QUANTIFICATION PROTOCOL FOR NITROUS OXIDE EMISSIONS REDUCTIONS FROM FARM OPERATIONS

Version: DRAFT FOR PUBLIC COMMENT **July 2010**

Specified Gas Emitters Regulation

Government of Alberta

Alberta

Disclaimer:

The information provided in this document is intended as guidance only and is subject to periodic revisions. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and applicable legislation for all purposes of interpreting and applying the law. In the event that there is a discrepancy between this document and the *Specified Gas Emitters Regulation* or other legislation, the *Specified Gas Emitters Regulation* and other legislation prevail.

All Quantification Protocols Accredited under the *Specified Gas Emitters Regulation* are subject to periodic review as deemed necessary by the Department, and will be re-examined at a minimum of every 5 years from the original publication date to ensure methodologies and science continue to reflect best-available knowledge and best practices. Any updates to protocols occurring as a result of the 5-year and/or other reviews that are not due to legal requirements will apply at the end of the first credit duration period for applicable project extensions and for all new projects coming forward.

Where a project condition differs from accredited government methodologies, or the Project Developer is unclear on protocol interpretation relative to their specific project, the Project Developer must contact Alberta Environment to discuss an appropriate interpretation and receive approval for any methodology changes prior to undertaking the project.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

Alberta Environment
Climate Change Secretariat
12th Floor, 10025 – 106 Street
Edmonton, Alberta, T5J 1G4
E-mail: **AENV.GHG@gov.ab.ca**

Date of Publication:

ISBN: 978-0-7785-8995-2
ISBN: 978-0-7785-8996-9

Table of Contents

List of Tables

List of Figures

Alberta Environment Related Publications

Climate Change and Emissions Management Act
Specified Gas Emitters Regulation
Specified Gas Reporting Regulation

Alberta's 2008 Climate Change Strategy

Technical Guidance for Completing Annual Compliance Reports
Technical Guidance for Completing Baseline Emissions Intensity Applications
Additional Guidance for Cogeneration Facilities
Technical Guidance for Landfill Operators

Technical Guidance on Third Party Verification[1]
Supplemental Bulletin on Validation and Verification

Technical Guidance for Offset Project Developers
Technical Guidance for Offset Protocol Developers
Quantification protocols (http://environment.alberta.ca/1238.html)

[1] Alberta Environment is developing guidance for third party verification.

1.0 Offset Project Description

Projects that are implemented according to this protocol generate carbon offsets by switching to an integrated set of Beneficial Nitrogen (N) Management Practices (BMPs) for annual and perennial cropping. These BMPs manage applied nitrogen sources in a more comprehensive and sophisticated way to reduce nitrous oxide emissions associated with nitrogen fertilizer application. These BMPs are integrated into a new technology called a **Consistent 4R (Right Source @ the Right Rate, the Right Time and the Right Place) Nitrogen Stewardship Plan.**

Implementing a comprehensive 4R Consistent Nitrogen Stewardship Plan results in applied nitrogen (N) being used more effectively to grow agricultural crops. Further, implementing the 4Rs together, across landscapes, generates real reductions of nitrous oxide emissions from agricultural cropping systems. Implementing the entire, comprehensive 4R Consistent Nitrogen Stewardship Plan at the appropriate performance levels as dictated by this protocol, generates Offset Credits. Projects that implement only individual elements of the new technology are not eligible to generate emission reductions using this protocol.

This quantification protocol is written for the farmer, agricultural professional, project developer and aggregator. Agricultural professionals will be assisting farmers in implementing the 4R Consistent Nitrogen Stewardship Plan. These professionals must be trained and accredited to apply this protocol. More detail on this accreditation program is given in the next few sections. The project developer/aggregator will work with the farmer and agricultural professional to compile the project(s) in accordance with this protocol and the criteria of the Alberta offset system.

1.1 Protocol Scope

The scope of this protocol is limited to on-farm reductions of emissions from nitrogen sources and fuel use associated with the management of fertilizer, manure and crop residues for each annual or perennial crop type grown. Lands grazed by animals are excluded from this protocol as are greenhouse gas reductions associated with carbon sequestration in the soil and the off-site emission reductions affected by the manufacture and distribution of nitrogen fertilizers[2]. The exclusion of off-site reductions of fertilizer manufacturing increases conservativeness in emission reduction calculations and limits the scope of quantification to those sources, sinks and/or reservoirs for which data is readily available.

[2] Implementing the protocol will result in reduced applications of nitrogen fertilizer relative to baseline conditions. It is conservative to exclude upstream emission reductions.

Farming and cropping systems are complex, often with interdependent practices. Farm greenhouse gas emissions may be impacted by a number of activities, in addition to emissions from the application of nitrogen fertilizer.

Other emission reduction activities, where quantification protocols exist, can be used in conjunction with this protocol. For example, the Quantification Protocol for Tillage System Management can be added or "stacked" to create greater opportunities for farms.

Emission Reduction Activity

Application of nitrogen from manure, biological fixation, fertilizer, and crop residues is an important component of agricultural production. Fertilizer-derived nitrogen, like any form of soil mineral nitrogen[3] (or 'free' or 'soluble' nitrogen), is subject to emission as nitrous oxide (N_2O) from nitrification/denitrification pathways in the soil, losses through leaching of nitrate, and/or volatilization and redeposition of ammonia gas. Beneficial practices for nitrogen management (BMPs), which synchronize the availability of nitrogen (N) with the requirements of the crop, minimize the emissions of N_2O per unit of crop production[4].

This protocol manages these N_20 emission pathways by managing on-farm applied nitrogen sources to:

- Optimize the crop response per unit of added nitrogen; and,
- Minimize the opportunity for nitrate-N to accumulate or persist in the soil where it is potentially denitrified, and/or emitted directly or indirectly as N_2O or lost to the system through leaching.

This is a risk-management approach to nitrogen management based on over 40 years of research and understanding of the risk to applied nitrogen in cropping systems in North America. The Right Source, Right Rate, Right Time, Right Place (4R) Consistent Nitrogen Stewardship plan used in this protocol is designed to address this risk by promoting comprehensive nitrogen management across the 4Rs to achieve the above two outcomes.

Eligible Project Conditions

The project condition, hereinafter called the 4R Consistent Plan, takes all forms of nitrogen into account, including inorganic fertilizers applied to a particular crop (i.e. manure nitrogen, crop residue nitrogen, irrigation nitrogen, etc). Emission reductions are calculated on a crop by crop basis known as 'crop events'. Both annual and perennial crops are eligible for participation, provided that nitrogen is added in the cropping system in the form of synthetic or organic fertilizer – thus, farms applying manure, or using pulse

[3] Mineral N refers to NH4+ (ammonium) or NO3- (nitrate)

[4] For a literature review of the beneficial nitrogen management practices to minimize N_2O emissions, see Snyder *et al.* 2007, Greenhouse Gas Emissions from Cropping Systems and the Influence of Fertilizer Management. This publication can be downloaded at http://www.ipni.net/ipniweb/portal.nsf/0/d27fe7f63bc1fcb3852573ca0054f03e/$FILE/IPNI%20BMPs%20&%20GHG.pdf.

crops are still eligible to use this protocol. Lands grazed by animals are excluded from this protocol; however, forages grown for silage or bailed are eligible.

Emissions and emission reductions are quantified on a per kg of each crop produced, so rotations used on the farm can be accommodated.

To use this protocol, Project Developers must:

- Provide evidence that a 4R Consistent Plan has been implemented (see, Table 1 for Drier soils in Canada (mostly prairie soils) and Table 2 for Moister soils in Canada);
- Develop the 4R Consistent Plan for each farm in consultation with an Accredited Professional Advisor at the selected performance management level of either Basic, Intermediate, or Advanced;
- Be able to calculate baseline N_20 emissions from a three year average of N_20 emissions per kg of crop produced prior to project implementation;
- Calculate project emission reductions on a per kg of crop produced under the 4R Consistent Plan using Canada's National Inventory Report quantification method and the Reduction Modifier for the performance level as outlined in this protocol (Table 1 and Table 2).
- Ensure that all eligible land managed by the participating farm is included in the 4R Consistent Plan and in the quantification of emissions and reductions.

The project condition requires more comprehensive data for nitrogen recommendations, more extensive monitoring procedures and more sophisticated Beneficial Management Practices (BMPs) relative to the baseline condition as outlined in the Tables below. As the performance level increases from Basic to Intermediate/Advanced, the 4R Consistent Plan must more precisely address field variability, and more sophisticated BMPs. The greater the performance level, the more potential there is for reduced emissions as shown by a smaller reduction modifier.

Table 1: Overview of the 4R Consistent Plan and BMP Performance Levels for the Drier Soils in Canada[5]

Performance Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
Basic	• Ammonium-based formulation;	• Apply N according to recommendation of 4R N stewardship plan*, using annual soil testing and/or N balance to determine application rate.	• Apply in spring; or • Split apply; or • Apply after soil cools in fall	Apply in bands / Injection	0.85

[5] Note – drier soils are defined as those found in Ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0 (see Appendix B).

Intermediate	• Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized N	• Apply N according to qualitative estimates of field variability (landscape position, soil variability)	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized N	Apply in bands / Injection	0.75
Advanced	• Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized N	• Apply N according to quantified field variability (e.g. digitized soil maps, grid sampling, satellite imagery, real time crop sensors.) and complemented by in season crop monitoring	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized N	Apply in bands / Injection	0.75

*4R Consistent Plan must account for all sources of N, including previous crop residues, fertilizer, manure or biosolids applications. Plan also prescribes assessment of N in crop, so this serves to supplement or replace information from soil testing.

Table 2: Overview of the 4R Consistent Plan and BMP Performance Levels for Moister Soils in Canada[6].

Performance Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
Basic	• Ammonium-based formulation;	• Apply N according to recommendation of 4R N stewardship plan*, using annual soil testing** and/or N balance to determine application rate.	• Apply fertilizer in spring only; or • Split apply. • Apply liquid or solid manure in spring; or • After soil cools in fall	Apply in bands / Injection	0.85
Intermediate	• Ammonium-based formulation;	• Apply N according to 4R N stewardship plan*, modified by qualitative estimates of field variability (landscape position, soil variability)	• Apply fertilizer or liquid manure in spring only; or • Split apply. • Apply solid manure in spring; or • Apply after soil cools in fall	Apply in bands / Injection	0.75

[6] Note – moister soils are defined as those found in Ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of 1.0 or higher (see Appendix B). [6] Consensus was not achieved at the science workshop to determine an actual measurable difference with the Advanced level in terms of emission modifier values, therefore more research is required to apply a lower value.

Advanced	• Ammonium-based formulation; • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized nitrogen.	• Apply N according to 4R N stewardship plan*, modified by quantified field variability (e.g. digitized soil maps, grid sampling, satellite imagery, real time crop sensors.), and complemented by in season crop monitoring	• Apply controlled release fertilizer or inhibitor / stabilized nitrogen fertilizer; or • Apply liquid manure in spring; or • Split apply; • Apply solid manure in spring; or • Apply after soil cools in fall.	Apply in bands / Injection	0.75[7]

*4R Consistent Plan must account for all sources of N, including previous crop residues, fertilizer, manure or biosolids applications. Plan also prescribes assessment of N in crop, so this serves to supplement or replace information from soil testing.
**where appropriate for the crop, and calibration data is available.

Justification for the Baseline

This protocol uses an **historic benchmark baseline** approach. This approach estimates the baseline greenhouse gas emissions based on three years of site-specific data for each crop from the participating farm, prior to the implementation of a 4R Consistent Plan.

Independent survey data of nutrient management practices across the country show that it is highly unlikely the complete suite of practices associated with the 4R Consistent Plan, applied consistently every year, is a common practice[8] and that the application of this plan will result in a technology change at the farm level.

The 4R Consistent Plan provides this technology change through:

1. A comprehensive and professionally-developed nitrogen management plan to account for all sources of nitrogen at the farm level and to address 4R management of nitrogen applicable essentially to all farmers; and
2. Providing greater assurance around nitrogen use for all farmers including those that had sophisticated nitrogen practices during baseline period. Farmers that already were already undertaking annual testing or variable rate application, likely would not achieve N_2O emission reductions without the framework of all the BMPs of the 4R Consistent Plan (i.e. there can be no assurance that N_2O reductions are achieved without assurance that all 4Rs are addressed).

[8]; According to recent surveys, 30% of Alberta farms do not perform annual soil nutrient testing at all, with 44% of farms performing the test every 2 to 5+ years (StatsCan 2001 , as confirmed by IPSOS 2006); Only 11% of Alberta's farms develop and implement nutrient management plans (StatsCan 2001). IPSOS survey (2006) indicated majority of plans were prepared by growers without support of trained advisors. Field-scale BMPs (Basic level) have informational and financial barriers; Landscape-directed BMPs (Intermediate and Advanced levels) have technological and financial barriers. The 4R Consistent Plan is a new technological innovation, and was adopted in Canada by the Canadian Fertilizer Institute and affiliated agencies in 2007.

The Accredited Professional Advisor, as part of the 4R Consistent Plan development, identifies the baseline management practice of the Project Developer. In cases where the Project Developer is already at the basic performance level of 4R management and implementing all the BMPs in the basic level every year, this level will be set as the baseline for the project. In this case, the Project Developer would need to ensure that the farm is implementing the intermediate/advanced performance level in the project condition.

A farm may also acquire new land holdings or expand management on new leased lands. The baseline performance of these lands will need to be assessed to determine prior to being incorporated into the farm’s 4R Consistent Plan. It is expected that in the early years of the program, these farms will not be performing at the basic or intermediate/advanced performance level; however, over time, fields may be brought in that are already 4R compliant. In these cases, the baseline will be set at the performance level and the field will need to meet a higher performance level to generate credits. The Project Developer should work with the former owner/land manager to understand and document the baseline activity for the field(s).

The comparable metric for calculating emission reductions between baseline and project conditions is achieved by expressing emissions on a per kg of crop produced basis. This ensures that emissions are normalized to a common base unit of production, thereby allowing quantification of real emissions reductions resulting from the project condition.

The quantification of direct and indirect N_2O emissions from more sophisticated use of fertilizer is based on published emission factors from Canada’s National Inventory Report and is calculated as a proportion of the amount of fertilizer nitrogen applied. This quantification is performed on an eco-district basis, which accounts for variables associated with soil type, texture, topography, and climate. The greenhouse gases involved in the calculation are shown in Table 3.

Table 3 Relevant Greenhouse Gases Applicable for this Protocol.

Specified Gas	Formula	100-year GWP	Applicable to Project
Carbon Dioxide	CO_2	1	
Nitrous Oxide	N_2O	310	

1.2 Protocol Applicability

To apply this protocol, the Project Developer must prove the following requirements:

1. The 4R Consistent Plan, including clear identification of the baseline and project condition has been accredited and signed by an Accredited Professional Advisor;

2. The project is being implemented according to the 4R Consistent Plan and has received annual sign-off by the Accredited Professional Advisor;
3. New crops being added to the project have correctly established three years of baseline data on crop events prior to including the crop in the project;
4. The quantification of reductions achieved by the project is based on actual measurement and monitoring as required in this protocol; and,
5. The project meets the eligibility criteria stated in section 7.0 of the *Specified Gas Emitters Regulation.* In order to qualify, emissions reductions must:
    a. Occur in Alberta;
    b. Result from actions not otherwise required by law;
    c. Result from actions taken on or after January 1, 2002;
    d. Be real, demonstrable, and quantifiable;
    e. Have clearly established ownership including, if applicable, appropriate, documented transfers of ownership from the land owner to land lessee;
    f. Be counted once for compliance; and
    g. Be implemented according to ministerial guidelines.

<u>Role of the Accredited Professional Advisor:</u>
Project Developers need to ensure that farmers implementing projects under this protocol work with an Accredited Professional Advisor to develop and implement a 4R Consistent Plan for their farm operations. Sign-off by the Accredited Professional Advisor is required as part of the mandatory project documentation required for Nitrous Oxide Emission Reduction projects.

Accredited Professional Advisors (APA) are persons who have completed training through the Canadian Fertilizer Institute and have been accredited under their program. Accreditation requires the basic credentials as an agricultural professional (Professional Agrologist, or Certified Crop Advisor) along with supplementary training on the 4R N Stewardship model and the requirements of the 4R Consistent Plan described in this protocol. The details of the Accredited Professional Advisor professional accreditation program, and required 4R qualifications are described in Appendix C.

The Accredited Professional Advisor is required to:

1. Review and sign-off on the baseline calculations made by the farmer and the Project Developer. This involves reviewing project documentation for baseline practices, providing an opinion concerning the appropriateness of the conclusions supported by the documentation, and attesting to the accuracy of calculations based on the documentation. See Section 2 for description of baseline conditions.
2. Design and sign-off on a 4R Consistent Plan for the participating farm. This plan will address all fields and all crops at the performance level selected by the

Project Developer/farmer. The details of the design of the 4R Plan are provided in Section 3.

3. Provide sign-off that the 4R Consistent Plan was implemented as designed for each participating farm in the Project Developer's project. This will involve a Post-Harvest Assessment of activities including responses to weather-related disruptions of yield data and testing results. It is expected this assessment will form the basis for the following year's 4R Consistent Plan. See Section 5.2.1 for a full description of post-harvest assessment required.

Note: The Accredited Professional Advisor sign-off does not constitute formal validation or verification for the project. Independent, third party verification is required for all Offset Credits being serialized and registered on the Alberta Emissions Offset Registry for use as a compliance option under the *Specified Gas Emitters Regulation*.

The general data requirements for this protocol are shown in Table 4. Additional details are provided in Sections 4 and 5.

Table 4: General Overview of Data Requirements to Justify the Baseline and Project Condition for Nitrous Oxide Emissions Reduction Projects for Annual and Perennial Cropping Systems.

Data Requirements:	**Examples of Records**	**Why do you need it?**
For all implementation levels: Legal Land location and aerial photographs of all fields. For intermediate/advanced performance levels, GPS coordinates or digital field maps.	Legal land description for the registration of the project and ownership agreements between land lessees/land title owners (in tenure situations) and commercial agreements between entitled parties.	Clear title to all or a portion of the offset credits (checked through the Registry) Actual field and sub-filed sizes.
For baseline: • Proof of crops grown, • Total area under each crop event, • Fertilizer rates for each crop event, • N inputs used per crop event, • Yields achieved per crop; and • Total area under summerfallow For 3 years of representative farming practices.	• Aerial or digital maps of fields. • Purchase receipts for seed, fertilizer. • Sales and/or delivery records for crops. • Spreading records for manure and/ or fertilizer. • Depending on the types of nitrogen management practices used in the project, it may be necessary to track fuel use (fuel purchase receipts).	To support calculations of baseline emissions of N_2O per kg of crop produced.
For project: A signed-off 4R Plan designed and implemented under supervision of an Accredited Professional	Signed and/or stamped 4R Plan, prepared according to requirements of the selected performance level (basic/intermediate/advanced). .	Ensures correct application of nitrogen based on crop type for the selected performance level.

