Quantification protocol for agricultural nitrous oxide emission reductions

Version 2.1

Classification: Public

Open Government Portal URL.
This publication is available online at https://open.alberta.ca/publications/9781460125502

Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions | Alberta Environment and Protected Areas

Summary of Revisions

Version	Date	Summary of Revisions
2.1	March 2023	• Updated quantification methodology and EcoDistrict-related emission and leaching factors, as per the approach used in Canada's National Inventory Report 2022 quantification method. • Added flexibility mechanism that a project may exclude fields inside the farm where 4R was not practiced, or applied, or an ineligible fertilizer was used. This does not exclude the whole farm, but must be tracked and documented. • Clarified the protocol records requirements to ensure emission reductions are clearly owned per Alberta emission offset system requirements. • Added protocol flexibility mechanism for mass determination. • Clarified project and subproject tracking requirements for aggregated projects. Clarified requirement for the aggregated project planning sheet to be submitted annually for all enrolled farms, allowing the addition and removal of subprojects (fields). • Removed Appendix B: Accredited Professional Advisor Qualification Requirements: These are included in the protocol section 1.4. • Removed Appendix C: Sample Form for Sign Off by the Accredited Professional Advisor: These will be drafted by the Accredited Professional Advisors. • Removed Appendix F: Sample Calculations. • Removed Appendix I: Acceptable Crop Mass Determination Methods: These are included in the protocol section 5.2.3, table 12.
2.0	September 2015	• The Protocol Scope and Applicability were updated to reflect requirements that the entire farm enterprise must be included in the project to qualify under this protocol. It was also specified that manure fertilizers are the only organic fertilizers eligible under the protocol, and that manure nitrogen sources are not subject to nitrous oxide greenhouse gas reductions through application of the 4R reduction modifier. An update was added to require annual soil sampling to inform 4R Plan nitrogen application recommendations in the project condition. These changes were made to strengthen emission reduction assurances under the protocol. • A Protocol Flexibility mechanism in the Baseline Condition was introduced, allowing use of two dynamic baseline approaches in place of a three-year conventional baseline. Use of the dynamic baseline approaches is subject to application of reduction modifiers. • Clarification was provided regarding 4R Accredited Professional Advisor training and qualifications, including a new requirement that Accredited Professional Advisors be approved to operate under the Alberta Institute of Agrologists Greenhouse Gas Assessment and Management Practice Standard. A requirement for at least one

		member of the verification team or government audit team to take the Fertilizer Canada (formerly Canadian Fertilizer Institute) 4R Management Plan training. • The Quantification Methodology has changed from area-based to mass-based accounting in order to streamline quantification and reduce verification risk. • The Quantification Methodology to calculate additional emissions associated with incremental fuel use in the project condition was updated. • Manure fertilizer was separated from the reduction modifier in the project emission reduction Quantification Methodology to increase protocol conservativeness. • The Quantification Methodology was amended to reference current emission factors in Alberta Environment and Protected Areas Carbon Offset Emission Factors Handbook. • The Records Requirements section was updated to detail baseline and project records requirements and to align with reasonable assurance verification requirements.
1.0	October 2010	• Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions was published for use in the Alberta emission offset system.

Contents

List of Tables

List of Figures

Related Publications

- *Emissions Management and Climate Resilience Act* (the Act)
- Technology Innovation and Emissions Reduction Regulation (the Regulation)
- Standard for Greenhouse Gas Emission Offset Project Developers (the Standard)
- Standard for Validation, Verification and Audit
- Technical Guidance for Offset Protocol Development and Revision
- Carbon Offset Emission Factors Handbook
- Alberta Greenhouse Gas Quantification Methodologies

1. Offset Project Description

Projects that are implemented according to this protocol may be eligible to generate Alberta emission offsets by committing and switching to an integrated set of Beneficial Nitrogen Management Practices (BMPs) for annual cropping systems. These BMPs manage applied nitrogen (N) sources in a comprehensive way to reduce overall nitrous oxide (N_2O) emissions associated with nitrogen fertilizer application. These BMPs are integrated into a methodology called a Comprehensive 4R (Right Source at the Right Rate, the Right Time and the Right Place) Nitrogen Stewardship Plan.

Implementing a comprehensive 4R Nitrogen Stewardship Plan (hereafter called the 4R Plan) results in applied nitrogen being used more effectively to grow agricultural crops. Further, implementing the 4Rs together across landscapes generates real reductions of N_2O emissions from agricultural cropping systems. Implementing the entire, comprehensive 4R Plan at the differing performance levels as dictated by this protocol is an additional activity and generates emission reductions that create Alberta emission offsets. Projects that implement individual elements of the BMPs are not eligible to generate emission reductions using this protocol.

This quantification protocol is written for professionals with experience and expertise in agronomy and emission reduction project quantification and implementation, which may include farm operators acting as emission offset project developers and/or contracted aggregator representatives acting as emission offset project developers. Agricultural professionals are required to assist in designing and implementing the 4R Plan. These professionals must be trained and accredited to apply this protocol and to sign off on 4R Plans. More detail on this accreditation program is provided in Section 1.4. The emission offset project developer, or aggregator, will work with each farm and an agricultural professional to draft and execute a 4R Plan for a farm enterprise and likely then aggregate many farms together into a project listing in accordance with this protocol and the criteria of the Alberta Emission Offset System as enabled under the Technology Innovation and Emissions Reduction (TIER) Regulation.

1.2 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 synthetic fertilizer, manure fertilizers and crop residues. Greenhouse gas (GHG) emission reductions associated with carbon sequestration in the soil and off-site emission reductions affected by the manufacture and distribution of nitrogen fertilizers are excluded. 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 are readily available and actively managed on farm.[1]

Other emission reduction activities, where quantification protocols exist, may be stacked with this protocol upon director approval. Emission offset project developers are required to include the entire farm enterprise that have committed to implementing the 4R Plan over the crediting period and must report enrolled farm enterprises on an annual basis to confirm farm boundaries. The Offset Project Plan may list all project eligibility and protocol criteria but the Aggregated Project Planning Sheets (APPS) are required to list all quarter sections covering each farm enterprise boundary, labelled with the unique Producer/Farm name and unique business identification number.

This protocol is first applicable for the 2023 cropping year on a go-forward basis and enrolled farms including all quarter sections within the enterprise boundary must be listed annually (by deadlines established in the Standard) in an Aggregated Project Planning Sheet submitted into the registry for each project listing. Each annual planning sheet will be used to report on emission reductions for each enrolled farm by vintage year. If an APPS is not submitted by the deadline the project is unable to make a claim for that vintage year.

The Government of Alberta requires that at least one member of a verification team and/or government reverification team has taken the “NERP Lite” course, offered by the Fertilizer Canada, in addition to other verification requirements per the Standard for Validation, Verification and Audit. Evidence that a verification team member has completed the course must be listed in the verification report with the Statement of Qualifications.

Additional land and/or crops acquired by the farm may be included in the project only on a go forward basis and can be listed in the annual submitted APPS. When land and/or crops are added or removed from the farm enterprise, the 4R plan will be updated and these added or removed land areas (quarter section) will be reflected in the annual APPS submitted to the Registry in order to generate emission offsets in that year (or not be reported on for the farm enterprise if removed).

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

New crops/land that are added are limited to the duration of the overall project consecutive offset crediting period (ineligible or non-claimed years are not eligible to extend the crediting period).

Emission Reduction Activity

Application of nitrogen from synthetic fertilizer, biological fixation, manure fertilizer and crop residues is an important component of agricultural production. Fertilizer-derived nitrogen, like any form of soil mineral nitrogen[2] (or free or soluble nitrogen), is subject to emission as N_2O either from nitrification/denitrification pathways in the soil, losses through leaching of nitrate, and/or volatilization and redeposition of ammonia gas. BMPs, which synchronize the availability of nitrogen with the requirements of the crop, minimize the emissions of N_2O per unit of crop mass.[3]

Application of this protocol minimizes these N_2O emission pathways by managing on-farm applied nitrogen sources through the implementation of the BMPs in the 4R Plan, resulting in:

- Optimization of the crop response per unit of added nitrogen, and,
- Minimization of the risk 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 and runoff. This 4R Plan is a risk-based approach, informed by years of peer-reviewed research on the effect specific management practices have on the biological processes that lead to nitrogen losses in North American cropping systems.

The 4R Plan is designed to address the risk of nitrogen losses by promoting comprehensive nitrogen management across the 4Rs to achieve the above two outcomes. (See Table 1 and APPENDIX E: The 4R Practices for more information on the 4R practices.)

