoir pressure fall-off test two years after the start-up of each injection well,
  - g) need for ongoing fall-off shut-in reservoir pressure tests in all injection wells,
  - h) updated geology, and
  - i) potential need for additional monitoring wells in the Winnipegosis and BCS towards the periphery of the pressure build up zone.
- 18) The Approval Holder must submit a closure report in 2040, which summarizes project total performance, updated surface and subsurface information, and detailed review of containment. It must also include a MMV plan update, with specific attention to any performance problems evident in the 25 years of operations.
- 19) The Approval Holder must submit a post closure report, which includes an update of its MMV plan. Further details will be provided upon review of the closure report as specified in clause 18).
- 20) The Approval Holder must allow additional water well owners to participate in the landowner water well portion of its MMV program at any time. The Approval Holder is required to include such wells in the MMV plan and associated reports.
- 21) The Approval Holder must immediately advise the ERCB of any changes to its pore space rights within the approval area.
- 22) The Approval Holder must comply with all ERCB Acts and Regulations, including all applicable directives and approvals issued by the ERCB.
- 23) The ERCB may at any time vary these terms and conditions or may suspend or revoke this approval if, in its opinion, circumstances so warrant.
- 24) This approval, insofar as it pertains to matters of the environment, is subject to the approval of the Minister of Environment and Sustainable Resource Development, Ministerial Order No. 18/2012, hereto attached as Appendix B.

25) The Approval Holder must submit the MMV plans and project reports referenced in conditions 6, 7, 8, 15, 18, and 19 to Alberta Environment and Sustainable Resource Development for review, who will provide comments and recommendations to the ERCB pertaining to matters of the environment, at:

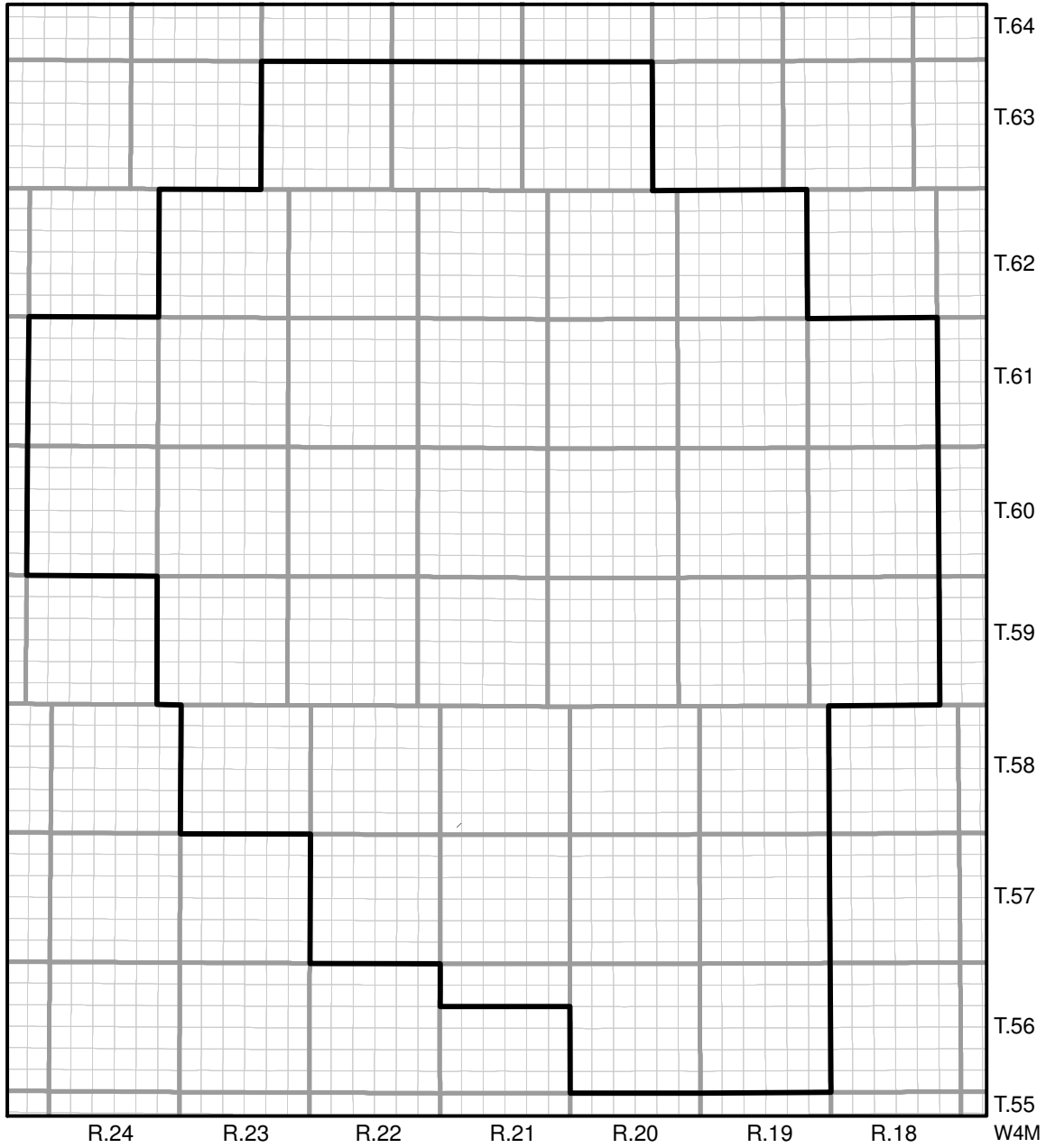
Water Policy Branch  
Environment and Sustainable Resource Development  
Oxbridge Place, 7 Floor  
9820 – 106 Street  
Edmonton, AB T5K 2J6  
[Steve.Wallace@gov.ab.ca](mailto:Steve.Wallace@gov.ab.ca)