Advisor.		
For project: • Proof of crops grown, • Summerfallow area, • Crop event area, • Derived nitrogen recommendations, • Fertilizer used and when • Other N inputs, • Crop yields achieved, • Test results (soils, tissues, manure, etc) • Fertilizer band application proof.	• Aerial or digital maps of fields or sub-fields. • Purchase receipts for seed/fertilizer. • Sales and/or delivery records for grains and oilseeds. • Spreading records for manure and/ or fertilizer. • Test results at resolution required for selected performance level for soil, plant tissue, manure, crop yield. • Depending on the types of nitrogen management practices used in the project, it may be necessary to track fuel use (fuel purchase receipts), • Confirmation of fertilizer opener type and row spacing of seed.	These data provide proof that the 4R plan was followed, and support calculations of project emissions of N_2O and any increased fuel based CO2 emissions, if needed, per kg of crop produced.

1.3 Protocol Flexibility

Flexibility in applying the quantification protocol is provided to Project Developers in the following ways:

1. A Project Developer may choose to select non-consecutive years for crop events to set the baseline to match with data availability and to account for any extra-ordinary growing seasons. However, any gaps between baseline seasons or gaps between the baseline period and project implementation period must be justified such that they are not contributing to an over-estimate of greenhouse gas emission reductions. The verifier must provide a written statement of agreement with the approach selected by the Project Developer;
2. The Project Developer may exclude On-Site Fertilizer and Lime Distribution (Table 6 - SS P7) from quantification where it can be demonstrated that no increased fuel use has occurred as a result of implementing the 4R Consistent Plan; and
3. This protocol applies to a single component (nitrogen management) of farm operations. As such, this protocol can be combined with other protocols where multiple projects are undertaken to lower overall greenhouse gas emissions from farm operations.

1.4 Glossary of New Terms

Ammonium Based Fertilizer	Any fertilizer which releases more than two-thirds of its N in the ammonium form.

Band Application	Fertilizer placed in a concentrated sub-surface row, where fertilizer row is not spread more than 30% of the row laterally.
Accredited Professional Advisor	For the purposes of this protocol the Accredited Professional Adviser (APA) is representative of an individual who fits the requirements outlined in **Appendix C.**
Controlled Release Products	Slow or controlled-release nitrogen products delay, slow or control the release of nitrogen from urea. This is done in order to help manage the timing of nitrogen release from fertilizer and help reduce the risk of leaching losses of NO_3^-. Once applied, urea in liquid or granular fertilizer converts to ammonia (NH_3). The NH_3 is then subject to volatilization losses when the urea-based nitrogen fertilizer is applied on the soil surface. Controlled-release fertilizer products available today include products such as urease inhibitors and polymer-coated urea products.
Denitrification	The conversion of nitrate to nitrogen gas (dinitrogen and various nitrogen oxides, including nitrous oxide) by soil denitrifying microbes under depleted oxygen conditions.
Ecodistrict	A region which has relatively homogenous biophysical and climatic conditions and has an average area of approximately 150,000 ha. Canada consists of approximately 1,000 ecodistricts, of which 400 are considered agricultural.
Fall Application	Fall application, for the purposes of this protocol, is defined as the application of fertilizer to cool soils that have a temperature of 10 degrees Celsius or lower, measured at a depth of 5 cm or deeper. Alternatively, these soils may be identified using the Temperature Map included in **Appendix A**.
Crop Event	The crop event is the operational unit for which N_2O emissions intensity (N_2O per kg crop) is calculated for Baseline and Project. The crop event has three elements —crop type, crop year, and management zone. The crop type is the annual or

perennial crop. For annuals, the crop year is accounted from harvest of previous crop to harvest of current crop. And, for perennials (and for baled or grazed forages and silages), the crop year is accounted from last harvest of previous year to last harvest of current year. The management zone varies with the selected performance level for which the 4R Consistent Plan is designed, and thus will vary between baseline and project (see Management Zone for more information).

Drier Soils	Drier soils are soils that are in an eco-district with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0.
Comparable Metrics	The Project and the Baseline should provide the same function, amount or quality of products or services. This type of comparison requires a common metric or unit of measurement (such as emissions per unit mass of crop produced per unit area in a field) for comparison between the Project and Baseline activity. For this protocol, it is the emissions per unit of crop production between the two conditions.
GPS Coordinates	The description, in alphanumeric characters, of a precise geographic location on earth. For the purposes of GPS navigation, coordinates are most often expressed in latitude and longitude.
Fallowing	Fallow cropland is land that is intentionally left idle or unseeded during a growing season with all plant growth periodically terminated with tillage (summerfallow) or pesticides (chemfallow).
Field Variability — Qualitative	An observation that the soils, topography and nutrient availability in a field vary considerably.
Field Variability — Quantitative	An attempt to take enough samples and observations and run simple statistics to show how variable a field is.
Management Zone	A sub-field unit of a crop event that is managed differently from other management zones within the same field. The management zone of the Basic

	performance level is a whole field of a crop type/event. For the Intermediate level, the management zone refers to each sub-field of a crop event (due to the added BMP of landscape-directed N application). And, the management zone of the Advanced level refers to the delineation of each slope and aspect on the digital map of a field of a crop event. The N_2O emission intensity in the Baseline and Project are calculated as the N_2O emissions per kg crop produced, averaged over all crop events.
Moister Soils	Moister soils are defined as those found in ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of 1.0 or higher. Note: irrigated soils automatically apply an EFeco of 1.7% regardless of which ecodistrict they are in (refer to **Appendix B**).
Nitrification	The microbial transformation of ammonium (NH_4^+) forms of N in a two stage process to nitrite (NO_2^-) and then to nitrate (NO_3^-), as accomplished by *Nitrosomonas* species*, and Nitrobacter* species bacteria respectively.
Nitrification Inhibitor	An additive to ammonium-based fertilizers that inhibits *Nitrosomonas* species bacteria from converting ammonium (NH_4^+) to nitrite (NO_2^-). This effectively keeps the N in ammonium form and slows down conversion to the nitrate (which can be denitrified to N_20 and other N compounds).
Organic Fertilizer	Organic fertilizers are fertilizers that are derived from animal or vegetable matter and include sources such as manure, slurry, worm castings, peat, seaweed, sewage, guano and others.
Precipitation/Potential Evapotranspiration ratio (P/PE)	A measure of the moisture regime in the soil that impacts nitrous oxide emission processes.
"Split Apply"	This term implies that nitrogen will be applied in either two or more applications in the spring and/or early summer.

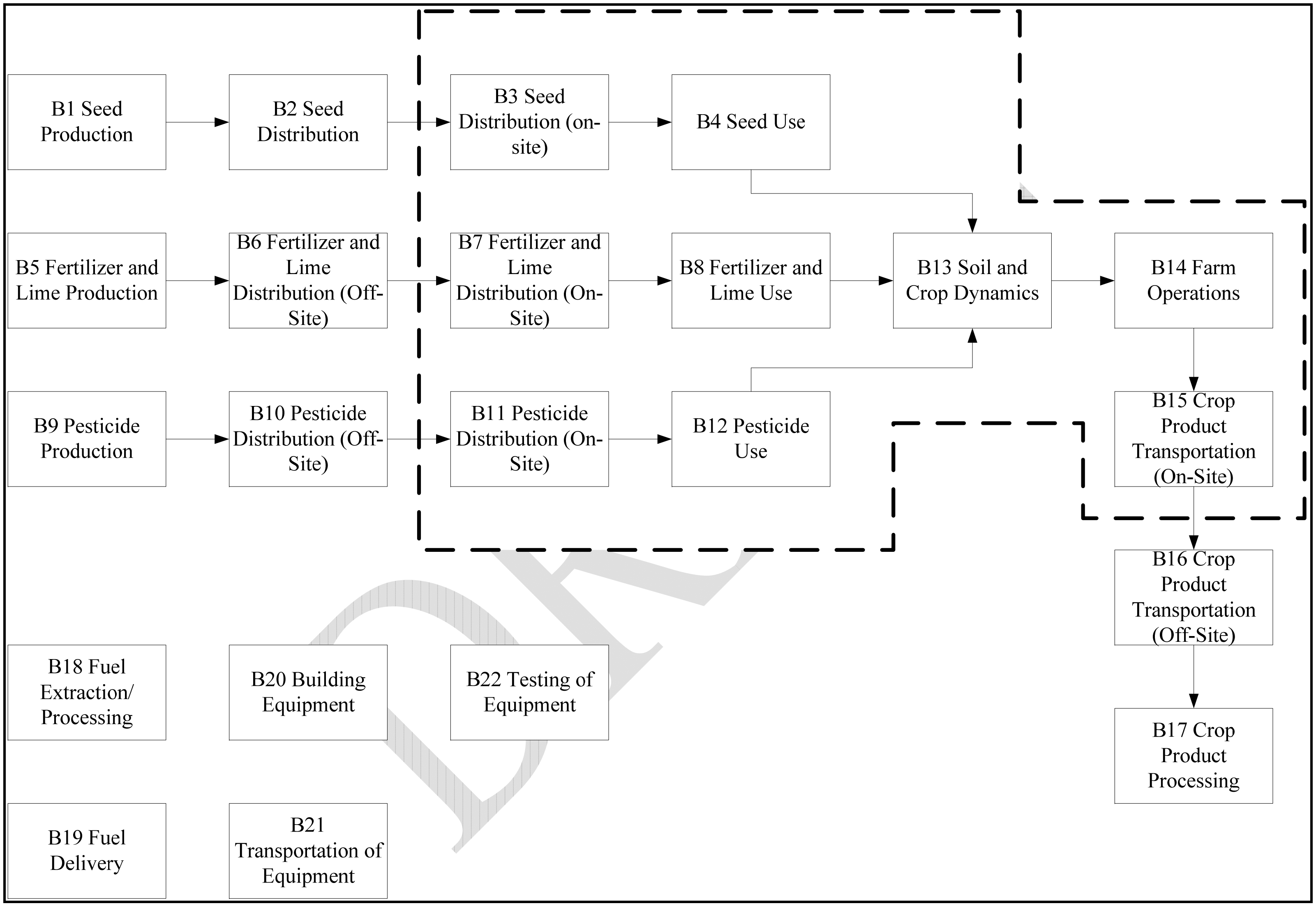
Real-time Crop Sensors	Sensors attached to an N fertilizer applicator used in-crop to assess the crop N status (greenness) and determine whether or not additional N fertilizer should be top-dress applied to the crop.
Spring Application	Spring application, for the purposes of this protocol, refers to application of fertilizer after thaw and before seeding.
Stabilized Nitrogen	This refers to an N fertilizer that has been treated with an additive to reduce potential losses via ammonia volatilization (e.g. an urease inhibitor) and nitrification/denitrification (e.g., a nitrification inhibitor); or, a product that slows down the dissolving of the fertilizer and reaction with the soil matrix (e.g. a polymer coating). It can also be used to describe slow-release N fertilizer products.
Urea-Ammonium Nitrate (UAN)	A nitrogen fertilizer solution composed of urea and ammonium nitrate and is considered an ammonium based fertilizer for this protocol. ***But, fall application of UAN is an ineligible use under the conditions of this protocol.***
Variable Rate Application	A method of automatically varying the rate of a crop input based on a prescription map, generated through soil testing. It consists of software and hardware to created the map, control the rate and locate the equipment in the field. Real-time crop sensors can also be used to measure what is needed by the crop and adjust the rate accordingly in real time.
Yield Monitors	A device mounted on a harvester to record the mass or volume of crop collected. It is typically mated with a GPS receiver to record the location of each yield reading to produce yield maps.

2.0 Baseline Condition

The protocol uses a static historic benchmark baseline condition. Under this scenario, baseline greenhouse gas emissions are quantified for each crop event based on historic nitrous oxide emissions from fertilizer activities. Comparable metrics between the baseline and the project condition are achieved by calculating emissions per kg of crop produced (crop events in the baseline year vs. the project year). While this factor will remain static over time, baseline emissions will vary as a function of the area of land under a specific crop under a specific kind of nitrogen management. The final numbers will have to be adjusted for the crop production differences between the baseline and project emissions to ensure consistency.

This protocol assumes a baseline condition where nitrogen fertilizers (organic and/or inorganic) are applied at higher, less efficient application rates compared to the project condition per crop event where the baseline condition is calculated as the average rate of nitrous oxide emissions from the crop being fertilized based on the average over the three years prior to project implementation. Figure 1 presents the process and material flow for the baseline condition.

Figure 1. Process Flow Diagram for the Project Baseline



2.1 Identification of Baseline Sources and Sinks

Sources and sinks for an activity are assessed based on guidance provided by Alberta Environment[9] and are classified as follows:

Controlled:	The behaviour or operation of a controlled source and/or sink is under the direction and influence of a Project Developer through financial, policy, management, or other instruments.
Related:	A related source and/or sink has material and/or energy flows into, out of, or within a project but is not under the reasonable control of the Project Developer.
Affected:	An affected source and/or sink is influenced by the project activity through changes in market demand or supply for projects or services associated with the project.

Baseline sources and/or sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts, national greenhouse gas inventory scientists and reviewing good practice guidance. This iterative process confirmed that the sources and/or sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided above, the baseline sources and/or sink were organized into life cycle categories in Figure 2. Descriptions of each of the sources and/or sink and their classification as controlled, related or affected are provided in Table 5.

[9] Offset Project Guidance Document for the Alberta Offset System http://xxxx

Figure 2. Baseline Sources and Sinks for Reducing Nitrous Oxide Emissions

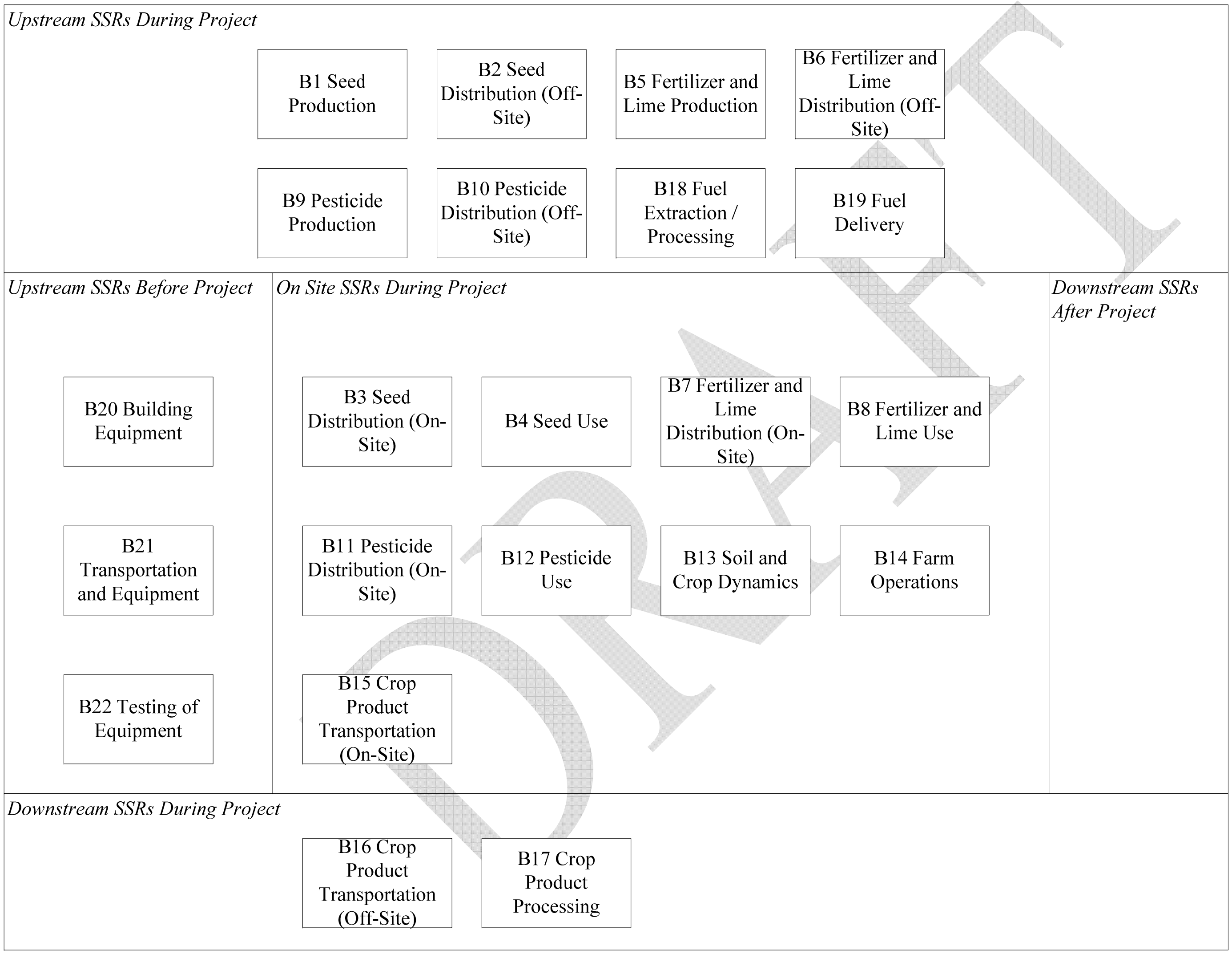


Table 5. Baseline Sources and Sinks.

Source or Sink	Description	Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Seed Production	Seed production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate comparable metrics with the project condition.	Related
B2 Seed Transportation (Off-Site)	Seed may be transported to the project site by truck, and/or train. The related energy inputs for fuelling this equipment are captured under this source for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Related
B5 Fertilizer and Lime Production	Fertilizer and lime production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate comparable metrics with the project condition.	Related
B6 Fertilizer and Lime Distribution (Off-Site)	Fertilizer and lime may be transported to the project site by truck and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Related
B9 Pesticide Production	Pesticide production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate comparable metrics with the project condition.	Related
B10 Pesticide Distribution (Off-Site)	Pesticide may be transported to the farm by truck and/or train. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Related
B18 Fuel Extraction and Processing	Each of the fuels used throughout the baseline will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site sources and sinks are considered under this source. Volumes and types of fuels are the important characteristics to be tracked.	Related

Source or Sink	Description	Controlled, Related or Affected
B19 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by truck, rail or by pipeline, resulting in the emissions of greenhouse gases.	Related
Onsite Sources and Sinks During Baseline Operation		
B3 Seed Distribution (On-Site)	Seed would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled
B4 Seed Use	Emissions associated with the use of the seeds. Inputs of embedded energy and materials would need to be tracked to ensure comparable metrics with the project condition.	Controlled
B7 Fertilizer and Lime Distribution (On-Site)	Fertilizer and lime would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled
B8 Fertilizer and Lime Use	Emissions associated with the use of the fertilizer and lime. Timing, composition, concentration and volume of fertilizer need to be tracked.	Controlled
B11 Pesticide Distribution (On-Site)	Pesticide distribution would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled
B12 Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of fertilizer need to be tracked to ensure comparable metrics with the project condition.	Controlled
B13 Soil Crop Dynamics	Flows of materials and energy that comprise the cycling of soil and plant carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as carbon dioxide and nitrous oxide.	Controlled

Source or Sink	**Description**	**Controlled, Related or Affected**
B14 Farm Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the farm facility and related equipment. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
B15 Crop Product Transportation (On-Site)	Crops would need to be harvested and transported from the field to storage. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled
Downstream Sources and Sinks During Baseline Operation		
B16 Crop Product Transportation (Off-Site)	Crops would need to be transported from storage to the market by truck and/or train. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the project condition.	Related
B17 Crop Product Processing	Inputs of materials and energy involved in the processing and end product utilization of the crop would need to be tracked to ensure comparable metrics with the project condition.	Related
Other		
B20 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B21 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
B22 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related

3.0 Project Condition

The 4R Consistent Plan, with the associated best management practices (BMPs) required for each performance level, are implemented to achieve the reduction of N_2O emissions in the project as compared to the baseline scenario. As the performance level increases from Basic to Intermediate/Advanced, the 4R Consistent Plan must address more precisely field variability through the development of more sophisticated BMPs. The greater the performance level, the more potential there is for emission reductions as shown by a smaller reduction modifier (Table 1 and 2).