In this protocol, N_2O emissions from agricultural soils are quantified using Canada's Tier II methodology for both baseline and project conditions. The emission reductions from implementing the 4Rs are based on reduction modifiers (RMs), which are conservative, science derived coefficients for estimating the synergistic effects of superior source, rate, time, and place practices on lowering N_2O emissions per unit of crop produced. Table 1 describes 4R practices and the corresponding reduction modifiers for drier soils in Canada.[4] Project emissions (Tier II method) are multiplied by the Reduction Modifier to provide an adjusted value. This adjusted project emissions value is a conservative estimate of the lower emissions achieved under an integrated system of BMP's.

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

<table>
<tr><th>Performance Level</th><th>Right Source</th><th>Right Rate</th><th>Right Time</th><th>Right Place</th><th>Reduction Modifier[i]</th></tr>
<tr><td>Basic</td><td>Ammonium-based formulation</td><td>Apply nitrogen according to recommendation of 4R Plan[ii], using annual soil testing and recommendations developed within the 4R Plan.</td><td rowspan="3">• Apply in spring,
• Split apply,
or
• Apply after soil cools to 10 degrees Celsius.</td><td rowspan="3">Apply in bands / Injection</td><td>0.85</td></tr>
<tr><td>Intermediate</td><td rowspan="2">Ammonium-based formulation and/or any of the following enhanced efficiency sources:
• Slow / controlled release fertilizers,
• Inhibitors,
or
• Stabilized N.</td><td>Apply nitrogen according to qualitative estimates of field variability (landscape position, soil variability) using annual soil testing and recommendations developed within the 4R Plan.</td><td>0.75</td></tr>
<tr><td>Advanced</td><td>Apply nitrogen according to quantified field variability (e.g., digitized soil maps, grid sampling, satellite imagery, real time crop sensors) using annual soil testing and</td><td>0.75</td></tr>
</table>

[2] Mineral nitrogen refers to NH_4^+ (ammonium), NO_3^- (nitrate) or NO_2^- (nitrite).
[3] For a literature review of the beneficial nitrogen management practices to minimize nitrous oxide emissions, see Snyder, ***et al***., 2009, Review of greenhouse gas emissions from crop production systems and fertilizer management effects.
[4] Drier soils are defined as those found in EcoDistricts with a precipitation/potential ratio (P/PE) of less than 1.0 (see Appendix A).

		recommendations developed within the 4R Plan.			

i - Scientific development and consensus of the reduction modifiers: Climate Check, 2009, Decision Paper for Nitrous Oxide Emission Reduction Protocol, prepared for Climate Change Central and Fertilizer Canada.
ii – The 4R Plan must account for all sources of nitrogen, including previous crop residues, synthetic fertilizer, manure or other organic fertilizers. The reduction modifier is not applied to nitrogen from manure. Fields receiving organic fertilizers other than manure are excluded for the quantification year in which they are applied.

The quantification of direct and indirect N_2O emissions from more sophisticated use of fertilizer are based on published emission factors from Canada's National Inventory Report and calculated as a proportion of the amount of fertilizer nitrogen applied. This quantification is performed on an EcoDistrict basis, which accounts for variables associated with soil type, texture, topography and climate. To determine the appropriate EcoDistrict for the farm, use maps available on the Agriculture and Agri-Food Canada National Soil Database (NSDB) and the Agricultural Region of Alberta Soil Inventory Database (AGRASID).

The greenhouse gases applicable in the emissions reductions methodology are listed in Table 2.

Table 2: Relevant Greenhouse Gases Applicable for this Protocol

Specified Gas	Formula	Applicable to Project
Carbon Dioxide	CO_2	Yes
Nitrous Oxide	N_2O	Yes
Methane	CH_4	Yes

This protocol requires the continuation of the project activity for the duration of the crediting period. It also requires planning and commitment to implement a 4R Plan, this could include a period of time since the last harvest (fall of the previous cropping year) for which the farming and 4R Plans are being executed. The offset start date for a project and/or the addition of new subproject fields/lands into a project to begin crediting under this protocol is subject to annual deadlines outlined in the Standard.

1.3 Protocol Applicability

This protocol is applicable to any farm in Alberta practicing enhanced nitrogen management through implementation of a 4R Plan as described. Projects must be able to provide sufficient records to verify the emission reductions being claimed.

This protocol relies on the proper documentation of field practices and requires that dated farm records and similar direct evidence of practices be retained by the farm operator, who may also be the emission offset project developer, but most commonly will contract with an aggregator to claim the reductions. The project developer and/or aggregator work with an Accredited Professional Advisor (APA). Supporting evidence for all emission reductions claims are to be made available to any third-party assurance provider and/or government reviewer upon request. Failure to provide all required documentation may lead to the invalidation of emission offsets. See Section 5 Data Management for minimum records requirements.

To apply this protocol, the emission offset project developer must document proper application and adhere to all of the following requirements (unless otherwise allowed by a flexibility mechanism which is documented and verified):

(1) Evidence an Accredited Professional Advisor (APA) approved 4R Plan has been implemented on each farm enterprise included in the project. The farm enterprise must be enrolled under the 4R Plan with a clear delineation of a farm boundary.

- Each enterprise must be assigned a unique name and the farm business number.
- To avoid leakage[5] of nitrogen or crop yield, the entire farm enterprise must enable 4R management and be incorporated into the project, however fields or management units being managed under pasture or ineligible crops can be excluded from emission reduction calculations for the year of ineligibility. If ineligible soil

[5] Leakage refers to the incorrect attribution of applied nitrogen or harvested crop yield to fields or management units which are not under 4R management for the implementation of this offset protocol. Leakage may occur either unintentionally (e.g., mistakes in records collection) or intentionally.

amendments are used, then fields where they were used are treated as ineligible for that year. Ineligible fields are listed and tracked in the Aggregated Project Reporting sheets (APRS), with a zero emission reduction claim(s) and stated reason for ineligibility documented in the comments.

- In a case where ineligible crops are grown, crop yields and fertilizer applied to these fields cannot contribute to quantification of the projects emission reductions for that year but are tracked and reported on. Nitrogen fertilizer applications to these ineligible crops must be tracked and clearly separated for that year.

- In the case of use of ineligible fertilizers in eligible crops, fertilizer applications to these fields must be tracked and clearly separated for that year.

(2) All farms included in a project are being implemented according to the 4R Plan and have received and will receive annual sign off by the Accredited Professional Advisor. Each farm enrolled and implementing a 4R Plan will be listed annually, and updated annually, ensuring any land added or removed is established for the farm, in an Aggregated Project Planning Sheet (APPS) submitted to the registry for each active project listing by annual deadlines established in the Standard.

- The nitrogen management must still occur according to the 4R Plan, with documentation collected to show conformance to the 4R Plan. If extreme weather conditions or other external conditions prevent the activities to occur according to the 4R Plan, project developers can apply a deviation as long as the deviation from the plan falls within the scope of approved 4R BMPs, documents are provided to support the request, and an APA review and sign off is obtained.
- The 4R Plan shall include a clear identification of the baseline and project conditions.
- The 4R Plan shall have been signed and sealed by an Accredited Professional Advisor. Electronic signatures are eligible as long as all required information for the APA is listed.

(3) The emission offset quantification is calculated on a mass basis using nitrogen inputs and crop mass per crop type across the farm enterprise:

- At the field level so long as the fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level, or,
- At the farm level so long as fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level.

If the farm is situated within multiple EcoDistricts, offset quantification must be completed separately for each EcoDistrict. Quantification can be done in aggregate across multiple EcoDistricts if the EcoDistrict value resulting in the most conservative offset quantification is used for all lands across the entire farm enterprise. Use of this flexibility option is described in Section 1.5 Flexibility Mechanisms.

(4) Only annual crops, and/or crops that are treated like an annual crop and meet the 4R eligibility criteria are eligible for participation. Annual crop types, are the same in the baseline and project to ensure equivalency in residue nitrogen accounting and include:

- wheat (all spring planted types)
- winter wheat
- fall rye
- barley
- barley silage
- corn
- corn silage
- pulses
- canola
- oats
- flax
- potatoes
- sugar beets
- timothy hay
- others. [6]

[6] In this category, the project developer must be able to demonstrate that the amount of straw/residue/biomass nitrogen is equivalent for the crop in both baseline and project conditions.

(5) Ineligible crops must be included in the 4R plan for the farm enterprise, however fields containing ineligible crops are excluded from being quantified in that reporting year (i.e. tracked in APRS with zero emission reduction). This means that both the crop yield and fertilizer applications in fields with ineligible crops are tracked but excluded from quantification.