26) The Approval Holder must immediately notify the Ministry of Environment and Sustainable Resource Development at 1-800-222-6514, regarding any loss of CO<sub>2</sub> to the atmosphere, soils or shallow (non-saline) aquifers and must provide a copy of any incident report required pursuant to condition 6 of this approval to Alberta Environment and Sustainable Resource Development at:

Water Policy Branch  
Environment and Sustainable Resource Development  
Oxbridge Place, 7 Floor  
9820 – 106 Street  
Edmonton, AB T5K 2J6  
[Steve.Wallace@gov.ab.ca](mailto:Steve.Wallace@gov.ab.ca)

END OF DOCUMENT





**CARBON DIOXIDE DISPOSAL APPROVAL AREA  
 RADWAY FIELD AND SURROUNDING AREAS  
 BASAL CAMBRIAN SAND FORMATION  
 APPENDIX A TO APPROVAL NO. 11837**

**Area(s) of Change**

////// Added

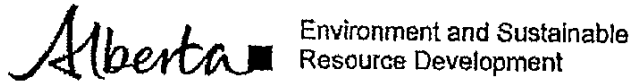
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**TABLE 1**  
**APPROVAL NO. 11837**

1	2	3	4	5
Unique Well Identifiers	Top of Injection Interval (Measured depth - metres KB)	Depth of Production Packer (Measured depth - metres KB)	<sup>1</sup> Maximum Bottomhole Injection Pressure (kilopascals gauge)	Maximum Injection Rate (Thousand Standard Cubic Metres/day)
00/08-19-059-20W4/0	2048.5	2034.4	30 000	600

<sup>1</sup> At top of injection interval (2048.5 metres KB measured depth)

## APPENDIX B



Deputy Minister  
11 Floor, South Petroleum Plaza  
9915 - 108 Street  
Edmonton, Alberta T5K 2G8  
Canada  
Telephone: 780-427-1799  
Fax: 780-415-9669  
[www.alberta.ca](http://www.alberta.ca)

### ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT


*OIL AND GAS CONSERVATION ACT*  
RSA 2000, c. 0-7

#### MINISTERIAL ORDER

18/2012

#### MINISTERIAL APPROVAL NO. 12-11837 ERCB

The attached Appendix B to Approval No. 11837 is ratified as MO 18/2012.

  
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Dana Woodworth  
Deputy Minister of Environment and  
Sustainable Resource Development

APPENDIX B TO APPROVAL NO. 11837

Environment and Sustainable Resource Development

MINISTERIAL APPROVAL

No. 12-11837 ERCB

Edmonton, Alberta  
August 8, 2012

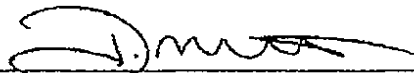
Pursuant to section 39 of the Oil and Gas Conservation Act respecting matters of the Environment, I, Diana McQueen, Minister of Alberta Environment and Sustainable Resource Development, approve an application to the Energy Resources Conservation Board for a Carbon dioxide disposal scheme for up to eight injection wells for the disposal of Class III fluids identified in *Directive 051* and generated from the Province of Alberta. This application shall be granted by Board Approval No. 11837 which includes conditions 25 and 26 as follows:

- 25) The approval holder must submit the monitoring measurement and verification plans and project reports referenced in conditions 6, 7, 8, 15, 18, and 19 to Alberta Environment and Sustainable Resource Development for review, who will provide comments and recommendations to the Energy Resources Conservation Board pertaining to matters of the environment, at:

Water Policy Branch  
Environment and Sustainable Resource Development  
Oxbridge Place, 7 Floor  
9820 – 106 Street  
Edmonton, AB T5K 2J6  
Steve.Wallace@gov.ab.ca

- 26) The approval holder must immediately notify the Ministry of Environment and Sustainable Resource Development at 1-800-222-6514, regarding any loss of carbon dioxide to the atmosphere, soils or shallow (non-saline) aquifers and must provide a copy of any incident report required pursuant to condition 6 of this approval to Alberta Environment and Sustainable Resource Development at:

Water Policy Branch  
Environment and Sustainable Resource Development  
Oxbridge Place, 7 Floor  
9820 – 106 Street  
Edmonton, AB T5K 2J6  
Steve.Wallace@gov.ab.ca



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MINISTER OF ENVIRONMENT AND SUSTAINABLE RESOURCE  
DEVELOPMENT