A number of resources to describe application of 4R principles are available[10] to support project implementation. Additionally, a comprehensive framework for the design of 4R Consistent Plan is provided in Appendix D. The Alberta Nutrient Management Planning Guide[11] is the primary reference for technical elements of the 4R Consistent Plan such as assessing fields on-site or remotely, soil sampling and testing, calculating fertilizer requirements, etc. The various elements of the 4R Consistent Plans and the technical methods pertinent to nutrient management are also integrated in the training provided to Accredited Professional Advisors.

In the case of catastrophic crop failure (owing to drought, frost, hail, weed infestation, etc.), yield may be decreased to the extent that project emissions per kg crop exceed baseline emissions. In this event, the affected land area would not enroll in the project for that year. Implications of this yield loss and nitrogen remaining in the soil must be addressed in the following year's 4R Consistent Plan approved by an Accredited Professional Advisor.

The steps necessary for meeting the 3 Performance Levels of the protocol are described below.

<u>Basic Performance Level</u>

The 4R Consistent Plan at the basic performance level will:

- Be implemented at a scale of whole fields;
- Use legal land locations and aerial photographs to determine field locations and field size;
- Describe field-scale sampling and testing of soil including accounting for nitrogen supplied as manure and remaining from previous crops to derive fertilizer rate requirements;
- Specify field-specific BMPs for fertilizer application source, rate, place and time;
- Describe yield monitoring for each field;
- Require post-harvest estimate of nitrogen balance for each field, using uptake and removal coefficients (Appendices 6A & 6B of Alberta's Nutrient Management Planning Guide);

[10] http://www.ipni.net/4r
[11] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920

- List the data to be recorded to document activities specified in the 4R Consistent Plan (see Section 5.1 for sample data sources).

<u>Intermediate Performance Level</u>

The 4R Consistent Plan at the intermediate performance level will:

- Be implemented at a scale of sub-fields for each crop, or crop event delineated by areas of above-average and below-average productivity based on the grower's experience and the Accredited Professional Advisor's professional judgment;
- Use GPS coordinates and aerial photographs to determine field location and field size, and to delineate sub-areas (i.e. management zones, according to productivity within fields);
- Describe sub-field-scale sampling and testing of soil based on management zones of below-average and above-average productivity, including accounting for nitrogen supplied as manure and remaining from previous crops, to derive fertilizer rate requirements for sub-field management zones;
- Specify sub-field, management zone-specific BMPs for fertilizer application source, rate, place and time;
- Describe yield monitoring for each sub-field management zone;
- Require post-harvest estimate of the nitrogen balance for each sub-field management zone using results of nitrogen analysis of crops according to the sub-field location;
- List the data to be recorded to document activities specified in the 4R Consistent Plan (see Section 5.1 for sample data sources).

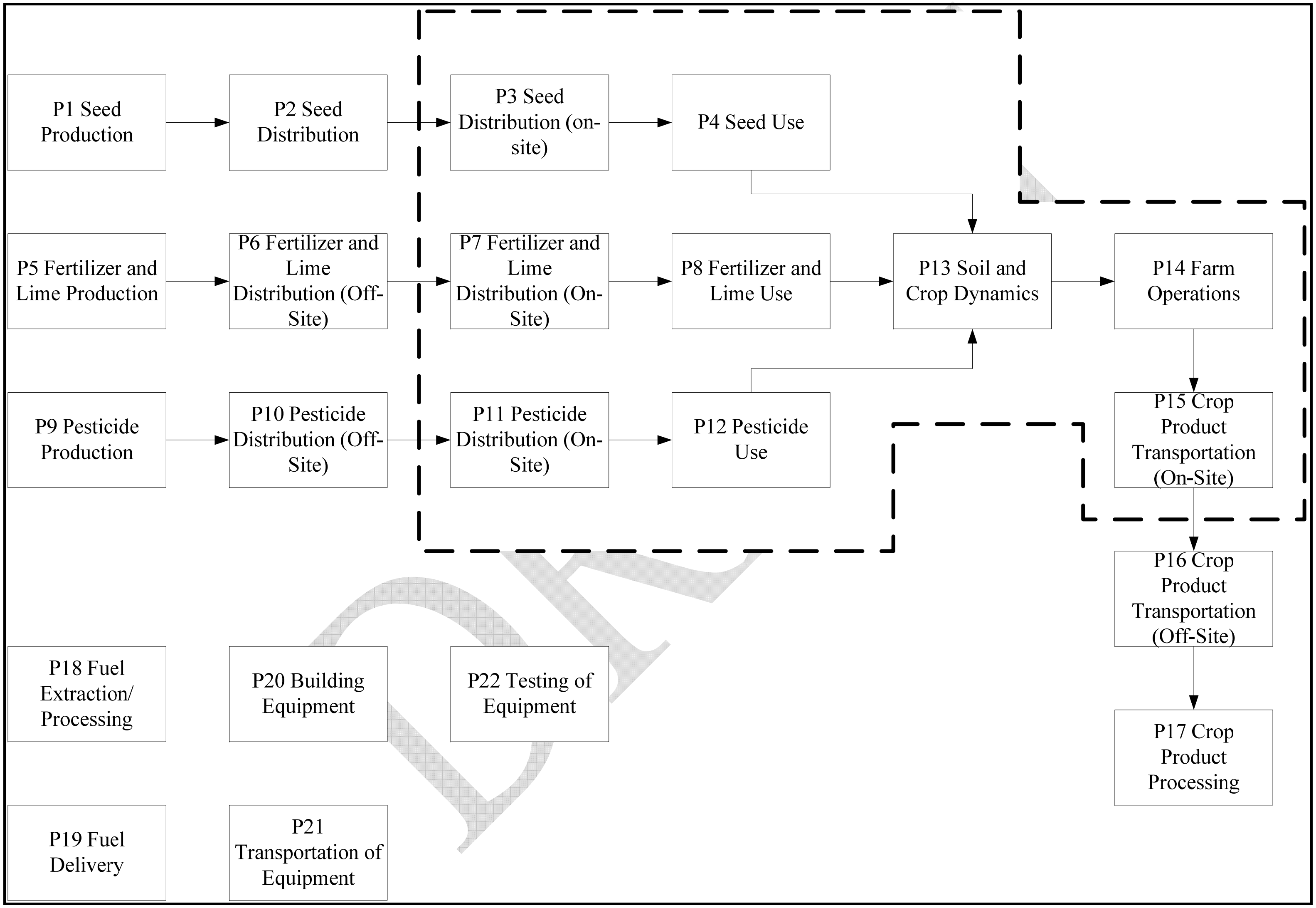
<u>Advanced Performance Level</u>

The 4R Consistent plan at the advanced performance level will:

- Be implemented at scale of sub-field management zone for each crop based on a digitized delineation of slope and aspect;
- Use GPS coordinates and digital maps to determine field location and field size, and to delineate and aggregate sub-field management zones according to slope and aspect;
- Describe sub-field management zone sampling and testing of soil, including accounting for nitrogen supplied as manure and remaining from previous crops to derive fertilizer variable rate requirements;
- Specify BMPs for fertilizer application source, rate, place and time for each management zone;
- Describe the use of combine-mounted yield monitors to map yield according to aspect and slope for each sub-field management zone;
- Require post-harvest mapping of nitrogen balance according to aspect and slope for each sub-field management zone using results of landscape-directed nitrogen analysis of crops;
- List the data to be recorded to document activities specified in the 4R Consistent Plan (see Section 5.1 for sample data sources).

Figure 3 presents the process and material flow for the project condition.

Figure 3. Process Flow Diagram for the Project Condition.



3.1 Identification of Project Sources and Sinks

Sources and sinks for the project were identified based on extensive scientific review. Sources and sinks were also identified for the project by reviewing good practice guidance, consulting with technical experts, national inventory scientists, and other relevant greenhouse gas technical sources. This iterative process confirmed that the sources and sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided above, the project sources and sinks were organized into life cycle categories in Figure 4 below. Descriptions of each of the sources and sinks and their classification as controlled, related or affected are provided in Table 6.

Figure 4. Project Sources and Sinks for Reducing Nitrous Oxide Emissions

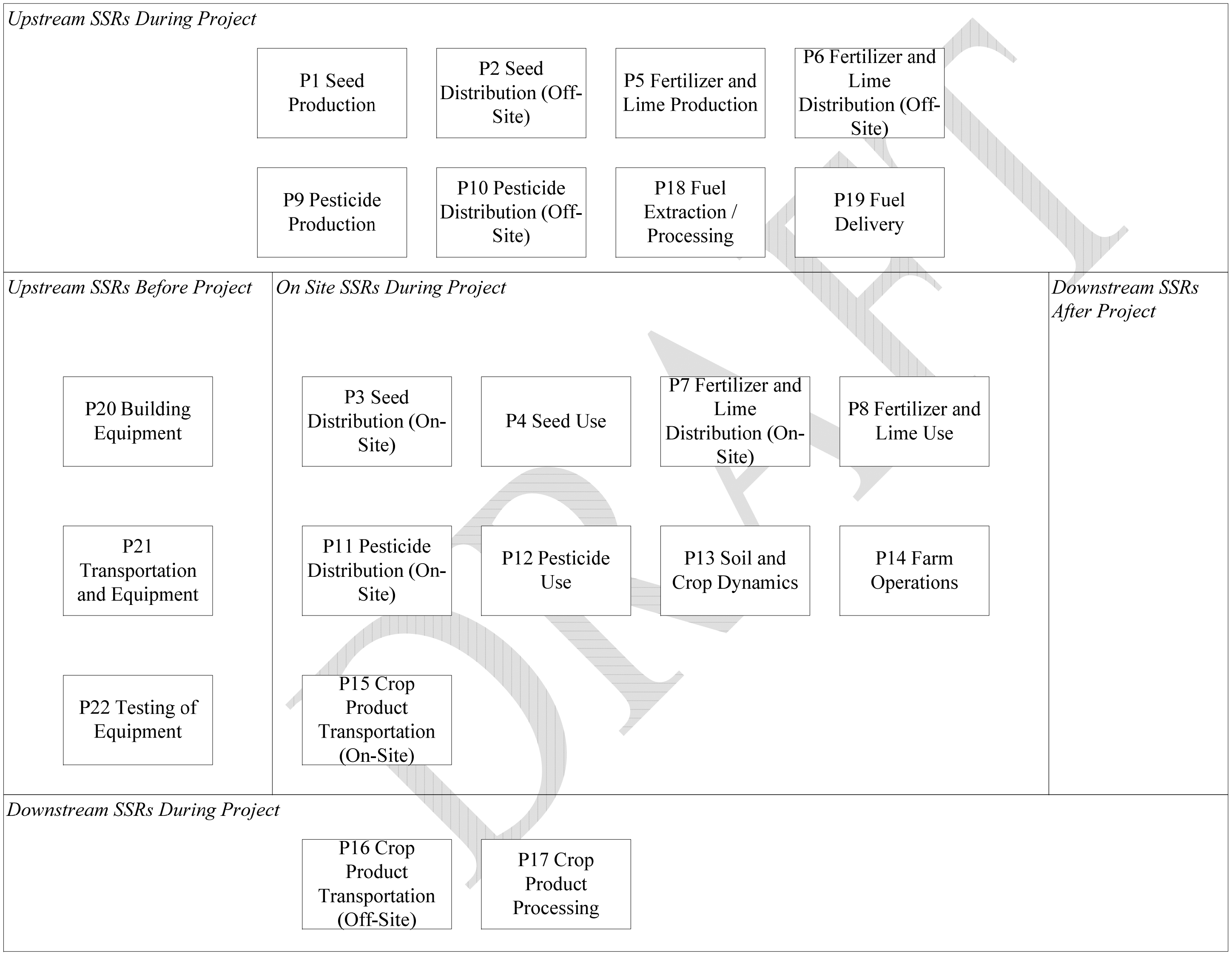


Table 6. Project Condition Sources and Sinks.

Sources and Sinks	**Description**	**Controlled, Related or Affected**
Upstream Sources and Sinks during Project Operation		
P1 Seed Production	Seed production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate comparable metrics with the baseline condition.	Related
P2 Seed Transportation (Off-Site)	Seeds may be transported to the project site by truck. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Related
P5 Fertilizer and Lime Production	Fertilizer and lime production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate comparable metrics with the baseline condition.	Related
P6 Fertilizer and Lime Distribution (Off-Site)	Fertilizer and lime may be transported to the project site by truck. The related energy inputs for fuelling this equipment are captured under this source/sink, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Related
P9 Pesticide Production	Pesticide production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to ensure comparable metrics with the baseline condition.	Related
P10 Pesticide Distribution (Off-Site)	Pesticide may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Related
P18 Fuel Extraction and Processing	Each of the fuels used throughout the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site sources/sinks are considered under this source. Volumes and types of fuels are the important characteristics to be tracked.	Related

Sources and Sinks	Description	Controlled, Related or Affected
P19 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by truck, rail or by pipeline, resulting in the emissions of greenhouse gases.	Related
Onsite Sources and Sinks During Project Operation		
P3 Seed Distribution (On-Site)	Seed would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled
P4 Seed Use	Emissions associated with the use of the seeds. Energy and material inputs would need to be tracked to ensure comparable metrics with the baseline condition.	Controlled
P7 Fertilizer and Lime Distribution (On-Site)	Fertilizer and lime would need to be transported from storage to the field. The implementation of a 4R Consistent Plan may result in increases fossil fuel consumption on farm due to split application of fertilizer or increased monitoring requirements. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled
P8 Fertilizer and Lime Use	Emissions associated with the use of the fertilizer and lime. Timing, composition, concentration and volume of fertilizer need to be tracked.	Controlled
P11 Pesticide Distribution (On-Site)	Pesticide distribution would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled
P12 Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of fertilizer need to be tracked to ensure comparable metrics with the baseline condition.	Controlled
P13 Soil Crop Dynamics	Flows of materials and energy that comprise the cycling of soil and plant carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as carbon dioxide and nitrous oxide.	Controlled
P14 Farm Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the farm facility and related equipment. This may include running	Controlled

Sources and Sinks	Description	Controlled, Related or Affected
	vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	
P15 Crop Product Transportation (On-Site)	Crops would need to be harvested and transported from the field to storage. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled
Downstream Sources and Sinks During Project Operation		
P16 Crop Product Transportation (Off-Site)	Crops would need to be transported from storage to the market by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Related
P17 Crop Product Processing	Inputs of materials and energy involved in the processing and end product utilization of the crop would need to be tracked to ensure comparable metrics with the baseline condition.	Related
Other		
P20 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P21 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
P22 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related

4.0 Quantification

Baseline and project conditions were assessed against each other to determine the scope for reductions quantified under this protocol. Sources and sinks were either included or excluded depending how they were impacted by the project condition. Sources that are not expected to change between baseline and project condition are excluded from the project condition. It is assumed that exclude activities will occur at the same magnitude and emission rate during the baseline and project and so will not be impacted by the project.

All sources and sinks identified in Tables 5 and 6 above are listed in Table 7 below. Each source and sink is listed as include or excluded. Justification for these choices is provided.

Table 7. Comparison of Sources/Sinks for Baseline and Project.

1. Identified Source and Sinks	2. Baseline (C, R, A)**	3. Project (C, R, A)**	4. Include or Exclude from Quantification	5. Justification for Inclusion / Exclusion
Upstream Source and Sinks				
P1 Seed Production	N/A	Related	Exclude	Excluded as these practices are not impacted by the project activity and emissions are not anticipated to change from the baseline to project condition.
B1 Seed Production	Related	N/A	Exclude	
P2 Seed Transportation (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario. The amount of seed transported between the baseline and project scenarios are likely equivalent.
B2 Seed Transportation (Off-Site)	Related	N/A	Exclude	
P5 Fertilizer and Lime Production	N/A	Related	Exclude	Excluded as fertilizer and lime production will either not change materially from the baseline and project conditions or fertilizer production would decrease in the project condition. Emissions are excluded and it is considered to be conservative.
B5 Fertilizer and Lime Production	Related	N/A	Exclude	
P6 Fertilizer and Lime Distribution (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely equivalent to the baseline scenario. The amount of fertilizer and lime distributed is not anticipated to change from the baseline to project condition.
B6 Fertilizer and Lime Distribution (Off-Site)	Related	N/A	Exclude	
P9 Pesticide Production	N/A	Related	Exclude	Excluded as these sources are not relevant to the project and fertilizer production should not change materially from the baseline and project conditions
B9 Pesticide Production	Related	N/A	Exclude	
P10 Pesticide Distribution (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely equivalent to the baseline scenario. The baseline and project conditions will not be materially different as a result of the project.
B10 Pesticide Distribution (Off-Site)	Related	N/A	Exclude	
P17 Fuel Extraction and Processing	N/A	Related	Exclude	Excluded as emissions from fossil fuel consumption will be equivalent or higher in the baseline condition and are not considered. This is

B17 Fuel Extraction and Processing	Related	N/A	Exclude	conservative.
P18 Fuel Delivery	N/A	Related	Exclude	Excluded as emissions from fossil fuel consumption will be equivalent or higher in the baseline condition and are not considered. This is conservative.
B18 Fuel Delivery	Related	N/A	Exclude	
Onsite Sources and Sinks				
P3 Seed Distribution (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from seed transportation in the project condition are likely equivalent to the baseline scenario.
B3 Seed Distribution (On-Site)	Controlled	N/A	Exclude	
P4 Seed Use	N/A	Controlled	Exclude	Excluded as the emissions from seeding are likely equivalent to the baseline scenario. Emissions will not change materially as a result of the project.
B4 Seed Use	Controlled	N/A	Exclude	
P7 Fertilizer and Lime Distribution (On-Site)	N/A	Controlled	Include	Included as the implementation of a 4R Consistent Plan may increase fossil fuel consumption required for fertilizer application as compared to the baseline scenario.
B7 Fertilizer and Lime Distribution (On-Site)	Controlled	N/A	Include	
P8 Fertilizer and Lime Use	N/A	Controlled	Include	Included as the emissions associated with fertilizer and lime use will be materially different between the baseline and project conditions and therefore must be quantified.
B8 Fertilizer and Lime Use	Controlled	N/A	Include	
P11 Pesticide Distribution (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from pesticide transportation are likely equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B11 Pesticide Distribution (On-Site)	Controlled	N/A	Exclude	
P12 Pesticide Use	N/A	Controlled	Exclude	Excluded as the emissions from pesticide use are likely equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B12 Pesticide Use	Controlled	N/A	Exclude	
P13 Soil Crop Dynamics	N/A	Controlled	Include	Included as the emissions associated with soil crop dynamics will be materially different between the baseline and project conditions and therefore must be quantified.
B13 Soil Crop Dynamics	Controlled	N/A	Include	
P14 Farm Operations	N/A	Controlled	Exclude	Excluded as the emissions from farm operations are likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B14 Farm Operations	Controlled	N/A	Exclude	
P15 Crop Product Transportation (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from crop harvesting and transportation are

B15 Crop Product Transportation (On-Site)	Controlled	N/A	Exclude	likely equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
Downstream Sources and Sinks				
P16 Crop Product Transportation (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B16 Crop Product Transportation (Off-Site)	Related	N/A	Exclude	
P17 Crop Product Processing	N/A	Related	Exclude	Excluded as the emissions from crop product processing are equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B17 Crop Product Processing	Related	N/A	Exclude	
Other				
P20 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
B20 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
P21 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
B21 Transportation of Equipment	Related	N/A	Exclude	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
P22 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
B22 Testing of Equipment	Related	N/A	Exclude	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.