- For example, fields under summer fallow must be included in the 4R Plan as part of the farm enterprise boundary, for considerations of crop rotation in the cropping program, but are excluded from the quantification in the reporting year since nitrogen is not applied.
- Lands under perennial forage grazed by animals, including swath grazing and cattle on stubble, are excluded from quantification under the project since 4R management does not occur.
- Lands under perennial forage are also excluded from quantification under the protocol.
- Burning of straw on a field makes that field ineligible for the year under this protocol. Annual forages grown for silage or baling are eligible.

(6) A farm where fields are receiving manure as fertilizer are eligible to participate under the protocol, but all other organic nitrogen sources are currently excluded from eligibility. If a crop receives an ineligible fertilizer, fields receiving the ineligible fertilizer must be excluded from quantification for the year (i.e. they are tracked in APRS with zero emission reductions). When using manure as a soil amendment, the project must be able to determine nitrogen content of the manure and the application rates for quantification under the protocol. The APA must confirm under seal the nitrogen content of the applied manure.

(7) Crops produced under irrigation in the baseline are also under irrigation in the project for the duration of the project.

(8) The conventional baseline N_2O emissions are based on the average three crop-type years prior to implementation of the 4R Plan. If a farm experiences a devastating year that results in 50 per cent less crop yield (from a five-year average), that year must be removed from the three-year average baseline and replaced with another adjacent crop year.

(9) When using the conventional baseline approach, all eligible crop types managed by the participating farm occurring in the baseline are included in the 4R Plan and in the quantification.

(10) Project emission reductions must be calculated on a crop mass basis (using Canada's National Inventory Report) quantification method as described in this protocol.

(11) Determining the mass of each crop type produced on the farm is conducted according to one of the acceptable crop mass methods outlined in Table 12: Crop Mass Determination Methods Records Requirements in this protocol.

The quantification of reductions achieved by the project is based on actual measurement and monitoring and documentation as required in this protocol.

The project meets the eligibility criteria stated in the Regulation. Of particular note, in order to qualify for participation in the Alberta emission offset system, emissions reductions must:

- Occur in Alberta.
- Result from actions not otherwise required by law.
- Result from actions taken on or after January 1, 2002.
- Be real, demonstrable and quantifiable.
- Have clear established ownership.
- Be counted once.

1.4 Accredited Professional Advisor

Emission offset project developers (or aggregators) are required to work with the farms committed to implementing the project activities under this protocol and work with an Accredited Professional Advisor (APA) to develop and then provide evidence of implementation of the 4R Plan for their farm enterprise over the crediting period. Farms are not anticipated to start and stop implementation of the project activities over the crediting period but regular updates to their 4R Plan are required.

Sign off, of the 4R Plan, by the APA is required as part of the mandatory project documentation under this protocol. APA's are regulated members of the Alberta Institute of Agrologists (AIA) who have obtained authorization by the AIA to operate under the AIA Practice Standard for the Greenhouse Gas Assessment and Management Practice Area, and have been accredited through the Fertilizer Canada 4R Nutrient Stewardship Courses (1-3) and NERP course.[7] Accredited Professional Advisors also receive supplementary training on the 4R Nutrient Stewardship model and the specific requirements of the 4R Plan described in this protocol.

An Accredited Professional Advisor is required to:

(1) Review and sign off on the baseline condition and calculations established by the farm and/or the project developer. This involves reviewing project documentation for baseline practices, providing an opinion concerning the appropriateness of the conclusions supported by the documentation, applying flexibility for exclusions of any crops/fields (e.g., summer fallow or ineligible crops), and attesting to the accuracy of calculations based on the documentation. See section 2 Baseline Condition for description of the baseline.

(2) Sign off on the 4R Plan for each participating farm enterprise including project boundary. This plan will address all farmed fields and crops under the control of the farm at the performance level selected by the farmer. The APA ensures that all nitrogen inputs and crop mass are accounted for. The details of the design of the 4R Plan are provided in Section 3 Project Condition.

(3) Provide sign off that the 4R Plan was implemented as designed for each participating farm enterprise. It is expected that nitrogen recommendations from annual soil testing will form the basis for the following year's 4R Plan.[8] This may involve assessment of activities including weather related disruptions of crop yield and deviations from the original 4R Plan where they occur.

(4) The APA will comply with Alberta legislation and professional designations.

Note: The Accredited Professional Advisor sign off does not constitute formal validation or verification for the emission offset project. Independent, third-party verification is required for all emission offsets being registered in the Alberta Emission Offset System for use as a compliance option under the Regulation. Participation in the Alberta Emission Offset System is voluntary but once a project determines it meets all criteria and begins generating emission offsets the project is subject to requirements of the regulation and subject to independent verification and government reviews.

APA's working within the context of this protocol as applied in Alberta must meet the following requirements for education, experience, and specific protocol training:

(1) Pass the requirements and become accredited under the Canadian Fertilizer Institute's 4R Nutrient Stewardship Courses (1-3) and NERP course, and have received an APA Certificate. All the persons with the needed education and work experience, as noted here will need to demonstrate competencies specific to the application of this Protocol:
   a) In 4R Nutrient Stewardship including the ability to prepare and sign off on 4R Plans under this protocol.
   b) The ability to outline the quantification methodology to calculate and/or verify emission calculations, create and implement soil sampling plans and derive nitrogen recommendations from soil test results, perform post-harvest assessments, and other specific requirements of the APA's role in the protocol, and
   c) An understanding of the APA's role in adhering to records requirements under the protocol.

(2) Meet one of the following sets of requirements:
   a) A graduate of a four-year Bachelor of Science (or equivalent) degree program:
      - With training in soils and crops and at least two years of relevant experience in crop management, and
      - A Professional Agrologist (P.Ag.) designation and current member of the Alberta Institute of Agrologists (AIA), or
   b) A graduate of a two-year science based technical diploma program:
      - With training in soils and crops and at least four years of relevant experience in crop management.
      - A Registered Technologist in Agrology (R.T.Ag.) designation and current member of the AIA, and
      - Working under the supervision of a Professional Agrologist, who is an Accredited Professional Advisor.

(3) Demonstrate confirmation from the AIA that the P.Ag. or R.T.Ag. is authorized to operate under the AIA's Practice Standard for the Greenhouse Gas Assessment and Management Practice Area.

[7] The Accredited Professional Advisors Training Program can be accessed on the Fertilizer Canada website for information purposes https://elearning.fertilizercanada.ca/en/4r-nutrient-stewardship-training/. To become an Accredited Professional Advisor, an individual will be required to take an exam. If training is updated by Fertilizer Canada, APA's must retake training within one year of the training being released.
[8] The Accredited Professional Advisor is responsible for approving and implementing the soil sampling procedures for the particular protocol performance level (basic, intermediate, and advanced).

1.5 Flexibility Mechanisms

Flexibility in applying this quantification protocol is provided to emission offset project developers in the following ways and is to be documented in the Offset Project Plan and then implementation of each flexibility mechanism is to be confirmed in the Offset Project Report to be independently verified:

(1) In the conventional baseline, a project may choose to select nonconsecutive years for crop types to set the baseline to match with data availability and to account for any extra-ordinary growing seasons. Trend data on extreme weather events to demonstrate how the excluded year is extraordinary will be needed for justification. 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-estimation of greenhouse gas emission reductions.

(2) One of two alternative dynamic baseline approaches may be employed by calculating the expected project emissions from the estimated baseline emissions and the application of the reduction modifiers outlined in Table 1. See **APPENDIX D**: Dynamic Baseline Quantification Approaches for details on the application of the dynamic baseline approaches.

- In order to provide consistency and completeness to the greenhouse gas emission reduction accounting under this protocol, farms in the project must have the whole farm enrolled in the 4R program and need to be part of the project and baseline accounting.
- As under the conventional baseline, fields or management units being managed under pasture or ineligible crops are excluded from emission reduction calculations for that year. If ineligible soil amendments are used, the fields must be tracked and then excluded (i.e. zero emission reduction) from the emission offset reduction claim in that year.
- Because the baseline is recalculated each year under the dynamic baseline flexibility mechanisms, additional land and/or crops that may be acquired by the farm must be included in the project and listed in the Aggregated Project Planning Sheets in the annual submissions. When this occurs, the 4R plan is updated and new land and/or crops are limited to the duration of the original project's crediting period. Conversely, if land is sold, the 4R Plan is updated accordingly and the farm will no longer make any claims for that area.
- Project developers can begin using Dynamic Baseline One or Dynamic Baseline Two. However, Dynamic Baseline Two can only be used for a maximum of two years. A project cannot switch from Dynamic Baseline One to using the Dynamic Baseline Two. A project using Dynamic Baseline Two must switch to Dynamic Baseline One within two years.

(3) The project may exclude On-Site Fertilizer and Lime Distribution (see Table 6: Identification of Project Condition Sources and Sinks) from quantification where it can be demonstrated that no increased fuel use due to an additional fertilizer and lime application in the project condition relative to the baseline condition has occurred as a result of implementing the 4R Plan. In cases where the dynamic baseline is used, any 4R management activities that result in extra field passes compared to the farm's previous management activities (e.g., split fertilizer application, new fertilization equipment that results in additional time spent on field such as broadcast to direct fertilizer injection) will require calculation of emissions from increased fuel usage.

(4) If a farm spans over multiple EcoDistricts, projects have the option of treating their farm as a single EcoDistrct providing that they calculate greenhouse gas emission reductions for the farm using each set of EcoDistrct values and use the most conservative. All sets of calculations using each applicable EcoDistrict will need to be maintained to demonstrate the conservativeness of the chosen EcoDistrct.

(5) The project developer may use combine-mounted yield monitors for assessment of the 4R Plan, and for emission reduction quantification as long as they can provide evidence that yield monitors are calibrated before harvest (following manufacturer's specifications), or if calibrated by grower (from grain/yard cart scale data), and there is no print-out record for these scales, then a logbook by field could be sufficient if photographed with a date stamp. In addition, calibration must be performed for each crop type. The APA is required to confirm under seal, all application of this flexibility mechanism to generate yield data.

1.6 Glossary of Terms

Ammonium-based Fertilizer	Any fertilizer which releases more than two-thirds of its nitrogen 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 (APA)	For the purposes of this protocol the Accredited Professional Advisor is a regulated member of the Alberta Institute of Agrologists who fits the requirements outlined in section 1.4.
Controlled Release Products	Slow or controlled-release nitrogen products delay 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 nitrate 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 N_2O) 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 five centimetres or deeper.
Crop Type	The crop type is the operational unit for which N_2O emissions intensity (N_2O per mass of crop) is calculated for the baseline and project. The crop type is the annual crop, with guidance listed in section 1.3. The crop year is accounted from harvest of previous crop to harvest of current crop.
Drier Soils	Drier soils are soils that are in an EcoDistrict 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 mass 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 herbicides (chemfallow).
Farm Enterprise	All lands and crops under the control of the farmer (aka. the farm). The entire Farm Enterprise must be included in each 4R Plan and be listed to a project to establish crediting start dates in the aggregated project planning sheet(s) (APPS).
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	For the purposes of the 4R Plan implementation (and not greenhouse gas accounting), a sub-field unit of a crop that is managed differently from other management zones within the same field. The management zone of the Basic Level is a whole field of a crop type. For the Intermediate Level, the management zone refers to each sub-field of a crop type based on qualitative field variability and the BMP requiring landscape directed nitrogen application. 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 grown. The level of performance identified in the 4R Plan will dictate nitrogen management.
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 (EcoDistrict Related Factor) of 1.7 regardless of which EcoDistrict they are in (refer to **APPENDIX A**: Annual ecodistrict emission factors for Alberta).
Nitrification	The microbial transformation of ammonium (NH_4^+) forms of nitrogen 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 nitrogen in ammonium form and slows down conversion to the nitrate (which can be denitrified to N_2O and other nitrogen compounds).
Organic Soil Amendment/ Organic Fertilizer	Organic soil amendments (or organic fertilizers) are fertilizers that are derived from animal or vegetable matter and include sources such as manure, compost, slurry, worm castings, peat, seaweed, sewage, guano and others. Manure is the only organic fertilizer applicable for quantification under this protocol.
Precipitation/Potential Evapotranspiration ratio (P/PE)	A measure of the moisture regime in the soil that impacts N_2O emission processes.
Professional Agrologist (P.Ag.)	Professional Agrologists are regulated members with the Alberta Institute of Agrologists.
Sink	Any process, activity or mechanism that removes greenhouse gas from the atmosphere and stores it in a reservoir.
Source	Any process or activity that releases greenhouse gas into the atmosphere.
Split Apply	Implies that nitrogen will be applied in either two or more applications in the growing season (e.g., spring and/or early summer) to synchronize supply with a crop's ability to use that nitrogen.
Real-time Crop Sensors	Sensors attached to a nitrogen fertilizer applicator used in crop to assess the crop nitrogen status (greenness) and determine whether or not additional nitrogen fertilizer should be top-dress applied to the crop.
Registered Technologist in Agrology (R.T.Ag.)	Registered Technologists in Agrology are regulated members with the Alberta Institute of Agrologists.
Spring Application	Spring application, for the purposes of this protocol, refers to application of fertilizer after thaw and before or at seeding.
Stabilized Nitrogen	This refers to a nitrogen 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 dissolution of the fertilizer and reaction with the soil matrix (e.g., a polymer coating). It can also be used to describe slow-release nitrogen 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. Note: 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 as defined in Management Zone, and can be generated through soil testing in each soil zone. It consists of software and hardware to create 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. Baseline Condition

This protocol uses both a static historic benchmark baseline condition (conventional approach), and allows for the use of one of two alternative dynamic baseline approaches (see **APPENDIX D**: Dynamic Baseline Quantification Approaches).

Under the conventional baseline condition, greenhouse gas emissions are quantified for each crop type, by performance level, by EcoDistrict, on each farm based on historic N_2O emissions from fertilizer activities, for three years prior to implementation of the 4R Plan. Comparable metrics between the baseline and the project condition are achieved by calculating emissions per mass of crop produced (crop types in the baseline year versus the project year). Baseline emissions will vary as a function of the mass of a specific crop produced for a farm under a specific kind of nitrogen management. The final numbers will have to be adjusted for the crop mass differences between the baseline and project period to ensure consistency.

This protocol assesses the baseline condition for each participating farm where nitrogen fertilizers (organic and/or inorganic) are applied at less efficient application rates or methods (such as source, timing, placement, etc.) from a nitrogen use efficiency perspective, compared to the project condition per crop type. The baseline condition is calculated as the average rate of N_2O emissions from the crop type being fertilized based on the average over the three years prior to project implementation.[9] Figure 1 presents the process and material flow for the baseline condition.

Independent survey data of nutrient management practices shows that in 2021, 31 per cent of producers in Alberta indicated that they use 4R nutrient management principles when applying fertilizer or manure on farm[10]. There are noted cautions however that should be considered when equating the application of a 4R Nutrient Stewardship Plan as implementation of all necessary BMPs within the plan. However, the 4R Plan as described in this protocol is a practice change at the farm level and represents an additional activity recognized in the Alberta emission offset system.

The 4R Plan enables this practice change through:

(1) A comprehensive and professionally-developed nitrogen management plan to account for all sources of nitrogen applied at each farm 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 the baseline period. Farmers that were already undertaking annual testing or variable rate application would not achieve N_2O emission reductions without the framework of all the BMPs in a 4R Plan (i.e., there can be no assurance that N_2O reductions are achieved without assurance that all 4Rs are addressed).

The flexibility mechanism offered in section1.5 allows the use of one of two dynamic baseline approaches. Under the dynamic baseline approaches, baseline greenhouse gas emissions are calculated each year and compared to the project condition on an annual basis to calculate emission reductions. Dynamic Baseline One uses measured crop mass from farms (using one of the acceptable crop mass determination methods in Table 12. Dynamic Baseline Two uses conservative five-year average default yields for crop risk zones across the province. These values are published annually by Agriculture Financial Services Corporation. The dynamic baseline approaches include application of either a 5 per cent or 10 per cent discount factor, depending on the chosen dynamic baseline.

The Accredited Professional Advisor, as part of the 4R Plan development, identifies the baseline management practice of the participating farm. To avoid leakage of nitrogen amendment or crop mass, the entire farm enterprise must be under 4R management and enrolled under this protocol. Under the baseline, if a farm acquires new land holdings or expanded

[9] If a farm experiences a devastating year that results in 50% less crop yield (from a five-year average), that year must be removed from the three-year average baseline and replaced with another crop year.
[10] Environmentally Sustainable Agriculture Tracking Survey Report, University of Alberta, August 2021.