**Where C is Controlled, R is Related, and A is Affected.

4.1 Quantification Methodology

This protocol quantifies direct and indirect N_2O emissions per unit of crop produced with a method specific to the ecodistrict where the farm is located. This means that the calculated N_2O emissions are corrected for the predominant soil type, the representative topography, and the climate for the farm. See Appendix F for sample calculations.

In the baseline condition, the N_2O emissions are quantified according to the methodology used in Canada's National Inventory Report. Application of the National Inventory Report emission factors and formulae to the geographical location and management practices of the farm during the 3 years prior to project implementation determines the baseline N_2O emissions. The direct and indirect emissions of N_2O from soil are calculated according to all nitrogen inputs including synthetic fertilizer, livestock manure added, and crop residue decomposition. The total N_2O emissions, based on total nitrogen inputs for each field of a crop event are then divided by the total yield of that crop to derive the N_2O emissions per unit of production. The emissions per unit of crop for all fields of the different crop events are then averaged for three years to determine the baseline emissions per unit of that crop produced. Since the baseline represents the nitrogen management practices in place before implementation of the 4R Consistent Plan, the baseline emission per kg of crop produced estimate only accounts for the amount of nitrogen added per each crop. This means that for the baseline condition only the amount of nitrogen inputs per crop event need to be documented.

The project condition is initiated by implementation of the 4R Consistent plan. Quantifying N_2O in the project involves accounting for all nitrogen inputs as listed above and meeting the specified requirements for time, place, rate and form of fertilizer for the performance level being used. To account for emission reductions achieved by project innovations (i.e. better management), a reduction modifier is multiplied against the emissions calculated according to the National Inventory Report method.

Quantifying N_2O emissions in the project condition involves two steps:

1. Quantifying the N_2O emission intensity, including direct and indirect emissions, is calculated per crop event according to the National Inventory Report method based on the nitrogen inputs per unit crop; and,
2. Multiplying calculated N_2O emissions by the reduction modifier for the selected performance level (0.85 for the basic and 0.75 for the intermediate and advanced levels (Tables 1.1 and 1.2).

Implications of fallowed lands for quantification — Since N_2O emissions are quantified per kg crop produced. Fallowed land (defined as lands where no crop is produced) requires special attention in the baseline and project condition.

In Canada's National Inventory Report, N_2O emissions from fallowed land are considered equal to those from continuously cropped fields[12]. This means N_2O emissions from fallowed land are calculated "by summing emissions from fertilizer [nitrogen], manure [nitrogen] application to annual crops and crop residue [nitrogen] for a given ecodistrict and multiplying the sum by the proportion of that area for the farm under fallow."

In quantifying baseline and project N_2O emissions, the emissions from the fallow year need to be added to the emissions for a crop event grown after fallow. This is achieved by calculating the N_2O emissions per kg crop grown after fallow, and then doubling these per kg emissions to account for the previous year's emissions.

4.1.1 Quantification Approach

Quantification of the reductions, removals and reversals of relevant sources and sinks for each of the greenhouse gases will be completed using the methodologies outlined in Table 8 below. These calculation methodologies serve to complete the following three equations (below) for calculating the emission reductions achieved by comparing the baseline and project conditions per kg of crop produced.

Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop event for each crop grown on the farms. The sequence of calculation for each crop event is as follows:

1. The CO_2e emissions in the baseline and project conditions are calculated using functional units of kilograms (kg) CO_2e per kg of crop produced on a dry matter basis. In the equations, the crop event will be referred to as 'crop i, zone j', representing the understanding that the project will consist of a number of crops, and each crop will be grown in a number of management zones.
2. The baseline condition is expressed for each crop event as the three year average kg CO_2e per kg of crop produced.
3. The project condition is calculated for each crop event on an annual basis using the same functional units.
4. The sum (kg CO_2e per kg crop produced) is multiplied by the appropriate reduction modifier for the selected 4R performance level to get the emission levels by project crop event;
5. The CO_2e reduction for each project crop event is calculated as the difference between the baseline emissions and project emissions (kg CO_2e per kg crop produced).
6. To get the total emission reductions (kg CO_2e) for crop events, multiply the reduction in number 5 above by the total kg of dry matter production for the crop

[12] The science basis for the method in Canada's National Inventory Report is described in Rochette *et al.* 2008. Estimation of N_2O emissions from agricultural soils in Canada. II. 1990-2005 Inventory. Can. J. Soil Sci. 88: 655-669.

and the total area (ha) of the crop fields and sub-fields (i.e. management zones) in the Project.

This procedure is repeated for each crop event in the project condition to obtain the aggregate CO_2e emission reductions from the implementation of the 4R Consistent Plan. See Appendix F for a sample calculation that walks through the steps above.

In certain project configurations, the implementation of the 4R Consistent Plan may result in additional fossil fuel consumption to spread fertilizer (e.g. split application) compared to management in the baseline scenario. If this occurs, the incremental project emissions from the distribution of fertilizer (Fert Dist P&) must be subtracted from the previously calculated CO_2e reductions that have been summed for all crop events.

$$\text{Emission Reduction}_{\text{crop } i} = \sum[(\text{Emissions}_{\text{Baseline, crop } i} - \text{Emissions}_{\text{Project, crop } i\text{, zone } j}) * \text{Area}_{\text{crop } i\text{, zone } j} * \text{Crop Production}_{\text{crop } i\text{, zone } j}] - \text{Emissions}_{\text{Project, Fert Dist}}$$

$$\text{Emissions}_{\text{Baseline, crop } i} = CO_2e_{\text{Baseline, crop } i}$$

$$\text{Emissions}_{\text{Project, crop } i} = \sum CO_2e_{\text{Project, crop } i\text{, zone } j}$$

Where:

$\text{Emissions}_{\text{Baseline, crop } i}$ = Average emissions over the three year baseline condition for crop i (kg CO_2e kg^{-1} of crop produced).

$N_2O_{\text{Baseline, crop } i}$ = Component of emissions under SS B8 Fertilizer and Lime Use & B13 Soil Crop Dynamics for crop event i (kg N_2O kg^{-1} of crop produced).

$\text{Emissions}_{\text{Project, crop } i}$ = Sum of the emissions under the project condition for crop i from zones 1 through j (kg CO_2e kg^{-1} of crop produced).

$N_2O_{\text{Project, crop } i}$ = Component of emissions under SS P8 Fertilizer and Lime Use & P13 Soil Crop Dynamics for crop event i (kg CO_2e kg^{-1} of crop produced).

$\text{Area}_{\text{crop } i\text{, zone } j}$ = The area of the crop management zone in the Project condition for crop event i as defined in Table 4.2 (ha).

$\text{Crop Production}_{\text{crop } i\text{, zone } j}$ = The production from the crop in the project condition for crop i in management zone j, expressed as Dry Matter, as defined in Table 4.2 (kg).

$RM_{crop\ i}$ = The emission reduction modifier as defined in Table 4.2, associated with the selected performance level.

$Emissions_{Project,\ Fertilizer\ Dist}$ = Sum of the emissions under the project condition SS P7 Fertilizer and Lime Distribution

See **Appendix F** for a sample calculation to illustrate the implementation of the quantification approach.

Table 8. Quantification Methodology

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
Project Sources and Sinks						
P7 Fertilizer and Lime Distribution (On-Site) (Note, this has to be quantified if there are additional N application events relative to the baseline (See Section 1.1, Flexibility Mechanisms)	$\text{Emissions}_{\text{Project, Fertilizer Dist}} = \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CO2})\ ;\ \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CH4})\ ;\ \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,N2O})$					
	$\text{Emissions}_{\text{Project, Fertilizer Dist}}$	kg of CO_2; kg CH_4; kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Incremental Volume of Fuel Consumed to Operate Farm Equipment for Implementation of 4R Plan / Vol. Fuel_i	L / m^3 / other	Estimated	Reconciliation of measurements of the volume of fossil fuel (e.g. diesel) consumed per hour of equipment operation or per field. The incremental fossil fuel consumption should be estimated based on the incremental hours of equipment operation required to implement the 4R Plan (e.g. due to split application of fertilizer).	Quarterly reconciliation.	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small.
	CO_2 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\,CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\,CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\,N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
						reporting on Canada's emissions inventory.
P8 Fertilizer and Lime Use & P13 Soil Crop Dynamics	Area of Crop Management Zone at Project Site Under Consideration — $Area_{crop\ i,\ zone\ j}$	ha	Measured	Direct measurement using GPS technology, satellite imagery or approximation from field maps.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	The production of the crop management zone in the Project condition for crop i, expressed in Dry Matter — $Production_{crop\ i,\ zone\ y}$	kg dry matter	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	Emission Reduction Modifier — RM	unitless	Estimated	Emissions modifier based on the 4R Consistent Plan undertaken by the Project Developer/Grower. Values are 0.85 or 0.75 which correspond to the implementation of Basic or Intermediate / Advanced 4R Consistent Nitrogen Plans, respectively.	Annually	For more detail please see Tables 1.1 and 1.2 for details of the 4- R Plan.
	$N_2O_{Project,\ crop\ i} = \sum (N_2O_{FN\ crop\ i,\ zone\ j} + N_2O_{res\ crop\ i,\ zone\ j} + N_2O_{man\ crop\ i,\ zone\ j} + N_2O_{VD\ crop\ i,\ zone\ j} + N_2O_{L\ crop\ i,\ zone\ j}) / Production_{crop\ i,\ zone\ j}$					
	Total Nitrous Oxide emission for crop i — $N_2O_{Project,\ crop\ i}$	kg N_2O /kg crop	N/A	N/A	N/A	Quantity being calculated.

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	The production of the crop management zone in the project condition for crop event i , expressed in Dry Matter — $Production_{crop\ i,\ zone\ j}$	kg dry matter	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	$N_2O_{FN\ crop\ i} = \sum(N_{FN\ \ crop\ i,\ zone\ j} * EF_{\ Eco} * 44/28)$					
	Direct Emissions of Nitrous Oxide from Nitrogen Fertilizer for crop — $N_2O_{FN,\ crop\ i}$	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Nitrogen Fertilizer Consumption per crop management zone — $N_{\ FN\ crop\ i,\ zone\ j}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.
	Emission Factor Related to Local Soil and Climatic Conditions — $EF_{\ Eco}$	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area. Also integrates influence of texture, tillage, and topography.	Annually	The value associated with EF_{Eco} is to be determined based on the eco-district which the farm is located in. The EF_{Eco} value for each eco-district is listed in **Appendix B**. As per the approach used in Canada's National Inventory Report quantification method. For irrigated fields, use a EF_{Eco} = 0.015.
	$N_2O_{man\ crop\ i} = \sum(N_{man\ \ crop\ i,\ zone\ j} * EF_{\ Eco} * 44/28)$					

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Direct Emissions of Nitrous Oxide from manure for crop — $N_2O_{man, crop\ i}$	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Manure nitrogen per crop management zone — $N_{man\ crop\ i,\ zone\ j}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.
	Emission Factor Related to Local Soil and Climatic Conditions — EF_{Eco}	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area. Also integrates influence of texture, tillage, and topography.	Annually	The value associated with EF_{Eco} is to be determined based on the eco-district which the farm is located in. The EF_{Eco} value for each eco-district is listed in **Appendix B**. As per the approach used in Canada's National Inventory Report quantification method. For irrigated fields, use a EF_{Eco} = 0.015.
	$N_2O_{res\ crop\ i} = \sum[\ (N_{res\ crop\ i,\ zone\ i} * EF_{eco}) * 44 / 28\ ]$					
	Direct Emissions of Nitrous Oxide from Crop Residue Decomposition per crop event — $N_2O_{res,\ crop\ i}$	kg N_2O / /ha	N/A	N/A	N/A	Quantity being calculated based on the average emissions over a three year period.

Project/Baseline Sources & Sinks	**Parameter / Variable**	**Unit**	**Measured / Estimated**	**Method**	**Frequency**	**Justify measurement or estimation and frequency**
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually — $N_{res, crop\ i\ zone\ j}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 30.	Annually	As per Canada's National Inventory Report Quantification process.
	Emission Factor Related to local climatic conditions — EF_{eco}	kg N_2O - N / kg N	Estimated	Base is calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area. Then, adjusts for integrated influence of texture, tillage, and topography.	Annually	The value associated with EF_{eco} is to be determined as per the eco-district to which the farm pertains. The EF_{eco} value for each eco-district is listed in **Appendix B**. As per Canada's National Inventory Report quantification method. For irrigated fields, use a EF_{Eco} = 0.015.
	$N_{res, crop\ i} = \sum [Crop_{i, zone\ j} * FRAC_{renew, crop\ i} * (R_{Ag, , crop\ i} * N_{AG, crop\ i, zone\ j} + R_{BG, crop\ i} * N_{BG, crop\ i})]$					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop — $N_{res, crop\ i}$	kg N / ha	N/A	N/A	N/A	Quantity being calculated.
	Harvested annual dry matter production for Crop management zone — $Crop\ i_{zone\ i}$	kg dry matter (DM)/kg	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method.

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Fraction of total area under crop that is renewed annually — $FRAC_{renew, crop\ i}$	-	Estimated	For annual crops $FRAC_{renew}$ = 1. In cases which crops are renewed on average every X years, $Frac_{renew}$ = 1/X.	Annually	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Ratio of above-ground residues dry matter to harvested production for crop i — $R_{Ag\ ,\ crop\ i}$	-	Estimated	This value is determined using the Table E.1 in **Appendix E**. The value is from the sixth column (AG residue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Nitrogen content of above-ground residues for crop — $N_{AG\ ,\ crop\ i}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the Table E.1 in **Appendix E**. The value is from the third column (AGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Ratio of below-ground residues to harvested production for crop— $R_{BG,\ crop\ i}$	-	Estimated	This value is determined using the Table E.1 in **Appendix E**. The value is from the seventh column (BGresidue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Nitrogen content of below-ground residues for crop — $N_{BG, crop\ i}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the Table E.1 in **Appendix E**. The value is from the fourth column (BGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	$N_2O_{VD\ crop\ i} = \sum [(N_{Fert,\ crop\ i\ zone\ j} * FRAC_f) + (N_{man,\ crop\ i\ zone\ j} * FRAC_m)] * EF_{VD} * 44/28$					
	Indirect Emissions of Nitrous Oxide from Volatilization and Re-deposition of NH_3 and NO_x per crop — $N_2O_{VD\ crop\ i}$	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Synthetic nitrogen fertilizer consumption per crop management zone — $N_{fert\ ,\ crop\ i\ zone\ j}$	kg N / ha	Estimated	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Fraction of synthetic fertilizer N applied to soils that volatizes as NH_3^- and NO_x-N — $FRAC_f$	(NH_3-N + NO_x-N) / kg	Estimated	Default factor set at 0.1 for commercial fertilizer.	Annually	As per Canada's National Inventory Report Quantification process.

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Manure nitrogen per crop management zone — $N_{man\ crop\ i,\ zone\ j}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.
	Fraction of manure N applied to soils that volatizes as NH_3-N and NO_x-N — $FRAC_m$	(NH_3-N + NO_x-N) / kg	Estimated	Default factor set at 0.2 for manure.	Annually	As per Canada's National Inventory Report Quantification process.
	Emission Factor for N_2O from Nitrogen Redeposited after Volatilization — EF_{VD}	kg N_20 - N / kg N	Estimated	Default factor set at 0.01 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process.
	$N_2O_{L\ crop\ i} = \sum [(N_{Fert\ crop\ i\ zone\ j} + N_{man,\ crop\ i\ zone\ j} + N_{res,\ crop\ i\ zone\ j}) * FRAC_L * EF_L * 44/28]$					
	Indirect Emissions of Nitrous Oxide from Leaching per crop — N_2O_L	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Nitrogen fertilizer consumption per crop in management zone — $N_{Fert\ ,\ crop\ i\ zone\ j}$	kg of actual N / ha	Measured	Direct measurement.	Continuous	Direct measurement is the most accurate method.

Project/Baseline Sources & Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Manure nitrogen per crop management zone — $N_{man\ crop\ i,\ zone\ j}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop in management zone — $N_{res\ ,\ crop\ i\ zozne\ j}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 30.	Annually	As per Canada's National Inventory Report Quantification process.
	Fraction of Nitrogen Lost in Leachate — $FRAC_L$	-	Estimated	Calculated using 0.3247*P/PE-0.00247, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Monthly	The $FRAC_{leach}$ value for each eco-district within Alberta is listed in **Appendix B**. As per Canada's National Inventory Report quantification method. For irrigated fields, use a $FRAC_L = 0.3$.
	Emission Factor for N_2O from Leachate — EF_L	kg N_20 - N / kg N	Default	Default factor set at 0.0125 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process

Baseline Sources and Sinks
The Baseline Sources and Sinks and quantification equations are the same as for the Project, but the Baseline emissions per kg crop will be determined for the three years and averaged to provide the value against which reductions in the Project will be determined.