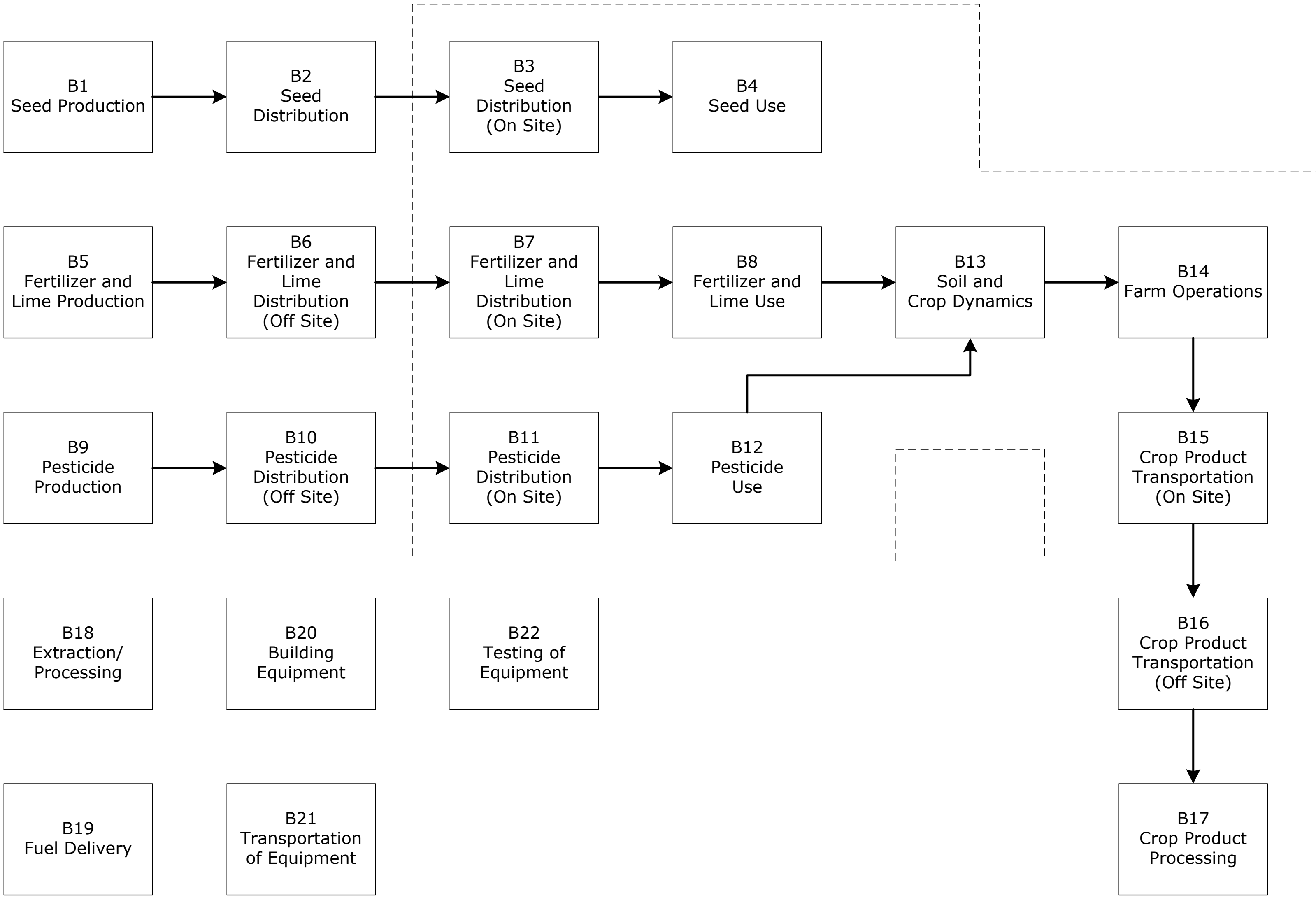
management on new leased lands where crop types were not included in the baseline for that farm, the 4R Plan will be required to be updated to address these new lands/crops where the 4R Plan will need to be implemented. The dynamic baseline approaches require that the entire farm enterprise boundary is under 4R management and included in the project condition for that year.

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

2.1 Baseline Condition Process Flow Diagram

Figure 1 presents the process and material flow for the baseline condition.

Figure 1: Process Flow Diagram for Baseline Condition



2.2 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on guidance in the ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (International Organization for Standardization). Sources and sinks are determined to be either controlled, related or affected by the project activity and are defined 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 sinks were organized into life cycle categories in Figure 2. Descriptions of each of the sources and/or sinks and their classification as controlled, related or affected are provided in Table 3.

Figure 2: Baseline Condition Sources and Sinks

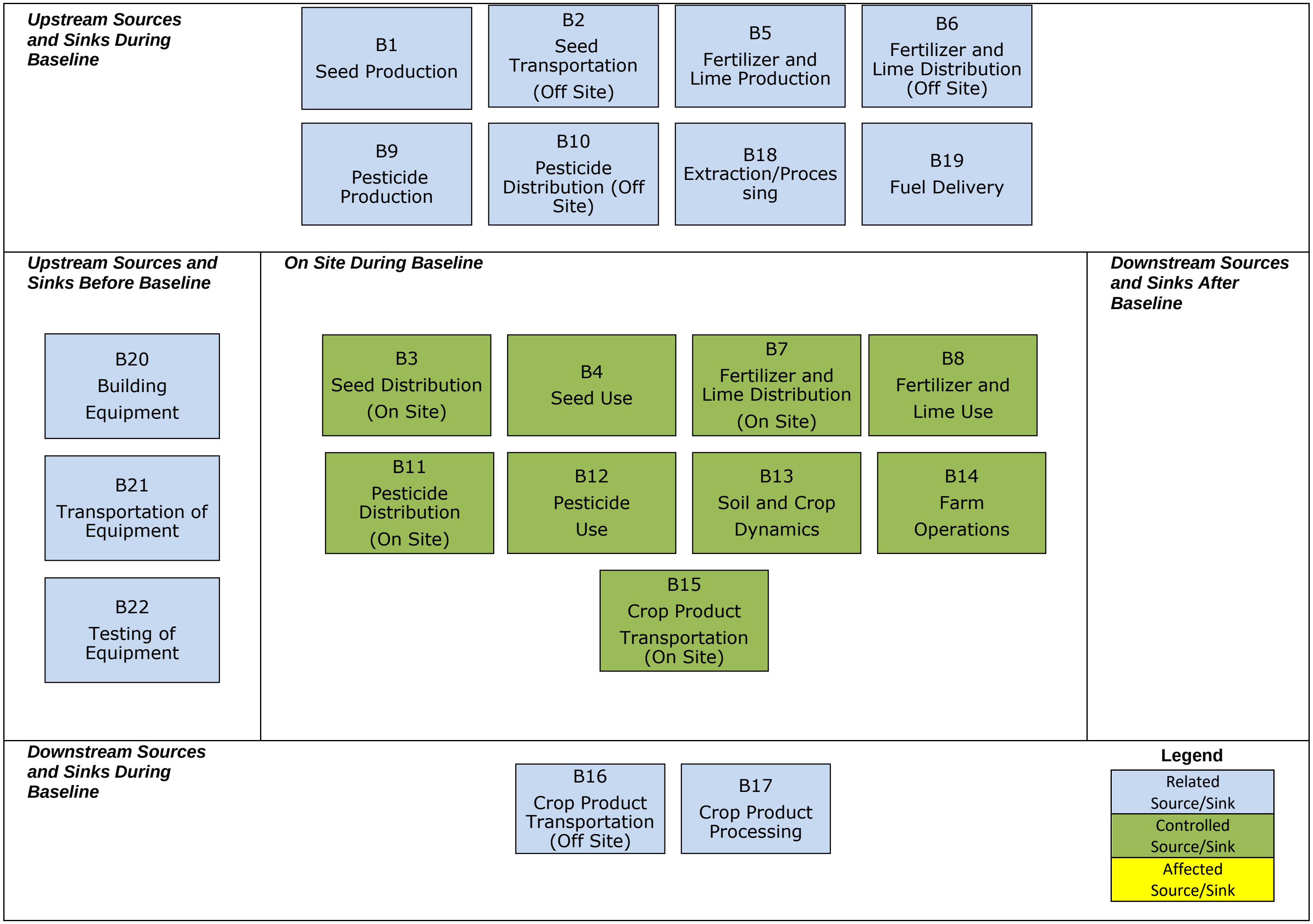


Table 3: Identification of Baseline Sources and Sinks

Sources and Sinks	Description	Type
Upstream Sources and Sinks 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 be 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
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
On Site 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 GHG 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 GHG 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 GHG 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 N_2O.	Controlled
B14 - Farm Operations	GHG 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 GHG emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled
Downstream SS 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 GHG 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. GHG 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 by courier. GHG 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 GHG emissions associated with the combustion of fossil fuels and the use of electricity.	Related

3. Project Condition

The project condition, also called the 4R Plan throughout this protocol, takes forms of nitrogen into account, in particular inorganic (synthetic) fertilizers applied to a particular crop to calculate direct and indirect N_2O emissions. Emission reductions are calculated on a crop-by-crop basis, known as crop types, in a given year for the entire farm enterprise (excluding ineligible fields).