4.1.2 Additional Quantification Explanation

The following sections provide additional guidance for some of the quantification steps outlined in Table 4.2 above.

4.1.2.1 Calculating Direct Emissions from Fertilizer

Direct Emissions from Fertilizer — $N_2O_{FN} = \sum(N_{FN,crop\ i\ zone\ j} * EF_{eco} * 44/28) / Yield_{crop\ i\ zone\ j}$): Direct N_2O emissions for each crop in the year of interest is calculated by summing the emissions from all crop events. The estimated N_2O emissions are then divided by the yield of the crop events to determine the N_2O emissions from fertilizer per kg crop produced.

Parameter	Units	Source
Amount of fertilizer N applied to the crop in each management zone	kg of N / ha	Nitrogen fertilizer use per crop event, monitored according to design of 4R Consistent Plan.
Emission factor for the soil	EF_{eco}	Ecodistrict factors, which integrate F_{TOPO}, F_{TILL}, F_{IRRI}, F_{TEXT}, provided in Appendix B.
Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

4.1.2.2 Calculating Direct Emissions from Crop Residue

Direct Emissions from Crop Residue — $N_2O_{res} = \sum(N_{res,Event\ i} * EF_{eco} * 44/28) / Yield_{Event\ i}$): Direct N_2O emissions for each crop in the year of interest is calculated by summing the emissions from all crop events. The nitrogen in crop residues is calculated from the yield using default factors provided in Table E.1, Appendix E. As in the method used in Canada's National Inventory Report, it is assumed that the N from crop residues grown in a year is available for N_2O generation in the year the residues are produced. The estimated N_2O emissions are then divided by the yield of the crop events to determine the N_2O emissions from crop residues per kg crop produced:

Parameter	Units	Source
Amount of nitrogen from Crop Residue Decomposition per crop in each management zone	Kg of residue N / ha	Nitrogen from crop residues per crop management zone, derived from yield value monitored according to design of 4R Consistent Plan. This method of determining crop residue nitrogen is used in Canada's National Inventory Report quantification process.
Emission factor for the soil	EF_{eco}	Ecodistrict factors, which integrate F_{TOPO}, F_{TILL}, F_{IRRI}, F_{TEXT}, provided in Appendix B.

Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

4.1.2.3 Calculating Direct Emissions from Manure

Direct Emissions from Manure — $N_2O_{man} = \sum(N_{man,Event\ i} * EF_{eco} * 44/28) / Yield_{crop\ i\ zone\ j}$): Direct N_2O emissions for each crop in the year of interest is calculated by summing the emissions from all crop management zones. The nitrogen in crop residues is calculated from the yield using default factors provided in Table E.1, Appendix E. The estimated N_2O emissions are then divided by the yield of the crop events to determine the N_2O emissions from crop residues per kg crop produced.

Parameter	Units	Source
Amount of N from manure spread per crop in each management zone	Kg manure N / ha	Nitrogen from manure per crop management zone.
Emission factor for the soil	EF_{eco}	Ecodistrict factors, which integrate F_{TOPO}, F_{TILL}, F_{IRRI}, F_{TEXT}, provided in Appendix B
Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

Total Direct Emissions from All Sources of N: The direct emissions per kg crop produced are calculated as the sum of direct emissions from fertilizer, crop residues, and manure.

4.1.2.4 Calculate Indirect N_2O Emissions from Volatilization

Volatilization Emissions from Fertilizer and Manure: Indirect N_2O emissions from the volatilization for each crop management zone must be calculated by multiplying the amount of fertilizer and manure N applied to the crop by the appropriate coefficient of volatilization ($FRAC_f$) and the emission factor for volatilized N (EF_{VD}). The values for $FRAC_f$ and EF_{VD} are constant across Canada. The estimated N_2O emissions are then divided by the yield of the crop events to determine the N_2O emissions from volatilization per kg crop produced.

Parameter	Units	Value
Amount of fertilizer N applied to the crop in each management zone	kg of N / ha	Nitrogen fertilizer use per crop management zone, monitored according to design of 4R Consistent Plan.
Amount of manure N	Kg	Nitrogen from manure per crop event.

spread on the crop in each management zone	manure N / ha	
$FRAC_f$	unitless	0.1
EF_{VD}	Kg N_2O-N kg N	0.01
Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Plan.

<u>Volatilization Emissions from Crop Residue:</u> By convention of IPCC, crop residues are not included in the calculation of indirect N_2O emissions.

<u>Total Volatilization Emissions from Crop:</u> The indirect N_2O emissions for each crop management zone are calculated by summing the volatilization emissions per kg crop produced from fertilizer and from manure.

4.1.2.5 Indirect N_2O Emissions from Leaching for Each Crop on an Area Basis

<u>Leaching Emissions from Fertilizer Use:</u> Indirect N_2O emissions from the leaching of fertilizer N for each crop management zone must be calculated by multiplying the amount of fertilizer applied to the crop by the appropriate coefficient of leaching ($FRAC_L$) and the emission factor for leached N (EF_L). The value for $FRAC_L$ varies according to climate, but EF_L is constant across Canada. The estimated N_2O emissions are then divided by the yield of the crop management zones to determine the N_2O emissions from leaching of fertilizer per kg crop produced.

Parameter	Units	Source
Amount of fertilizer N applied to the crop in each management zone	kg of N / ha	Nitrogen fertilizer use per crop management zone, monitored according to design of the 4R Consistent Plan.
Amount of N from manure spread per crop in each management zone	Kg manure N / ha	Nitrogen from manure per crop management zone.
Leaching factor ($FRAC_L$)	unitless	Unique for each ecodistricts in Canada, Appendix B. For irrigated crops, use $FRAC_L$ = 0.30.
Emission factor for leached N (EF_L)	Kg N_2O-N kg N	Constant for all ecodistricts across Canada. Currently, this value is 0.025 in Canada's National Inventory Report (NIR 2008). This may change in the future. Please refer to the most recent NIR to ensure this is still current.
Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

Leaching Emissions from Crop Residue: Indirect N_2O emissions from the leaching of crop residue N for each crop management zone must be calculated by multiplying the amount of crop residue N by the appropriate coefficient of leaching ($FRAC_L$) and the emission factor for leached N (EF_L). The value for $FRAC_L$ varies according to climate, but EF_L is constant across Canada. The estimated N_2O emissions are then divided by the yield of the crop management zones to determine the N_2O emissions from leaching of crop residue N per kg crop produced.

Parameter	Units	Source
Amount of nitrogen from Crop Residue Decomposition per crop in each management zone	Kg of residue N / ha	Nitrogen from crop residues per crop management zone, derived from yield value monitored according to design of 4R Consistent Plan. This method of determining crop residue nitrogen is used in Canada's National Inventory Report quantification process.
Leaching coefficient ($FRAC_L$)	unitless	Unique for each eco-districts in Canada, provided in Appendix B. For irrigated crops, use $FRAC_L$ = 0.30.
Emission factor for leached N	Kg N_2O-N kg N	Constant for all ecodistricts across Canada. Currently, this value is 0.025 in Canada's National Inventory Report (NIR 2008). This may change in the future. Please refer to the most recent NIR to ensure this is still current.
Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

Leaching Emissions from Manure: Indirect N_2O emissions from the leaching of manure N for each crop event must be calculated by multiplying the amount of manure N applied to the crop by the appropriate coefficient of leaching ($FRAC_L$) and the emission factor for leached N (EF_L). The value for $FRAC_L$ varies according to climate, but EF_L is constant across Canada. The estimated N_2O emissions are then divided by the yield of the crop events to determine the N_2O emissions from leaching of fertilizer per kg crop produced. It is assumed that all manure N is available in the year of application:

Parameter	Units	Source
Manure N spread on each crop in each management zone	kg of actual N / ha	Nitrogen Fertilizer Consumption per crop management zone monitored/measured directly and continuously
Leaching co-efficient ($FRAC_L$)	unitless	Unique for each ecodistricts in Canada, provided in Appendix B. For irrigated crops, use $FRAC_L$ = 0.30.
Emission factor for leached N	Kg N_2O-N kg N	Constant for all eco-districts across Canada. Currently, this value is 0.025 in Canada's National Inventory Report (NIR 2008). This may change in the future. Please refer to the most recent NIR to ensure this is still current.

Amount of crop yield per crop in each management zone	Kg / ha	Yield monitored according to design of 4R Consistent Plan.

Total Leaching Emissions from Crop: The indirect leaching emissions per kg crop produced are calculated as the sum of indirect leaching emissions from fertilizer, crop residues, and manure.

4.1.2.6 Corroborating Assessment of Nitrogen Uptake

Generating a post-harvest N balance can be a valuable tool to assess the success of a 4R Consistent Plan in meeting crop N needs, and thereby minimizing N_2O emission. A complete field N balance is not practical, because N in belowground biomass is difficult to measure directly. However, the 4R Consistent Plan will calculate the proportion of N added as fertilizer and manure, which is recovered in the harvested crop. Therefore, this N balance should be calculated at the crop event level.

With the assistance of the Accredited Professional Advisor, participants implementing the basic performance level will calculate the N balance at the field scale, while those implementing the intermediate and advanced levels will calculate at the sub-field scale, and according to the digital delineation of slope and aspect, respectively. The balance should be quantified at the level of detail required for the performance level. In the basic level, the N uptake will be calculated by multiplying yield per crop event by the N content values tabulated in the protocol appendices. In the intermediate and advanced levels, the N uptake will be calculated using measured values from samples of crop from a crop event.

This partial N balance will help to refine nitrogen fertilizer rate recommendations in the following year's plan.

5.0 Data Management

The Project Developer's data quality management system must meet regulatory quality standards to fulfill the quantification requirements of this protocol and ensure the offset credits meet the required level of assurance for compliance use in Alberta. The system must contain substantiated evidence including farm records corroborated by supporting documentation where possible.

The Project Developer shall establish and apply data quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements and should be discussed in the Offset Project Plan. Any changes in data retention, monitoring or other procedures, must be identified in the Offset Project Report compiled annually. The greater the rigour of the management system for the data, the more easily verification will be to conduct for the project.

5.1 Project Documentation

Minimum information required to support this activity is:

1. The name, contact information, and statement of qualifications of the Project Developer;
2. The name, contact information, and statement of credentials and training of the Accredited Professional Advisor(s);
3. The name and contact information of the individual farmers enrolled in the project;
4. The years chosen for the baseline, and the year the project was initiated;
5. The number, sizes, and locations of fields/sub-fields enrolled in the project, including
    a. Legal land location (preferably GPS coordinates) of each field;
    b. Field area substantiated with aerial photographs; and
    c. Ecodistrict location of each field determined using the tool[13] provided by Alberta Agriculture and Rural Development.
6. The performance level of the 4R Consistent Plan to be implemented.

5.1.1 Baseline Considerations

The baseline N_2O emissions are calculated per kg of crop produced as the average over the three years prior to project implementation[14]. It is not required that the same fields are farmed in the baseline and project condition. However, all fields in the baseline and project must be within the same ecodistrict, and 3 years of baseline data are needed for any crop included in the project.

Direct evidence is required to substantiate the rate of nitrogen inputs for each crop in the 3 years used to derive the baseline emissions of N_2O per kg of crop produced. This direct evidence includes recommendations for fertilizer requirements, invoices for total seed and fertilizer purchased, records for total manure spread (if applicable), and sales documents for all crops produced. Because this evidence pertains to activities before the implementation of the 4R Consistent Plan, data may not be available to document the amount of fertilizer applied and the yield achieved for each crop in each field and therefore, the evidence is not required to be at the same resolution as the project:

The documentation of the baseline condition will include:

1. For each year, list total area and total yield for each crop, including area in fallow, providing substantiating documentation for seed purchases, field areas, and crop sales;

---

[13] This tool to locate fields within ecodistricts is available at http://www.agric.gov.ab.ca/app21/rtw/index.jsp. The ecodistrict must be specified to determine the appropriate factor to quantify N_2O emissions for the filed.

[14] Refer to Section 1.1 and Section 4.0 for details on flexibility of the 3 years required, and what to do if new crop types are introduced to the project.

2. For each year, list total N applied from all sources, providing substantiating documentation for fertilizer, manure, and crop residues (calculated from documented yield) used;
3. For each year, calculate average yield and fertilizer use for each crop;
4. For each year, estimate N_2O emissions per kg produced for each crop, adjusting for crops seeded after fallow;
5. Calculate average N_2O emissions per kg crop produced for the three years of baseline; and
6. Retain an Accredited Professional Advisor to attest that the assumptions underlying the baseline estimate are reasonable, and that the baseline calculations are accurate.

5.1.2 Project

The beginning of the project corresponds to the implementation of a 4R Consistent Plan as prescribed by this protocol, and signed off by an Accredited Professional Advisor. Because the 4R Consistent Plans are tuned to performance level, the activities prescribed, and the form of documentation required, will vary in the project condition according to the selected performance level. The following sections describe the required documentation to be reported and collected (for project and baseline where available, in light of the section above) in order to support the calculations, the project assertion and the verification of the project.

The series of tables in the next sub-section are meant to provide examples of information that could be used to provide evidence for the data requirements of the project. For each of the data sets, examples are provided for information that may be gathered at the farm level, as well as third party supporting information that can be used for verification. Additional sources could be used that have equivalent levels of accuracy. While these tables provide illustrations of the potential sources of data, the Project Developer will need to ensure the documentation collected will meet the requirements of verification.

Note: The abbreviation AFSC refers to the Agriculture Financial Services Corporation, while the abbreviation CWB refers to the Canadian Wheat Board. APA refers to the Accredited Professional Advisor.

5.1.2.1 Reporting Area of Fields

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	Total number of hectares seeded to each crop type by year for the three years used to establish the	Number of hectares seeded to each crop type for each field included in the project	Number of hectares seeded to each crop type for each sub-field included in the project	Number of hectares seeded to each crop type for each sub-field, by slope and aspect,

	baseline			included in the project
On-Farm Sources	Farm records, GPS data, readings from seeding equipment	GPS data, readings from seeding equipment, legal land descriptions	GPS data	GPS data and digital field maps
Supporting Documentation	AFSC records, hail insurance records, CWB records, crop advisor records	AFSC records, hail insurance records, crop advisor and/or APA records	Crop advisor and/or APA records	Crop advisor and/or APA records
Other sources	Aerial or satellite photos*	Aerial or satellite photos*	Aerial or satellite photos*	Aerial or satellite photos*

** Aerial and/or satellite photos can be accessed from a number of sources and can provide an excellent tool for validating the reported area of a field. However, there are limitations to the availability of historical records. Further, it not always practical or possible to obtain photos for every field each year. The Alberta Soil Information Viewer can be a good source supporting documentation :**http://www.agric.gov.ab.ca/app21/rtw/index.jsp**.*

5.1.2.2 Reporting Crop Seeded

It is necessary to document the type of crop seeded in order to calculate the nitrogen requirements and the nutrient uptake over the growing season. It is only necessary to document the crop seeded[15]. The data sources available for the baseline and the various project levels are noted in the chart below.

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	Types of crops grown in the three years used to establish the baseline	Crop grown for each field included in the project	Crop grown for each sub-field included in the project	Crop grown for each sub-field, by slope and aspect, included in the project
On-Farm Sources	Farm records, GPS data, readings from seeding equipment	GPS data, readings from seeding equipment	GPS data from seeding equipment settings	GPS data and digital maps based on seeding equipment settings
Supporting Documentation	AFSC records, hail insurance records, crop advisor records, CWB records	AFSC records, hail insurance records, crop advisor and/or APA records	Crop advisor and/or APA records, including field visits	Crop advisor and/or APA records, including field visits
Other sources	Seed purchase receipts*	Seed purchase receipts*	Seed purchase receipts*	Seed purchase receipts*

** Seed purchase receipts may be used to provide supporting evidence of the crop seeded when the seed has been purchased from a third party.*

[15] There is no need to record different crop varieties.

5.1.2.3 Reporting Testing of Soil and/or Tissue

In order meet the 4R Consistent Plan requirements soil and/or tissue tests must be documented. The Offset Project Plan must include the methodology for the testing where soil/tissue testing is conducted at an accredited lab. Results for the tests will be provided by the lab and should be maintained by the enrolled farmer, the Accredited Professional Advisor and the Project Developer. Note: soil/tissue testing is not required for establishing a project baseline

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	n/a	Field scale sampling and testing of soil to derive fertilizer rate requirements	Sub-field scale sampling and testing of soil to derive fertilizer rate requirements	Sub-field scale sampling and testing of soil to derive fertilizer variable rate requirements
On-Farm Sources		Lab reports, recommendations from APA	Lab reports, field maps, recommendations from APA	Lab reports, field maps, recommendations from APA
Supporting Documentation		Lab reports, crop advisor and/or APA records	Lab reports, crop advisor and/or APA records	Lab reports, crop advisor and/or APA records

5.1.2.4 Reporting Yield for Each Crop

Collecting yield data for each crop event of each crop is key to the implementation of the protocol. Yields must be reported on a dry matter basis. To calculate dry matter, use the water content of the crop at time of sale. Data is needed from field area measurements and total crop produced, but the means of obtaining this data are dependent on the performance level for which the 4R Consistent Plan is designed.

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	Yield by crop grown for each of the three years used to establish the baseline	Yield by crop for each field included in the project	Yield by crop for each sub-field included in the project	Yield by crop for each sub-field, by slope and aspect, included in the project
On-Farm Sources	Farm records, GPS data, yield monitors, weigh wagon records	Farm records, GPS data, yield monitors, weigh wagon records	GPS data generated from yield monitors, weigh wagon records	GPS data and digital maps generated from yield monitors
Supporting Documentation	AFSC records, hail insurance records, crop	AFSC records, hail insurance records, crop	Crop advisor and/or APA records	Crop advisor and/or APA records

	advisor records, bin counts	advisor and/or APA records		
Other sources	Sales receipts	Sales receipts	Sales receipts	Sales receipts

5.1.2.5 Reporting of Nitrogen Inputs

<u>Fertilizer:</u>

Report on the amount, timing and type of fertilizer nitrogen applied for each crop event for each crop. The pattern of distribution for fertilizer (i.e. the distribution for each crop event), and the resolution of the documentation, will vary with the selected performance level. Documentation will involve data from fertilizer purchase invoices, supported by application recommendations from the Accredited Professional Advisor in the 4R Consistent Plan, and supported by application records (invoices from custom spreaders or, if own equipment used, grower's equipment logs). Total annual fertilizer application is supported with documentation from purchase invoices and application records for each crop event.