The 4R Plan, with the associated BMPs required for each performance level, are implemented to achieve a reduction of N_2O emissions in the project as compared to the baseline condition. As the performance level increases from Basic to Intermediate/Advanced, the 4R Plan must address more precisely the 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 larger reduction modifier (Table 1).

A number of resources to describe application of 4R principles are available[11] to support project implementation. The Alberta Nutrient Management Planning Guide[12] is the primary reference for technical elements of the 4R Plan such as assessing fields on site or remotely, soil sampling and testing, calculating fertilizer requirements, etc. The various elements of the 4R Plan 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.), the total mass of crop produced may be decreased to the extent that project emissions per mass of crop exceed baseline emissions. In this event, the fields/crops would be excluded from the mass-based accounting for emission reductions for that year. Implications of nitrogen remaining in the soil due to crop loss **must be** addressed in the following year's 4R Plan, as confirmed by soil test results reviewed by an Accredited Professional Advisor.

The steps necessary for conforming to the 4R Plan at the various performance levels identified in this protocol are outlined below.

Basic Performance Level

The 4R Plan at the basic performance level will:

- Be implemented at a scale of whole fields.
- Track and use all legal land locations and aerial photographs to determine field locations and field size.
- Require annual soil testing for each field.
- Describe field-scale sampling and annual soil testing of nitrate-nitrogen remaining in the soil from the previous year to derive fertilizer rate requirements for the upcoming crop year[13].
- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year).
- Specify field-specific BMPs for fertilizer application source, rate, place and time.
- Describe yield monitoring for each field, and which one of the crop mass determination methods will be used for the emission reduction quantification.
- List the data to be recorded to document activities specified in the 4R Plan (see section 5.1 for sample data sources).

Intermediate Performance Level

The 4R Plan at the intermediate performance level will:

- Be implemented at a scale of sub-fields (or management zones) for each crop type delineated by qualitative field variability (or areas of above average and below average productivity) based on the grower's experience and the Accredited Professional Advisor's professional judgment.
- Identify and track management zones by using aerial photographs or field imagery to determine field location and field size, and to delineate management zones.
- Require annual soil testing for each field management zone.
- Describe sub-field sampling and annual soil testing of nitrogen remaining in the soil at the management zone level from the previous year to derive fertilizer rate requirements for the upcoming crop year.

---

[11] International Plant Nutrition Institute. 2011. The 4Rs: Right Source, Right Rate, Right Time, Right Place.
[12] Alberta Agriculture and Rural Development, 2007, Alberta's Nutrient Management Planning Guide. https://open.alberta.ca/publications/7086752
[13] For a description of acceptable soil sampling best practices see the Introduction to 4R Course (Fertilizer Canada) or Alberta Agriculture and Rural Development, Alberta's Nutrient Management Planning Guide.

- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year).
- Specify sub-field, management zone-specific BMPs for fertilizer application source, rate, place and time for each management zone.
- Describe yield monitoring for each field and which crop mass determination method will be used for the emission reduction quantification, and may include use of satellite imagery for mapping acres, equipment with acres counters (must have sectional controls implanted).
- List the data to be recorded to document activities specified in the 4R Plan (see section 5.1 for sample data sources).

Advanced Performance Level

The 4R Plan at the advanced performance level will:

- Be implemented at scale of sub-field management zone for each crop type based on a digitized delineation of slope and aspect.
- Use GPS coordinates and digital imagery to determine field location and field size, and to delineate and aggregate sub-field management zones according to slope and aspect.
- Track and describe sub-field sampling and annual soil testing of nitrogen remaining in the soil at the sub-field management zone level from the previous year to derive fertilizer rate requirements for the upcoming crop year.
- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year).
- 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.
- List the data to be recorded to document activities specified in the 4R Plan (see section 5.1 for sample data sources).

Generating a post-harvest nitrogen assessment is a valuable tool to assess the success of a 4R Plan in meeting crop nitrogen needs, and thereby minimizing N_2O emissions.[14] In years where an ineligible organic fertilizer is used, the remaining nitrogen available from these ineligible sources must also be addressed by the Accredited Professional Advisor and incorporated into the following year's nitrogen rate recommendations. Post-harvest assessment does not replace annual soil testing for fertilizer rate recommendations, however a complete field nitrogen assessment is not practical, because nitrogen in below ground biomass is difficult to measure directly. The 4R Plan will calculate the proportion of nitrogen inputs recovered in the harvested crop.

In exceptional circumstances where soil testing cannot be completed for a certain field in a given year (due to weather and soil conditions), the Accredited Professional Advisor must use their experience and knowledge of the project soils, previous amendments and past and current cropping conditions to recommend rates that ensure no over-application for the upcoming crop.[15] This is an exception that can only be applied a maximum of once for a field within an entire project crediting period.

3.1 4R Plan Development

The beginning of the project corresponds to the implementation of a 4R Plan as prescribed by this Protocol. Since 4R plans are adjusted to performance level (basic/intermediate/advanced), the activities prescribed by the 4R Plan and the documentation required to substantiate project activity will vary according to the selected performance level. The 4R plan must be created signed and sealed by an Accredited Professional Advisor (APA). Electronic signatures are eligible as long as all required information for the APA is listed.

The 4R Plan to be implemented on the project farm shall be signed by the farmer committing to the activities over the crediting period and stamped by the APA. The 4R Plan shall describe the activities to be implemented, provide the rationale for determining these activities, and specify the data to be collected to document completion of these activities.

4R Documentation

While an independent professional prepares the 4R Plan documentation, these materials, including all background and supporting materials, must still be available to the third-party verifier for assessment, including for government review. The

[14] Consider post-harvest assessment for each field, using crop uptake and removal coefficients (Appendices 6A and 6B) of Alberta Agriculture and Rural Development, Alberta's Nutrient Management Planning Guide.
[15] Tools available to the Accredited Professional Advisor include (1) Agriculture, Forestry and Rural Economic Development Recommended Rates in their Agdex publications; or (2) a post-harvest assessment of the nitrogen uptake by the crop the year before; and/or (3) the AFFIRM model to predict nitrogen recommendation rates.

work of the APA supports the review being conducted by the verifier, but does not replace it as these are two independent processes.

Soil Sampling

A soil sampling plan, scaled to correspond with each 4R implementation level management zone, must be included in annual 4R plans. Soil sampling plans will be signed off by the APA. The APA will use annual soil test results from soil sampling programs to inform nutrient recommendations for each management zone in the 4R Plan. The APA will ensure that annual soil sampling conforms to the plan, and that soil test results are used in the plan.

Fertilizer

The 4R Plan must include a report on the quantity, application, timing and type of fertilizer nitrogen applied for each crop type. The pattern of distribution for fertilizer (i.e., the distribution for each crop type) and the resolution of the documentation will vary with the selected performance level. The APA should identify applicable records and documentation that will support fertilizer use in the 4R Plan.

Crop Residues

Calculating the amount of crop residue nitrogen, above ground and below ground, for each crop type is a required nitrogen input. This estimate is derived from default look-up tables provide in **APPENDIX B**: Crop Residue Nitrogen Factors of this protocol. Crop mass 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 crop mass data is collected and reported for implementation of the baseline and project for the 4R Plan.

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

Table 4: Parameter Description for Calculating Crop Residues

Parameter	Units	Source
Annual crop mass (dry matter)	kg dry matter	Crop mass
Crop-specific factors	kg N / kg dry matter	From Table B-1 (see APPENDIX B: Crop Residue Nitrogen Factors): Ratio of above-ground residue dry matter to harvested production (AGresidue_ratio) Nitrogen content of above-ground residues (AGresidue_n_conc) Ratio of below-ground residue dry matter to harvested production (BGresidue_ratio), Nitrogen content of below-ground residues (BGresidue_N_conc)

Manure Soil Amendments

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. Manure is the only organic soil amendment applicable for quantification under this protocol. Project documentation should include but not limited to:

- Analysis or approved sources determining the manure nutrient content of the manure.
- 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).
- Results of soil tests and nitrogen balance assessment to track the nutrient status of the soil.

Wherever possible, the spreading of manure should be planned at the same level of field variability as is the fertilizer application. It is anticipated that in Alberta manure will make up the large majority of organic soil amendments. Manure spreading **must be recorded per crop type at the whole field, sub-field or variable rate** application as appropriate for the corresponding performance level (basic/intermediate/advanced). Laboratory manure analysis can be used to determine manure nutrient content. Alternatively, manure production and nutrient content tables from the Alberta Nutrient Management Planning Guide[16] will provide another means of estimating nutrient content of manure and nutrient application based on rate of manure application. If manure comes from a confined feeding operation, it is expected that records on the analysis will be available from the confined feeding operation.

Baseline calculations require that farm records be available to support which fields organic fertilizer was applied to. Supporting evidence that organic fertilizer 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 APA via the 4R Plan, and the project developer/aggregator.

Fertilizer Nitrogen Placement

The 4R 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.

The general equation to be applied is:

% Band Concentration = Width of Spread/Fertilizer Opener Spacing* 100

Where:

Width of Spread is determined by the type of opener (Table 5).

Fertilizer Opener Spacing is the distance between fertilizer openers.

Table 5: Expected Band Concentration in Fertilizer Application

	Width of Spread of Fertilizer in the Row[i]											
	2.5 cm (disc or knife)			5.0 cm (spoon or hoe)			7.5 cm (sweep)			10.0 cm (sweep)		
Fertilizer Opener Width (cm)	15	23	30	15	23	30	15	23	30	15	23	30
Fertilizer Band Concentration (%)[ii]	17	11	8	33	22	17	50	30	25	67	44	33

i - 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 spread (e.g., double disc).
ii – Fertilizer concentration refers to 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% seed bed utilization (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, and this approach cannot be applied to these spreaders.

Fall Applied Fertilizers

The 4R Plan allows for some fall application of fertilizers, so long as the temperature of the soil is less than 10º Celsius for three consecutive days. To prove that fall application of fertilizers occurred at the correct time, appropriate data sources must include farm records showing soil temperature readings (a minimum of five centimetres below the soil surface) for three consecutive days. As an alternative to direct soil temperature sampling, nearby publicly available weather station data (daily high temperature) can be used to predict soil temperature using the equation below[17]. Daily high temperatures for five consecutive days must result in soil temperatures below 10º Celsius using the following equation in order to support appropriate fall application of fertilizers:

Soil temperature = $0.6287t + 0.3339$

[16] Standard Values for Nutrient Manure Content from Appendix 4A of the Nutrient Management Planning Guide must be used if laboratory analysis is not undertaken. Alberta Agriculture and Rural Development, Alberta's Nutrient Management Planning Guide.
[17] Koehler-Munro et al., 2005, Soil Temperature Dynamics of Adjacent Catenas on Farmland in the Black Soil Zone.

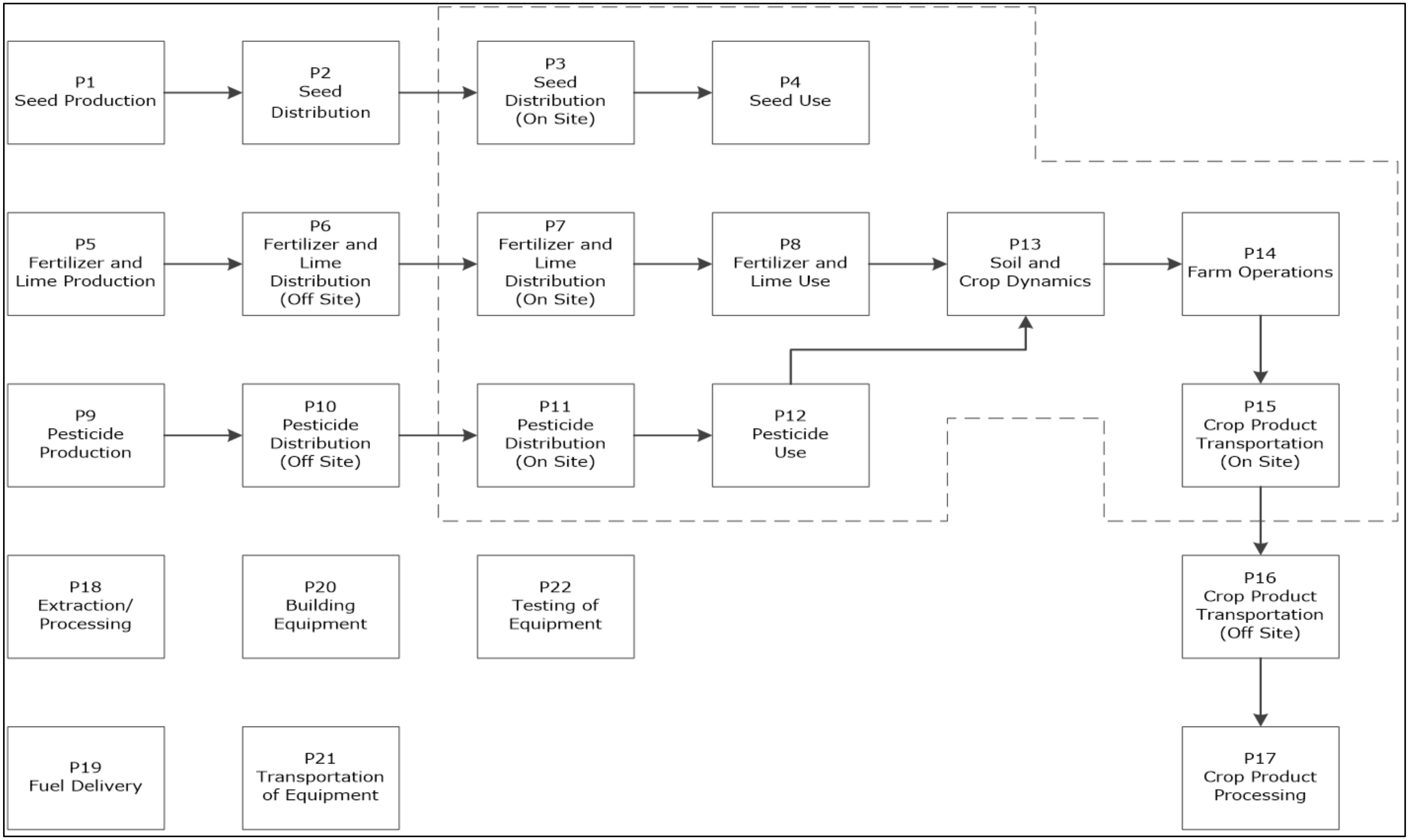
t	=	Air temperature in degrees Celsius (daily high)

Temperature data can be obtained from the AgroClimatic Information Service that is maintained by Agriculture, Forestry and Rural Economic Development (https://agriculture.alberta.ca/acis/). The APA must ensure that this is well documented in the 4R Plan.

3.2 Project Condition Process Flow Diagram

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

Figure 3: Process Flow Diagram for the Project Condition



3.3 Identification of Project Sources and Sinks

The identification of sources and sinks in the project condition are based on guidance in the ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (International Organization for Standardization). Sources and sinks are determined to be either controlled, related or affected by the project activity and are defined 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.