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	Amount of nitrogen fertilizer applied per hectare by crop type across the full farm in each of the three years used for the baseline;	Amount of nitrogen fertilizer applied per hectare by crop type for each field included in the project; the type of ammonium-based fertilizer applied; when the fertilizer is applied.	Amount of nitrogen fertilizer applied per hectare by crop type for each sub-field included in the project; the type of ammonium-based fertilizer applied; when the fertilizer is applied.	Amount of nitrogen fertilizer applied per hectare by crop type for each sub-field, by slope and aspect, included in the project; the type of ammonium-based fertilizer applied; when the fertilizer is applied.
On-Farm Sources	Farm records, GPS data, readings from application equipment	Farm records, GPS data, readings from application equipment	GPS data from application equipment	GPS data and digital maps generated from application equipment
Supporting Documentation	AFSC records, hail insurance records, crop advisor records	AFSC records, hail insurance records, crop advisor and/or APA records	Crop advisor and/or APA records	Crop advisor and/or APA records
Other sources	Fertilizer purchase receipts, custom application records	Fertilizer purchase receipts, custom application records	Fertilizer purchase receipts, custom application records	Fertilizer purchase receipts, custom application records

Crop Residues:
Calculating the amount of crop residue nitrogen, above ground and below ground, for each crop event is a required nitrogen input needing to be taken into account. This estimate is derived from default look-up tables provide in Appendix E of this protocol. Crop yield is the basis for deriving this nitrogen input so the residue calculations are delineated on the fields according to the selected performance level in the same way as yield data is collected and reported.

In some instances, crop residue management may be complicated by events such as baling, burning, etc. The implications of these events for nitrogen input calculations will need to be addressed in the 4R Consistent Plan. For example, the amount of nitrogen removed in these events should be treated as crop yield and should be included in the post-harvest assessment of nitrogen uptake using default or measured nitrogen values as appropriate for the performance level.

Parameter	Units	Source
Annual average crop yield (dry matter)	Kg dry matter / ha	Yield is recorded by crop event, delineated by field, by sub-field, or according to GPS-based monitors.
Crop-specific factors	Kg N / kg	AGresidue_ratio, AGresidue_n_conc, BGresidue_ratio, BGresidue_N_conc from table E1 (Appendix E)

Manure:
If manure is used on the farm, the N_2O quantification method of Canada's National Inventory Report assumes that all manure nitrogen is available in the year of application. If possible, the project documentation should describe:

- Determination of nutrient application rates per hectare for crops grown;
- Calibration of spreading equipment to attain nutrient application rates;
- Time of year of spreading (if more than one spreading per year, the proportion of annual volume at each spreading); and,
- Results of soil tests to track the nutrient status of the soil.

The following data should be collected. Wherever possible, the spreading of manure should be planned at the same level of field variability as is the fertilizer application. That is, it should be recorded per crop event at the whole field, sub-field, or variable rate application. The Alberta Nutrient Management Planning Guide[16] describes how to calculate the crop available N for each year of manure application - See Section 4.3 page 161 or page 213. Manure analysis provides the most accurate estimate of nutrient content of manure. Alternatively, manure production and nutrient content tables will provide another means of estimating nutrient content of manure and nutrient application based on rate of manure application.

[16] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920.

Baseline calculations require that farm records be available to support which fields manure was applied to. If the manure comes from a commercial feedlot, it is expected that records on the analysis and rate of application will be available from the feedlot. Supporting evidence that manure was spread on the land may come from receipts for custom services.

For project implementation, it will be necessary to ensure manure-sampling procedures and application rate documentation are kept by the enrolled farmer, the Accredited Professional Advisor and the Project Developer.

	Baseline	Basic Level	Intermediate Level	Advanced Level
Data Required	Amount of nitrogen contained in manure applied per hectare by crop type across the full farm in each of the three years used for the baseline	Amount of nitrogen contained in manure applied per hectare by crop type for each field included in the project	Amount of nitrogen contained in manure applied per hectare by crop type for each sub-field included in the project	Amount of nitrogen contained in manure applied per hectare by crop type for each sub-field, by slope and aspect, included in the project
On-Farm Sources*	Farm records Manure Management Plans	Farm records Manure Management Plans	Farm Records Manure Management Plans	Farm records Manure Management Plans
Supporting Documentation	Crop advisor records	Crop advisor and/or APA records	Crop advisor and/or APA records	Crop advisor and/or APA records
Other sources	Feedlot records, custom application records	Feedlot records, custom application records	Feedlot records, custom application records	Feedlot records, custom application records

** Manure management plans are a requirement for larger operations in Alberta under the Agricultural Operation Practices Act. The Plans need to record who manure is sold or given to and where it's being applied and at what rate. Nutrient content of the manure is in the Manure Management Plan as well.*

5.1.2.6 Reporting of Fertilizer Nitrogen Placement

The 4R Consistent Plan requires placing fertilizer in bands, either through injection or in concentrated sub-surface rows. The band must have a fertilizer spread that is not more than 30 per cent of the row laterally. Determining and documenting the proper placement is described below.

The general equation to be applied is:

% Band Concentration = Width of Spread/Row Spacing* 100

where,

Width of spread is determined by the type of opener (see table below); and

Row Spacing is the distance between seed rows.

Expected Band Concentration in Fertilizer Application

	Width of spread of fertilizer in the row[a]											
	2.5 cm (Disc or knife)			5.0 cm (Spoon or hoe)			7.5 cm (Sweep)			10.0 cm (Sweep)		
Row spacing (cm)	15	23	30	15	23	30	15	23	30	15	23	30
Fertilizer Concentration (%)[b]	17	11	8	33	22	17	50	30	25	67	44	33

a The width of spread of fertilizer and seed depends on the type of opener, soil type and moisture content, air flow, etc. Some openers give less than 2.5 cm (1") spread (e.g., double disc).
b The width of spread of fertilizer and seed relative to the row spacing. For example a 7.5 cm spread with a 15 cm row spacing is 50% SBU (7.5/15 x 100 = 50%). If the same rate of fertilizer is applied with a 7.5 cm spread and a 30 cm row spacing, the concentration of fertilizer in the seed row is doubled (7.5/30 x 100 = 25% concentration). Some openers spread seed and fertilizer vertically – this approach cannot be applied to these spreaders.

The data required to prove that placement was done appropriately, includes date stamped photos of fertilizer spreading equipment and openers, and row spacing of fields; if custom applicators were hired to apply fertilizer, the type of opener, row spacing and concentration should be collected as either part of the invoice for the work or an additional letter by the third party applicator confirming the placement.

5.1.2.7 Reporting of Fall Applied Fertilizers

The 4R Consistent Plan allows for some fall application of fertilizers, so long as the temperature of the soil is less than 10^{o} Celsius for three consecutive days. To prove that fall application of fertilizers occurred at the correct time, appropriate data sources could include farm records showing soil temperature readings or documented reference to the ‘safe dates’ shown on the Soil Temperature map in Appendix A of this protocol. The Accredited Professional Advisor would need to ensure that this is well documented in the 4R Consistent Plan.

5.2 Record Keeping

Alberta Environment requires that Project Developers maintain appropriate supporting information for the project, including all raw data for the project for a period of 7 years **after** the end of the project credit period. Where the Project Developer is different from the person implementing the activity, as in the case of an aggregated project[17], the individual farmer and the aggregator, as well as the Accredited Professional Advisor, must both maintain sufficient records to support the Offset Project. The Project Developer (farmer and aggregator) must keep the information listed below and disclose all information to the verifier and/or government auditor upon request.

Record Keeping Requirements:

- Raw baseline period energy, feed, milk production, livestock, and manure management data, independent variable data, and static factors within the measurement boundary
- A record of all adjustments made to raw baseline data with justifications
- All analysis of baseline data used to create mathematical model(s)
- All data and analysis used to support estimates and factors used for quantification
- Expected end of life date of equipment removed or renovated under the project
- Common practices relating to possible greenhouse gas reduction scenarios discussed in this protocol (such as manure management practices)
- Metering equipment specifications (model number, serial number, manufacturer's calibration procedures)
- A record of changes in static factors along with all calculations for non-routine adjustments
- All calculations of greenhouse gas emissions, emissions reductions and emission factors
- Measurement equipment maintenance activity logs
- Measurement equipment calibration records
- Initial and annual verification records and audit results

5.2.1 Additional Considerations for this Protocol

4R Documentation:
While an independent professional prepares the 4R Consistent Plan documentation, these materials, including all background and supporting materials, **must** still be available to the third party verifier, including government auditor, for assessment. The work of the Accredited Professional Advisor supports the work of the verifier, but does not replace it.

Accredited Professional Advisor Credentials:
The farmer and the project developer shall retain documents to attest the credentials of the Accredited Professional Advisor. This documentation includes:

- Proof of professional accreditation of the Accredited Professional Advisor, comprised of a copy of the certificate of pertinent professional designation (such as CCA or P.Ag.); and

[17] Please see Alberta's Technical Guidance for Offset Project Developers http://environment.alberta.ca/02278.html

- Proof of successful completion of the Canadian Fertilizer Institute's 4R Training Course.

4R Consistent Plan:
The 4R Consistent Plan to be implemented on the project farm shall be signed and if applicable, stamped by the Accredited Professional Advisor, and shall be signed by the farmer. The 4R Consistent Plan shall describe the activities to be implemented by the farmer, provide the rationale for determining these activities, and specify the data to be collected to document completion of these activities.

Post-Harvest Assessment:
The Post-Harvest Assessment of the 4R Consistent Plan, which will provide a written assessment that the Plan was implemented as designed, shall be signed and if applicable, stamped by the Accredited Professional Advisor, and shall be confirmed by the farmer. The post-harvest assessment of activities will be carried out at the resolution consistent with the selected performance level.

The assessment will involve:

(1) Description of changes to the 4R Consistent Plan in response to weather-related disruptions;
(2) Analysis of yield data and of testing results including the nitrogen balance assessment; and
(3) Identification of issues to be addressed in the next year's 4R Consistent plan.

Post-Harvest Assessment must be included in the annual Offset Project Report.

Operational Records:
The operational records provided by the farmer will be the primary target of the verifier's efforts to ensure the protocol has been implemented correctly. Again, these should be maintained by the farmer as well as by the Project Developer (aggregator) and the Accredited Professional Advisor.

All records collected as part of the implementation of the 4R Consistent Plan should be retained, and must be made available to the third party verifier. These records must be linked to crop events to support data management processes and systems designed and implemented according to scale of field, sub-field, or digital field map as required in the selected performance level. These records include:

- Sampling plan for soil and/or plant tissue;
- Results of soil and/or plant tissue tests;
- Purchases of seed and fertilizer;
- Records for cropping activity — for each field, record:
    - planting date and rate;
    - fertilizer and/or manure application(s) source, rate, date, place;
    - harvest date.
- Sampling plan for yield assessment;

- Results of yield assessment.

In addition to the records above, time-stamped digital photographs of equipment and cropping activity are helpful for purposes of documenting BMPs.

5.3 Site Visits

A risk-based sample size of farms visits is required for verification. Verifiers will typically request access to records, as well as do physical inspections for equipment practices and other inspections. All farmers participating in an offset project should be prepared to receive a verifier. By having documentation on hand at the farm, such visits will be easily accommodated.

In order to support the third party verification and the potential supplemental government audit, the Project Developer must put in place a system that meets the following criteria:

- All records must be kept in areas that are easily located;
- All records must be legible, dated and revised as needed;
- All records must be maintained in an orderly manner;
- All documents must be retained for 7 years after the project crediting period;
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored in two locations to prevent loss of data.

Note: Farmer attestations are not considered sufficient proof that an activity has taken place and do not meet verification requirements.

5.4 Quality Assurance/Quality Control Considerations

Quality Assurance/Quality Control can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Ensuring that the changes to operational procedures (including feed intake, manure management, etc.) continue to function as planned and achieve greenhouse gas reductions
b Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate
c Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data
d Performing recalculations of quantification procedures to reduce the possibility of mathematical errors
e Storing the data in its raw form so it can be retrieved for verification
f Protecting records of data and documentation by keeping both a hard and soft copy of all documents
g Recording and explaining any adjustment made to raw data in the associated report and files.
h A contingency plan for potential data loss.

5.5 Liability

Offset projects must be implemented according to the approved protocol and in accordance with government regulations. Alberta Environment reserves the right to audit Offset Credits and associated projects submitted to Alberta Environment for compliance under the *Specified Gas Emitters Regulation* and may request corrections based on audit findings.

6.0 References

Alberta Agriculture and Rural Development. Alberta's Nutrient Management Planning Guide. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920.

Alberta Agriculture and Rural Development. Alberta's Soil Information Viewer. http://www.agric.gov.ab.ca/app21/rtw/index.jsp.

Alberta Environment. Technical Guidance for Offset Project Developers http://environment.alberta.ca/02278.html.

Alberta Research and Extension Council of Alberta. 2010. Precision Farming and Variable Rate Technology: A Resource Guide. http://areca.ab.ca/userfiles/files/VRT_Resource_Manual_Mar_2010.pdf

Climate Change Central 2010. Supporting Documentation for the Development of the Nitrous Oxide Emissions Reduction Protocol. http://carbonoffsetsolutions.climatechangecentral.com/offset-protocols/alberta-protocol-development-workshops and http://carbonoffsetsolutions.climatechangecentral.com/offset-protocols/alberta-protocol-review-process/5th-cycle-protocol-development.

Rochette, P., D.E. Worth, E.C. Huffman, J.A. Brierley, B.G. McConkey, Jingyi Yang, J.J. Hutchinson, R.L. Desjardins, R. Lemke, and S. Gameda. 2008. Estimation of N_2O emissions from agricultural soils in Canada. II. 1990-2005 Inventory. Can. J. Soil Sci. 88: 655-669.

Snyder, C.S., T.W. Bruulsema, and T.L. Jensen. 2007. *Greenhouse gas emissions from cropping systems and the influence of fertilizer management—a literature review.* International Plant Nutrition Institute, Norcross, Georgia, U.S.A.

Roberts, T.L. 2007. Right product, right rate, right time and right place...the foundation of best management practices for fertilizer. pp 29-32. *In* Fertilizer Best Management Practices: General Principles, Strategy for their Adoption, and Voluntary Initiatives vs Regulations. IFA International Workshop on Fertilizer Best Management Practices. 7-9 March 2007.

Statistics Canada 2001. Census of Agriculture. http://www.statcan.gc.ca/pub/21-021-m/2004002/t/4144642-eng.htm

IPSOS 2006

7.0 Appendices

Appendix A: Soil Temperature Map

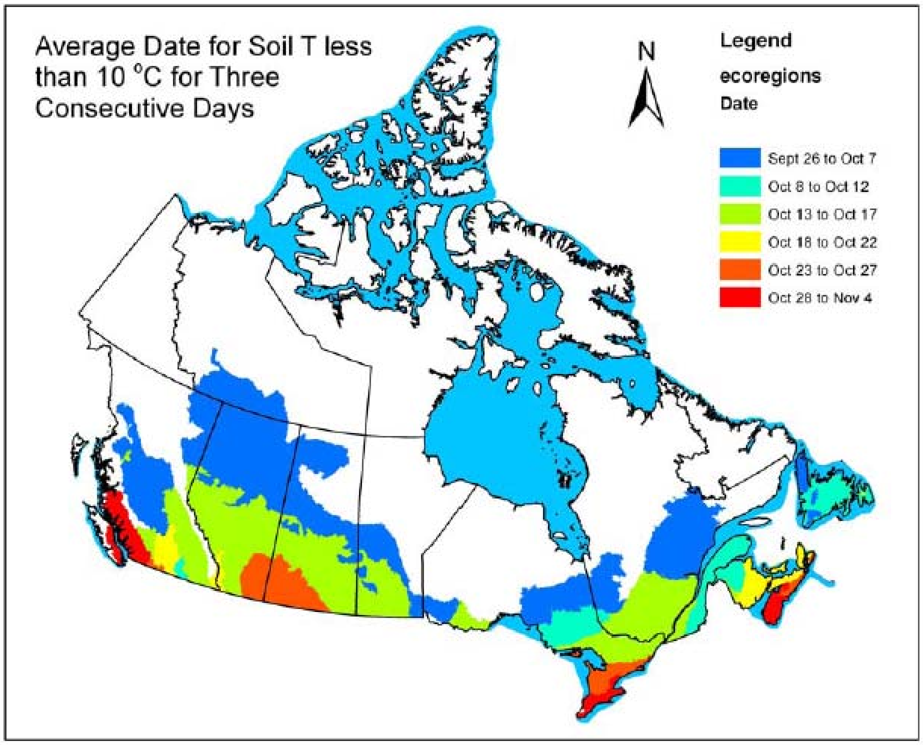


Figure A.1. Suitable dates for applying N fertilizer in the fall across Canada. These zones roughly correspond to the Eco-regions of Canada in the National Eco-Stratification of Canada.

Appendix B: Eco-District Related Factors (P/PE, $FRAC_{leach}$, EF_{eco}).

Note: Drier soils are those soils which have a P/PE ratio of < 1; while moister soils have a P/PE ratio ≥ 1.

TABLE B.1: Eco-District Related Factors for Alberta

Ecodistrict	P/PE	FracLeach	EFeco
	mm/mm	%	%
244	0.56	16	0.791
583	0.58	17	0.962
586	0.56	16	0.803
587	0.56	16	0.836
588	0.52	15	0.680
589	0.55	15	0.770
590	0.58	16	0.838
591	0.67	19	1.019
592	0.61	17	0.912
593	0.63	18	0.922
594	0.64	18	0.964
595	0.59	17	0.717
596	0.58	17	0.811
597	0.61	17	0.906
598	0.65	18	0.945
599	0.62	18	0.767
600	0.63	18	0.954
607	0.56	16	0.745
609	0.56	16	0.791
610	0.64	18	0.946
611	0.59	17	0.943
612	0.61	17	0.897
614	0.76	22	1.219
615	0.75	22	1.216
616	0.74	22	1.181
617	0.74	22	1.174
618	0.65	19	1.035
619	0.77	23	1.241
622	0.79	23	1.314
623	0.74	22	1.159
624	0.85	25	1.395
625	0.75	22	1.189
626	0.75	22	1.188
627	0.74	21	1.141
628	0.72	21	1.141
629	0.74	22	1.198
630	0.72	21	1.142
631	0.59	17	0.858

Ecodistrict	P/PE	FracLeach	EFeco
	mm/mm	%	%
650	0.62	18	0.982
678	0.73	21	1.143
679	0.63	18	1.005
680	0.62	18	0.888
681	0.70	20	1.099
683	0.69	20	0.906
684	0.71	21	1.147
686	0.58	16	0.866
687	0.57	16	0.666
688	0.57	16	0.893
692	0.70	20	1.093
703	0.71	21	1.167
708	0.69	20	1.121
727	0.68	20	0.884
728	0.59	17	0.719
729	0.53	15	0.612
730	0.56	16	0.714
731	0.65	19	1.044
732	0.67	19	1.152
737	0.65	19	0.903
738	0.56	16	0.723
739	0.51	14	0.789
740	0.64	18	0.883
743	0.51	14	0.652
744	0.61	17	0.813
746	0.65	19	0.917
750	0.55	16	0.806
769	0.52	14	0.811
771	0.46	12	0.643
777	0.52	14	0.797
779	0.51	14	0.736
781	0.50	14	0.638
786	0.48	13	0.610
787	0.41	11	0.831
788	0.42	11	0.578
790	0.42	11	0.573
791	0.46	12	0.583
793	0.42	11	0.779
797	0.44	12	0.691
798	0.52	14	0.709
799	0.48	13	0.682
800	0.50	14	0.757
801	0.61	17	0.948
802	0.48	13	0.721
804	0.41	11	0.568
805	0.35	9	0.382
806	0.34	9	0.769
809	0.35	9	0.476
811	0.36	9	0.406

Ecodistrict	P/PE	FracLeach	EFeco
	mm/mm	%	%
812	0.37	10	1.330
814	0.34	9	0.545
815	0.34	9	0.432
818	0.38	10	0.982
821	0.34	9	0.301
823	0.35	9	1.060
828	0.36	9	0.608
829	0.36	9	1.157
833	0.35	9	0.562
836	0.35	9	0.295
837	0.36	9	0.451
838	0.37	9	0.386
1016	0.61	17	0.904
1017	0.56	16	0.798
1018	0.57	16	0.847
1019	0.58	16	0.832
9593	0.67	19	0.907
9609	0.75	22	1.182
9687	0.60	17	0.857
9787	0.42	11	0.712

Appendix C: Accredited Professional Advisor Requirements

Accredited Professional Advisor Qualification Requirements

An Accredited Professional Advisor is a soil, crops, environmental, or agronomy-trained individual with field experience. They must have at least the following qualification requirements:

- Requirements of a combination of education, training and experience:
  - An agriculture soils-crop science trained two-year diploma with 4 years of field experience, or 4-yr BSc ag graduate with at least two years of field level experience; or
  - A Professional Agrologist (PAg) and current member of a provincial Institute of Agrologists (e.g Saskatchewan, Manitoba, British Columbia, Ontario, etc.) with 2 years of field level experience in soils, agronomy, or crop science advising; or a Technical Ag (TAg) with 4 years of field level experience in soils, agronomy, or crop science advising.
  - A Certified Crop Advisor (CCA), these persons have went through a combination of training, experience, study, and have passed CCA certification exams. They may be an agriculture soils-crop science trained two-year diploma or 4-yr BSc ag graduate, or a person with high school graduation and sufficient field experience (minimum 4–yr) experience; or
  - An environmental science trained two-year diploma with 4 years of related field experience, or 4-yr BSc graduate with 2 years field experience; or
  - An environmental engineer with 2 years agronomic field experience.
- All the persons with the needed education and work experience, as noted above, would need to show competency to prepare and sign-off on 4R Consistent Plans under this protocol:
  - Know necessary required learning objectives.
  - Show the capability of being able to prepare a 4R Consistent Plan, given a standard set of background farm field information.

Appendix D. Framework for the Design of a 4R Consistent Plan

Accredited Professional Advisor Learning Objectives

(Note based on the American Society of Agronomy and Prairie Provinces Certified Crop Advisor, nutrient management learning objectives.)

- Explain how soil pH affects symbiotic N fixation.
- Describe how clay and organic matter affect the cation exchange capacity (CEC) of a soil.
- Describe how Cation Exchange Capacity (CEC) affects inherent soil fertility.
- Recognize soils with high, medium and low CEC.
- Describe the soil conditions and fertilizer management that stimulate or inhibit mineralization, immobilization, nitrification, denitrification, symbiotic N fixation, nitrate leaching and volatilization.
- Describe how prairie fall and winter conditions and the spring thaw period affect mineralization, immobilization, nitrification and denitrification and nitrate leaching.
- Describe how nutrient credits from animal manure, biosolids, legumes, and cover crops influence fertilizer recommendations.
- Explain the advantages and disadvantages of band, broadcast and seed-placed fertilizer application methods.
- Describe the physical form, analysis, handling precautions, advantages and disadvantages of the common sources of N, P, K, & S used on prairie crops.
- Describe the attributes of the following fertilizer(s) and fertilizer amendments:
    - ESN
    - Agrotain
- List factors that affect seed-placed application rates of the following materials:
    - urea
    - ammonium nitrate
    - anhydrous ammonia
    - ESN
    - monoammonium phosphate
    - UAN (28-0-0 or 32-0-0)
    - Agrotain coated urea
    - ammonium sulphate
    - elemental S
    - blends of these products
- For N fertilizers on prairie crops describe factors affecting:
    - pre or post emergent timing
    - placement method (band, broadcast, seed-placed and foliar)
    - application rates
- Describe the principles of nitrous oxide emissions from agricultural sources and practices for mitigation.

- Describe the effect of nutrient management practices on surface and ground water quality.
- Indicate the type of information obtained from surface and sub-surface soil sampling depths.
- Describe the limitations of surface soil sampling for developing a fertilizer recommendation.
- Explain the effect of soil electrical conductivity (E.C.) values on plant growth.
- Use soil test information to make economically and environmentally sound fertilizer recommendations.
- Describe common philosophies used by soil testing labs to make fertilizer recommendations (soil building, replacement and sufficiency).
- Describe the following recommended soil sampling and handling procedures:
    - time of sampling
    - depth of sampling
    - frequency of sampling
    - sample density
    - addressing the field (including use of remote or digital information to assess filed size, location, and management)
    - sampling pattern (including random, benchmark, grid and topographic methods)
- Distinguish between extractable, plant-available and total soil nutrient levels.
- Interpret a soil test report, including case study with invented lab report.

4R Plan Training

Prepare a baseline N_2O scenario and both a basic and intermediate Alberta 4R Plan.

- This would be done given necessary field information from three cropping seasons, i.e.
    - How N fertilizer was applied, specifically noting N form, rate, timing and placement.
    - Records of actual N fertilizer purchased for the field.
    - Yields of harvested crops and estimated N removal.
    - Type of cropping system used i.e. tillage and planting equipment and

Sample Form for Sign-Off by Accredited Professional Advisor

ACCREDITED PROFESSIONAL ADVISOR'S CERTIFICATE/OPINION

TO:

AND TO:

RE: Design and Implementation of the Comprehensive 4-R Nitrogen Stewardship Plan (the "4R Plan") as specified by the Quantification Protocol for Nitrous Oxide Emission Reduction Protocol (the "Protocol") Under the *Specified Gas Emitters Regulation*

AND RE: [Insert name of project] (the "Project") Conducted by [name of farmer] (the "Farmer")

AND RE: [Insert name of Project Developer/Aggregator] whose program the farmer is enrolled in]

---

1. Capitalized terms used herein and not defined herein shall have the meanings ascribed to such terms in the Protocol.

2. I, ________________________________, am an Accredited Professional Advisor (APA) who has completed training through [organization] and has been accredited under [name of accreditation program] and have successfully completed supplementary training on the 4R Plan of the Protocol.

3. As an Accredited Professional Advisor, I have assisted [name of farmer] in the design and development of a 4R Plan as part of a Protocol offset project for [description of farm and land] for aggregation by [aggregator name] according to all the Accredited Professional Advisor requirements set out in the Protocol to the best of my abilities and in accordance with all applicable professional standards.

4. I have reviewed the Project documentation provided to me by the Farmer and, to the best of my knowledge, [I hereby certify/in my opinion]:

    (a) the baseline calculations contained in the Project documentation are accurate and correct;

    (b) the conclusions contained in the Project documentation are appropriate and are supported by baseline calculations; and

    (c) the 4R Plan for the Project was implemented in accordance with the 4R Plan by the Farmer.

5. In my opinion, based on my review of the Project documentation that I have been provided and my participation in the design of the 4R Plan and my inspections of the implementation of the 4R Plan, the farmer enrolled in this Project has met the requirements specified under the Nitrous Oxide Emission Reduction Protocol.

6. I have made or caused to be made such examinations or investigations as are, in my opinion, necessary to make the statements contained herein, and I have furnished this [certificate/opinion] with the intent that it may be relied upon by the addressees as a basis for the serialization and registration of Offset Credits for the Project on the Alberta Emissions Offset Registry under the *Specified Gas Emitters Regulation*.

DATED at___________________, this __________day of ________________, 20__.

____
Name of Accredited Professional Advisor:

____
Signature of APA

Appendix E: Crop Residue N Factors

Table E.1 Crop Residue Factors from Holos Methodology which is based on IPCC methods but are modified for Canadian conditions and this Protocol.

				Relative dry matter allocation		
Crop	*moisture_ content* (w/w)	*AGresidue_N_ conc* (kg N kg^{-1})	*BGresidue_N_ conc* (kg N kg^{-1})	*Yield_ ratio*	*AGresidue_ ratio*	*BGresidue_ ratio*
Barley	0.12	0.007	0.01	0.38	0.47	0.15
Buckwheat	0.12	0.006	0.01	0.24	0.56	0.20
Canary seed	0.12	0.007	0.01	0.20	0.60	0.20
Canola	0.09	0.008	0.01	0.26	0.60	0.15
Chickpeas	0.13	0.018	0.01	0.29	0.51	0.20
Coloured, white, faba beans	0.13	0.010	0.01	0.46	0.34	0.20
Dry peas	0.13	0.018	0.01	0.29	0.51	0.20
Flaxseed	0.08	0.007	0.01	0.26	0.60	0.15
Fodder corn	0.70	0.013	0.007	0.72	0.08	0.20
Grain corn (shelled)	0.15	0.005	0.007	0.47	0.38	0.15
Hay and forage seed	0.13	0.015	0.013	0.12	0.48	0.40
Hay - grass	0.13	0.016	0.01	0.18	0.12	0.70
Hay - legume	0.13	0.015	0.015	0.40	0.10	0.50
Hay - mixed	0.13	0.015	0.015	0.40	0.10	0.50
Lentils	0.13	0.010	0.01	0.28	0.52	0.20
Mixed grains	0.12	0.0063	0.01	0.33	0.47	0.20
Mustard seed	0.09	0.008	0.01	0.26	0.60	0.15
Oats	0.12	0.006	0.01	0.33	0.47	0.20
Potatoes	0.75	0.020	0.01	0.68	0.23	0.10
Rye	0.12	0.006	0.01	0.34	0.51	0.15
Safflower	0.02	0.010	0.01	0.27	0.53	0.20
Soybeans	0.14	0.006	0.01	0.30	0.45	0.25
Spring wheat, durum	0.12	0.006	0.01	0.34	0.51	0.15
Sunflower seed	0.02	0.010	0.01	0.27	0.53	0.20
Triticale	0.12	0.006	0.01	0.32	0.48	0.20
Winter wheat	0.12	0.006	0.01	0.34	0.51	0.15

Janzen *et al.* 2003.

Appendix F: Sample Calculations

The quantification of reductions achieved by a project is based on actual measurement and monitoring as indicated by the proper application of the 4R Plan. This sample calculation will help guide project proponents through the data collection procedures and methodology implementation.

First off, before initiating a project, the project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System. Of particular note:

- The date of equipment installation, operating parameter changes or process reconfiguration are initiated or have effect on the project on or after January 1, 2002 as indicated by farm and project developer records;
- The project may generate emission reduction offsets for a period of eight years unless an extension is granted by Alberta Environment. Additional credit duration periods require a reassessment of the baseline condition; and,
- Ownership of the emission reduction offsets must be established as indicated by land owner/land lessee agreements.

For this particular sample calculation, we are considering a farm in Alberta, situated on the Highway 2 corridor between Bowden and Wetaskiwin. The sample calculation will describe the step-by-step procedure to estimate emissions from the farm in the year after the 4R Plan was implemented, but the emissions from the baseline year (used for the calculation of reductions) will be given as 0.5350 kg CO_2e per kg canola (no calculations shown).

> **NOTE:** Calculations for baseline period and project year follow the same procedures, but baseline calculations for each crop will be completed per kg crop using all fields of a crop on the farm as the management zone. Crop area does not need to be the same in baseline period and project year. However, the baseline is the average of three years, and the reduction modifier is used only in the project. In the project, the sample calculation for canola below would need to be repeated for all management zones of each crop on the farm.

Sample Ecodistrict

In this illustration, only the calculations are shown for the canola grown on the farm, for which no manure or any soil N amendment other than fertilizer is used in the project year. In addition, no summerfallow was used on this farm in the baseline or in the project.

Ecodistrict 746 (Crossfield to Bowden) — area of annual crops is 148 122 ha or 148.122 km^2

- Black/Gray Chernozem, Medium texture, P/PE 0.65, F_{TILL} 0.9106, F_{TOPO} 0.11, no irrigation.
- EF_{Eco} 0.00917 kg N_2O-N kg^{-1} N (includes tillage, topography, irrigation, and texture), $FRAC_{LEACH}$ 0.19.

Ecodistrict 737 (Bowden to Wetaskiwin) — area of annual crops is 142 352 ha or 142.352 km^2

- Black/Gray Chernozem, Medium texture, P/PE 0.65, F_{TILL} 0.9216, F_{TOPO} 0.16, no irrigation.
- EF_{Eco} 0.00903 kg N_2O-N kg^{-1} N (includes tillage, topography, irrigation, and texture), $FRAC_{LEACH}$ 0.19.

NOTE: The two Ecodistricts are shown to emphasize the similarity of emission factors within a region encompassing almost 300 km^2 of annual crops. The values from Ecodistrict 737 will be used to estimate emissions in this sample calculation.

Sample Project

In the project year, 500 ha of canola are grown. The farm has implemented the intermediate performance level, involving (1) design and use of the 4R Consistent Plan with specific direction for sub-field areas of below- and above-average yield, and (2) use of spring-banded instead of fall broadcast application of controlled-release fertilizer.

Step 1 - Calculate Area of Fields

The 4R Plan specifies the delineation of sub-fields as illustrated in the sample landscape map (Figure 1). The fields are segmented into management zones as follows:

- Upper Slope (UPS) — generally water shedding and in upper landform positions;
- Mid-Slope (MID) — generally water neutral and in mid-slope landform positions;
- Lower Slope (LOW) — generally water receiving and in lower landform positions; and
- Depression (DEP) — generally undrained areas with ephemeral water accumulations.

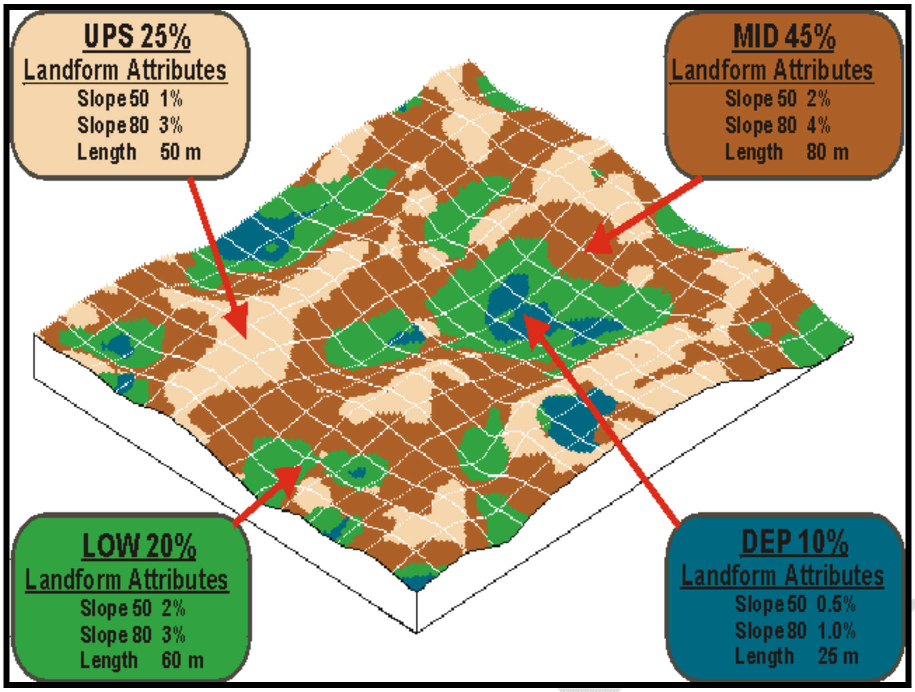


Figure 1. Sample map of field showing distribution of landforms on the Case Study farm. (From MacMillan and Pettapiece 2000[18]).

As the sample project is carried out at the Intermediate performance level, GPS data will provide the basis for the calculation of area of fields and of the sub-field management zones. Additional information, such as aerial photographs, is helpful to support the calculation. The Accredited Professional Advisor will provide sign-off for this calculation.

In this sample calculation project year, the 4R Plan identifies 10 canola management zones for below-average expected yield of and 15 canola zones for above-average expected yield (Table 4).

The characterization of these sub-field segments as below or above-average yield areas for nutrient management, including the guide for testing to support post-harvest assessment, will vary according to the soil water status before seeding. For example, in ‘normal years’ the UPS and DEP segments would receive N amendment to support below-average yields, while the MID and LOW segments would be applied with sufficient N to support above-average yields. In ‘dry years’ the UPS and MID segments would be managed as below-average, and the LOW and DEP would be managed as above-average. And, in ‘wet years’ the LOW and DEP segments would be managed as below-average (receiving no N if water standing), and the MID and UPS would be managed as above-average. Further, top-dressing could be considered for UPS in

[18] MacMillan, R.A. and W.W. Pettapiece. 2000. Alberta landforms: Quantitative morphometric descriptions and classification of typical Alberta landforms. Technical Bulletin No. 2000-2E. Research Branch, Agriculture and Agri-Food Canada, Semiarid Prairie Agricultural Research Centre, Swift Current, SK. 118 pp.

'normal years' if late spring precipitation provides reasonable potential for sufficient increase in yield to justify the increased expense. The 4R Plan would specify the testing method (sub-field soil sampling, post-harvest N balance assessment, etc.) to determine the N status of the soil to provide appropriate application rate recommendation for the below and above-average yield management zones. A 'normal year' is considered for this sample calculation.

Step 2 - Report Testing of Soil and Plant Tissue

To substantiate the testing, the 4R Plan will tabulate the testing done and the results used to determine the N application recommendation. The testing plan and lab reports will be retained by the participating farm. The Accredited Professional Advisor will sign off on the 4R plan to attest to the validity of the testing plan and to the interpretation of the testing results.

To simplify the example, all canola management zones in this project year were sown to wheat in the previous year, and are assigned similar soil N status. Thus, all below-average yield management zones received 70 kg N ha^{-1}, and all above-average yield management zones received 90 kg N ha^{-1} (Table 4).

Table 4. Management zones of below and above-average yield sown to canola in the project year of sample calculation.

		Area (ha)	N Applied (kg N ha^{-1})	Yield (kg Canola ha^{-1})
Below-Average (UPS and DEP)	Canola BA-1	15.0	70	1300
	Canola BA-2	16.0	70	1500
	Canola BA-3	17.0	70	1350
	Canola BA-4	18.0	70	1450
	Canola BA-5	17.5	70	1250
	Canola BA-6	19.0	70	1500
	Canola BA-7	18.5	70	1450
	Canola BA-8	20.0	70	1400
	Canola BA-9	17.0	70	1350
	Canola BA-10	17.0	70	1450
	BA AVERAGE	**17.50**	**70**	**1400**
Above-Average (MID and LOW)	Canola AA-1	22.0	90	1750
	Canola AA-2	24.5	90	1775
	Canola AA-3	19.0	90	1775
	Canola AA-4	20.5	90	1900
	Canola AA-5	22.0	90	1800
	Canola AA-6	21.5	90	1725
	Canola AA-7	23.5	90	1700
	Canola AA-8	21.0	90	1800
	Canola AA-9	19.0	90	1925
	Canola AA-10	22.5	90	1700

	Canola AA-11	21.5	90	1650
	Canola AA-12	23.5	90	1700
	Canola AA-13	24.0	90	1650
	Canola AA-14	20.0	90	1700
	Canola AA-15	20.5	90	1700
	AA AVERAGE	**21.67**	**90**	**1750**

Step 3 - Report Crop Seeded for Each Crop Management Zone

The crop seeding plan will be included in the 4R Plan signed off by the Accredited Professional Advisor. To substantiate the plan, documentation retained at the farm will include seed purchase (or seed cleaning) receipts, and GPS data from seeding equipment.

Step 4 - Report Yield for Each Crop Management Zone

Since this sample calculation is at the intermediate performance level, yields are reported at the sub-field scale. Thus, combine yield monitors will provide the main dataset. However, the sum of yield values obtained for management zones from yield monitors should be corroborated against the total yield values from weigh wagons, sales receipts, etc. The sign-off by the Accredited Professional Advisor will attest to the reasonableness of the yield values.

Yields, and total emissions per unit of yield, are reported on a dry mater basis. To calculate dry matter, the yield data from the yield monitors need to be adjusted for the water content of the crop. This water content can be determined at time of sale, or from the farm-measured value if the crop is still in the bin at time of calculation.

Step 5 - Calculate Nitrogen Inputs for Each Crop Management Zone

Fertilizer

The amount of fertilizer N applied per hectare for each management zone of canola is specified in the 4R Plan, and will be signed off by the Accredited Professional Advisor to attest successful application as recommended by source, rate, time, and place. The primary evidence to document fertilizer application per management zone will be provided from GPS data from application equipment. Again, the GPS data will be attested by application recommendations from the Accredited Professional Advisor, and supported by purchase invoices.

Crop Residues

According to the convention used in Canada's National Inventory Report, the values used to estimate direct and indirect N_2O emissions from crop residues are based on the yield for the year of interest. Calculate the amount of crop residue N, above ground and below ground, accumulated in the year of interest per hectare for each crop.

> **NOTE:** In this sample, the calculations will be shown for CanolaAA-1. The same calculation process would be followed for all management zones of canola.

Multiply the average yield for the year for each crop using the crop-specific factors from Table E1, Appendix E. For example, for the sample farm for canola:

$$\begin{aligned} N_{AG,Canola} &= Yield_{Canola} * 1/Yield\_ratio * AGresidue\_ratio * AGresidue\_N\_conc \\ &= 1750 \text{ kg DM ha}^{-1} * 1/0.26 * 0.60 * 0.008 \text{ kg N kg}^{-1}\text{DM} \\ &= 1750 \text{ kg DM ha}^{-1} * 0.0185 \text{ kg N kg}^{-1}\text{DM} \\ &= 32.308 \text{ kg N ha}^{-1} \end{aligned}$$

$$\begin{aligned} N_{BG,\ Canola} &= Yield_{Canola} * 1/Yield\_ratio * BGresidue\_ratio * BGresidue\_N\_conc \\ &= 1750 \text{ kg DM ha}^{-1} * 1/0.26 * 0.15 * 0.01 \text{ kg N kg}^{-1}\text{DM} \\ &= 1750 \text{ kg DM ha}^{-1} * 0.0058 \text{ kg N kg}^{-1}\text{DM} \\ &= 10.096 \text{ kg N ha}^{-1} \end{aligned}$$

$$\begin{aligned} N_{res,\ Canola} &= N_{AG,\ Canola} + N_{BG,\ Canola} \\ &= 32.308 \text{ kg N ha}^{-1} + 10.096 \text{ kg N ha}^{-1} \\ &= 42.404 \text{ kg N ha}^{-1} \end{aligned}$$

Manure

No manure is applied on this sample farm for the project year of interest. If manure were used on the farm, average manure N spread on each crop in the year of interest would be included as a source of N for the crop. That is, according to the convention used in Canada's National Inventory Report, it is assumed that all manure N is available in the year of application.

Step 5 - Calculate Direct N_2O Emissions for Each Crop

Direct Emissions from Fertilizer

Calculate direct N_2O emissions for each crop in the year of interest by multiplying the amount of fertilizer N applied to the crop by the emission factor for the soil (EF_{ECO}). The EF_{ECO} value is provided as the ecodistrict-specific factor which integrates the average for the ecodistrict of factors including F_{TOPO}, F_{TILL}, F_{IRRI}, and F_{TEXT}.

$$\begin{aligned} N_2O_{FN,\ Canola} &= N_{Canola} * EF_{Eco} * 44/28 \\ &= 90 \text{ kg N ha}^{-1} \text{ canola} * 0.00903 \text{ kg } N_2O\text{-N kg N} * 44/28 \\ &= 1.2771 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola} \end{aligned}$$

Direct Emissions from Crop Residue

Calculate direct N_2O emissions for each crop in the year of interest by multiplying the amount of crop residue N accumulated from the crop by the emission factor for the soil (EF_{ECO}).

$$\begin{aligned} N_2O_{res,\ Canola} &= N_{res,\ Canola} * EF_{Eco} * 44/28 \\ &= 42.404 \text{ kg N ha}^{-1} \text{ canola} * 0.00903 \text{ kg } N_2O\text{-N kg N} * 44/28 \\ &= 0.6017 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola} \end{aligned}$$

Direct Emissions from Manure

No manure on this farm. If manure were used on the farm, average manure N spread on each crop in the year of interest would be included as a source of N in the calculation for direct N_2O emissions for the crop. That is, it is assumed that all manure N is available in the year of application.

Total Direct Emissions from Crop Management Zone

Calculate direct N_2O emissions for each crop in the year of interest by summing the direct emissions from fertilizer, from crop residues, and from manure.

$$N_2O_{D,\ Canola} = N_2O_{FN,\ Canola} + N_2O_{res,\ Canola}$$
$$= 1.2771 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola} + 0.\ 6017 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola}$$
$$= 1.8788 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola}$$

Step 6 - Calculate Indirect N_2O Emissions from Volatilization for Each Crop Management Zone on an Area Basis

Volatilization Emissions from Fertilizer

Calculate indirect N_2O emissions from volatilization for each crop management zone in the year of interest by multiplying the amount of fertilizer N applied to the crop by the appropriate coefficient of volatilization ($FRAC_f$) and the emission factor for volatilized N (EF_{VD}). The values for $FRAC_f$ and EF_{VD} are constant across Canada.

$$N_2O_{VD,\ Canola} = N_{Canola} * FRAC_f * EF_{VD} * 44/28$$
$$= 90 \text{ kg N ha}^{-1} \text{ canola} * 0.1 * 0.01 \text{ kg } N_2O\text{-N kg N} * 44/28$$
$$= 0.1414 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola}$$

Volatilization Emissions from Crop Residue

By convention of IPCC, crop residues are not included in the calculation of indirect N_2O emissions from volatilization.

Volatilization Emissions from Manure

No manure on this farm. If manure were used on the farm, average manure N spread on each crop management zone in the year of interest would be included as a source of N in the calculation for volatilization N_2O emissions for the crop. That is, it is assumed that all manure N is available in the year of application.

Total Volatilization Emissions from Crop Management Zone

Calculate direct N_2O emissions for each crop in the year of interest by summing the volatilization emissions from fertilizer and from manure.

$$N_2O_{VD,\ Canola} = 0.1414 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola}$$

Step 7 - Calculate Indirect N_2O Emissions from Leaching for Each Crop Management Zone on an Area Basis

Leaching Emissions from Fertilizer

Calculate indirect N_2O emissions from leaching for each crop management zone in the year of interest by multiplying the amount of fertilizer N applied to the crop by the appropriate coefficient of leaching ($FRAC_L$) and the emission factor for leached N (EF_L).

The values for $FRAC_L$ are calculated for each ecodistrict in Canada, and are provided in Table B1, Appendix B. The value for EF_L is constant across Canada, and currently is set as 0.025 kg N_2O-N kg N. The 2006 IPPC value for EF_L is 0.0075, but Canada's National Inventory Report will use the 1996 IPPC value of 0.025 until the 2006 IPPC value is officially Accredited as the international standard. Thus, it is possible Alberta Environment will adjust this value in the future.

$$N_2O_{L,F,\ Canola} = N_{F,\ Canola} * FRAC_L * EF_L * 44/28$$
$$= 90\ kg\ N\ ha^{-1}\ canola * 0.19 * 0.025\ kg\ N_2O\text{-}N\ kg\ N * 44/28$$
$$= 0.6718\ kg\ N_2O\ ha^{-1}\ canola$$

Leaching Emissions from Crop Residue

By convention of IPCC, crop residues are not included in the calculation of indirect N_2O emissions.

$$N_2O_{L,res,\ Canola} = N_{res,\ Canola} * FRAC_L * EF_L * 44/28$$
$$= 42.404\ kg\ N\ ha^{-1}\ canola * 0.19 * 0.025\ kg\ N_2O\text{-}N\ kg\ N * 44/28$$
$$= 0.3165\ kg\ N_2O\ ha^{-1}\ canola$$

Leaching Emissions from Manure

No manure on this farm. If manure were used on the farm, average manure N spread on each crop management zone in the year of interest would be included as a source of N in the calculation for leaching N_2O emissions for the crop. That is, it is assumed that all manure N is available in the year of application.

Total Leaching Emissions from Crop Management Zone

Calculate direct N_2O emissions for each crop management zone in the year of interest by summing the leaching emissions from fertilizer, from crop residues, and from manure.

$$N_2O_{L,\ Canola} = N_2O_{L,F,\ Canola} + N_2O_{res,\ Canola}$$
$$= 0.6718\ kg\ N_2O\ ha^{-1}\ canola + 0.\ 3165\ kg\ N_2O\ ha^{-1}\ canola$$
$$= 0.9883\ kg\ N_2O\ ha^{-1}\ canola$$

Calculate Total CO2e Emissions for Each Crop Management Zone on an Area Basis

> **NOTE:** In some instances, implementation of the 4R Plan will involve extra fuel consumption for field operations (for example, if split applications of fertilizer are used). Any difference in baseline and project fuel consumption will need to be quantified and added to the project emissions.

Step 8 - Total N_2O Emissions from Crop Management Zone

Total N_2O emissions for each crop management zone in the year of interest are calculated by summing the direct and indirect N_2O emissions from fertilizer, from crop residues, and from manure.

$$N_2O_{Canola} = N_2O_{D,\ Canola} + N_2O_{VD,\ Canola} + N_2O_{L,\ Canola}$$

$= 1.8788 \text{ kg } N_2O \text{ ha}^{-1} + 0.1414 \text{ kg } N_2O \text{ ha}^{-1} + 0.9883 \text{ kg } N_2O \text{ ha}^{-1}$

$= 3.0085 \text{ kg } N_2O \text{ ha}^{-1}$ canola

Convert to Total CO_2e Emissions from Crop Management Zone

To convert total N_2O emissions to total emissions on a carbon dioxide equivalent (CO_2e) basis, multiply the N_2O emissions by the global warming potential. Canada's National Inventory Report uses a Global Warming Potential of 310 for N_2O.

$CO_2e_{\text{Canola}} = 3.0085 \text{ kg } N_2O \text{ ha}^{-1} \text{ canola} * 310 \text{ kg } CO_2e \text{ kg}^{-1} N_2O$

$= 932.635 \text{ kg } CO_2e \text{ ha}^{-1}$ canola

$= 0.9326 \text{ Mg } CO_2e \text{ ha}^{-1}$ canola

Step 9 - Determine Total CO_2e Emissions for Each Crop Management Zone in the Project Year

Calculate Total CO_2e Emissions for Each Crop Management Zone on a Dry Matter Basis

To express emissions on a dry matter basis for each crop management zone in this project year, divide the total CO_2e emissions for the crop management zone in the year of interest by the yield of dry matter reported for the crop management zone.

$CO_2e_{\text{Canola, DM}} = CO_2e_{\text{Canola, ha}} / \text{Yield}_{\text{Canola}}$

$= 932.635 \text{ kg } CO_2e \text{ ha}^{-1} / 1750 \text{ kg ha}^{-1}$

$= 0.5329 \text{ kg } CO_2e \text{ kg}^{-1}$ canola

Apply Reduction Modifier

The reduction modifier corresponding to the performance level implemented on the farm is applied to the emission calculated per dry matter produced. In the case of the sample farm, the Intermediate level is implemented so a reduction modifier (F_{INT}) of 0.75 is used.

$CO_2e_{\text{Canola, INT}} = CO_2e_{\text{Canola, DM}} * F_{INT}$

$= 0.5329 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola} * 0.75$

$= 0.3997 \text{ kg } CO_2e \text{ kg}^{-1}$ canola

Step 10 - Calculate Total CO_2e Reductions for Each Crop Management Zone

Calculate Reductions for Each Crop Management Zone per Unit of Dry Matter Basis

To express reductions per kg production for the management zone on a dry matter basis, subtract the emissions calculated on a dry matter basis for the project year for the management zone from the emissions calculated on a dry matter basis for the crop in the baseline period. Reductions are calculated on the basis of a unit of dry matter production to provide functional equivalence between Baseline period and Project year.

> **NOTE:** The emissions calculated for the baseline period for this sample farm are 0.5350 kg CO_2e kg^{-1} canola.

$$RED_{CanolaAA-1} = CO_2e_{Canola, BASE} - CO_2e_{CanolaAA-1, INT}$$
$$= 0.5350 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola} - 0.3997 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola}$$
$$= 0.1353 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola}$$

Calculate Offsets Generated in the Crop Management Zone in the Project Year

To calculate total reductions for each crop management zone, multiply the reductions per unit of crop production by the total production of the crop management zone in the project year.

$$OFF_{CanolaAA-1} = RED_{CanolaAA-1} * (\text{Total Area}_{CanolaAA-1} * \text{Yield}_{CanolaAA-1})$$
$$= 0.1353 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola} * (22.0 \text{ ha} * 1750 \text{ kg canola ha}^{-1})$$
$$= 0.1353 \text{ kg } CO_2e \text{ kg}^{-1} \text{ canola} * 38\ 500 \text{ kg canola}$$
$$= 5\ 209 \text{ kg } CO_2e$$
$$= 5.2 \text{ Mg } CO_2e \text{ or } 5.2 \text{ tonnes } CO_2e$$

Step 11 - Determine Offsets Generated in the Canola Crop in the Project Year

To determine total reduction (total offsets generated) for the canola crop with 4R management of applied N, sum the offsets generated from each management zone (Table 5).

$$OFF_{Canola} = \sum OFF_{CanolaBA\ i} + \sum OFF_{CanolaAA\ i}$$
$$OFF_{Canola} = 35.18 \text{ Mg } CO_2e + 48.81 \text{ Mg } CO_2e$$
$$OFF_{Canola} = 83.99 \text{ Mg } CO_2e \text{ or } 83.99 \text{ tonnes } CO_2e$$

Table 5. Emission reductions from 4R Plan of nitrogen of canola in management zones of below- and above-average yield in the project year of sample calculation.

	Net Emissions† (kg CO_2e kg^{-1})	Reductions†† (kg CO_2e kg^{-1})	Reductions (kg CO_2e ha^{-1})	Reductions (Mg CO_2e)
Canola BA-1	0.4128	0.1222	158.91	2.38
Canola BA-2	0.3740	0.1610	241.51	3.86
Canola BA-3	0.4020	0.1330	179.56	3.05
Canola BA-4	0.3827	0.1523	220.86	3.98
Canola BA-5	0.4244	0.1106	138.26	2.42
Canola BA-6	0.3740	0.1610	241.51	4.59
Canola BA-7	0.3827	0.1523	220.86	4.09
Canola BA-8	0.3920	0.1430	200.21	4.00
Canola BA-9	0.4020	0.1330	179.56	3.05
Canola BA-10	0.3827	0.1523	220.86	3.75
			Total BA	**35.18**
Canola AA-1	0.3997	0.1353	236.76	5.21
Canola AA-2	0.3958	0.1392	247.09	6.28
Canola AA-3	0.3958	0.1392	247.09	4.69
Canola AA-4	0.3778	0.1572	298.72	6.12
Canola AA-5	0.3920	0.1430	257.41	5.66
Canola AA-6	0.4037	0.1313	226.44	4.87
Canola AA-7	0.4079	0.1271	216.11	5.08
Canola AA-8	0.3920	0.1430	257.41	5.41
Canola AA-9	0.3745	0.1605	309.04	5.87
Canola AA-10	0.4079	0.1271	216.11	4.86
Canola AA-11	0.4165	0.1185	195.46	4.20
Canola AA-12	0.4079	0.1271	216.11	5.08
Canola AA-13	0.4165	0.1185	195.46	4.69
Canola AA-14	0.4079	0.1271	216.11	4.32
Canola AA-15	0.4079	0.1271	216.11	4.43
			Total AA	**48.81**
			CANOLA (500 ha) TOTAL	**83.99**

† Net emissions obtained by multiplying emissions by reduction modifier (0.75)
†† Reductions calculated by subtracting net emissions from baseline emission (0.5350 kg CO_2e kg^{-1})

Appendix G: Fossil Fuel Combustion Emission Factors

All fuel combustion emission factors interpreted from Environment Canada's National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada.

Table G1: Fossil Fuel Combustion Emission Factors

Diesel		
Emission Factor (CO_2)	2.730	kg CO_2 per Litre
Emission Factor (CH_4)	0.000133	kg CH_4 per Litre
Emission Factor (N_2O)	0.0004	kg N_2O per Litre
Natural Gas (Electric Utilities)		
Emission Factor (CO_2)	1.891	kg CO_2 per m^3
Emission Factor (CH_4)	0.00049	kg CH_4 per m^3
Emission Factor (N_2O)	0.000049	kg N_2O per m^3
Gasoline		
Heavy-Duty Gasoline Vehicles (3-way catalyst)		
Emission Factor (CO_2)	2.360	kg CO_2 per Litre
Emission Factor (CH_4)	0.000068	kg CH_4 per Litre
Emission Factor (N_2O)	0.0002	kg N_2O per Litre