Project sources and 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 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 condition sources and sinks were organized into life cycle categories in Figure 4. 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

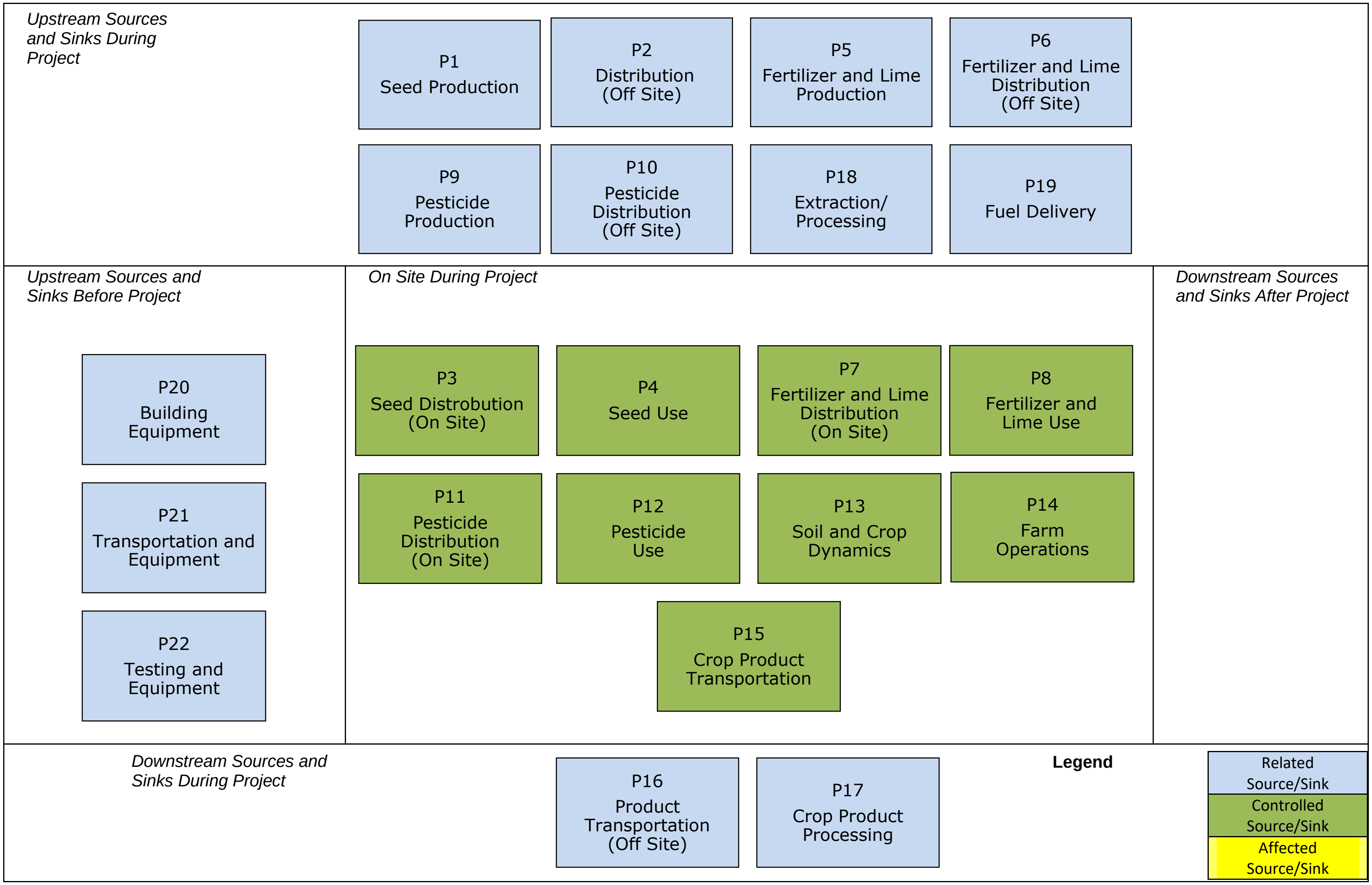


Table 6: Identification of Project Condition Sources and Sinks

Source/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 fueling 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 fueling 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 fueling 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 be 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
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

On Site 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 fueling 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 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 fueling 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 fueling 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 pesticide 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 N_2O.	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 vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
P15 - Crop Product Transportation (On Site)	Crops would need to be harvested and transported from the field to storage. The related energy inputs for fueling 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 fueling this equipment are captured under this source, for the purposes of calculating the	Related

	resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	
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. Quantification

Baseline and project conditions were assessed against each other to determine the scope for the emissions reductions quantified under this protocol. Sources and sinks are either included or excluded depending how they were impacted by the project activity. Sources that are not expected to materially change between baseline and project conditions are excluded from quantification. This consistency between the baseline and project condition greenhouse gas emissions serves to justify the exclusion of these emission sources for projects being implemented under this protocol.

Project developers must assess included emission sources for their specific project. If assumptions are not valid for a specific project, the associated emissions must be quantified and documented in the Project Plan and/or Project Report.

All sources and sinks identified in Table 5 Baseline and Table 6 Project are listed and assessed in Table 7. Each source and sink is listed as include or excluded with justification.

Table 7: Comparison of Sources/Sinks Required for Quantification

Identified Source/Sinks	Baseline	Project	Quantification	Justification
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 pesticide 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 conservative.
B17 - Fuel Extraction and Processing	Related	N/A	Exclude	

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	
On Site 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**	Incremental P7 Fertilizer and Lime Distribution (On-Site) emissions are included in cases where implementation of the 4R Plan requires additional passes to apply fertilizer or lime in comparison to normal farm operations.
B7 - Fertilizer and Lime Distribution (On Site)	Controlled	N/A	Exclude	
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 likely equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B15 - Crop Product Transportation (On Site)	Controlled	N/A	Exclude	
Downstream Sources and Sinks				
P16 - Crop Product Transportation (Off Site)[i]	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[i]	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.

i - Analysis of the impact of increased crop mass as a result of the project activity on downstream crop transportation and processing emissions was conducted by Cecil Nagy at the Department of Bioresource Policy, Business and Economics, University of Saskatchewan, Saskatoon. Even with a 30% crop mass increase as a result of implementing a 4R Plan, the impact on downstream crop transportation and handling emissions is immaterial to the overall project reduction. See APPENDIX C: Impact of the Project Activity on Downstream Crop-Related Emissions for more information.

4.1 Quantification Methodology

This protocol quantifies direct and indirect N_2O emissions per unit of crop produced for each crop type on each farm in the project condition using Canada's Tier II quantification methodology 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.

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 each farm during the three years prior to project implementation determines the baseline N_2O emissions in the conventional baseline approach. Section 1.5 Flexibility Mechanisms and APPENDIX D: Dynamic Baseline Quantification Approaches describe calculation of the baseline condition under the dynamic baseline approaches.

The quantification methodology includes net emission reductions, with a breakdown of the offset-eligible emission reductions and transparency for any priced emission reductions. In some projects, some sources and sinks may be subject to a carbon price, whereas in others they may not be. The project developer/aggregator will need to determine if any sources and sinks are subject to a carbon price and which sources are included in offset-eligible or priced emission reductions, depending on the nature of the project implemented and the regulatory status of the site at which the project is implemented.

Emission offset quantification is calculated on a mass basis using nitrogen inputs and crop mass per crop type, across the entire farm enterprise, in two ways:

(1) At the field level so long as the fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level, or

(2) At the farm level so long as fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level.

The basic analytical unit for calculating a reduction in N_2O emissions for a farm occurs for crop type by EcoDistrict by performance level. This means that separate reduction calculations must be made each time the crop type occurs in a different EcoDistrict and/or 4R performance level. For example, a farm within one EcoDistrict that applies only one 4R performance level, and grows only one crop will only require one calculation of emission reductions.

The project developer will need to repeat the quantification of emission reductions in their entirety for each analytical unit and then sum the reductions across the entire farm enterprise to obtain the emission reduction claim for that year. Each emission reduction claim is tracked by project, by subprojects, for the farm enterprise, in the Aggregated Project Reporting Sheet (APRS) for each applicable vintage year based on that year's submitted Aggregated Project Planning Sheet.

The 4R nitrogen management must still occur according to the 4R Plan, with project documentation collected to show conformance to the 4R Plan.

The direct and indirect emissions of N_2O from soil are calculated according to nitrogen inputs from synthetic fertilizer, manure, and crop residue decomposition per crop type.[18] The N_2O emission calculations are based on the total mass of nitrogen per crop type divided by the total crop mass for each particular crop. This results in N_2O emissions per crop mass. Since the baseline represents the nitrogen management practices in place before implementation of the 4R Plan, the baseline emission calculations only account for mass of nitrogen added per crop type. This means that for the baseline condition only the mass of nitrogen inputs and yield per crop type need to be documented. Nitrogen inputs from both inorganic (synthetic) and organic soil amendments must be accounted for in the baseline condition.

The project condition is initiated by implementation of the 4R Plan. Quantifying N_2O in the project involves accounting for nitrogen inputs and meeting all specified requirements for time, place, rate and source of fertilizer for the performance level being used. If manure is applied in the project condition, the 4R reduction modifier is not applied to the emissions from these sources.

Projects must account for incremental increases in greenhouse gas emissions associated with differences in the nitrogen fertilizer application practices between baseline and project. The Accredited Professional Advisor will assess and document nitrogen fertilizer application practices prior to project implementation as part of developing the initial 4R Plan. As part of this assessment, the Accredited Professional Advisor will establish and document the number of field passes used by the grower for nitrogen fertilizer application prior to project implementation.

[18] Fields which receive organic fertilizers other than manure or crop residue must be included in the 4R Plan, but those fields are ineligible to generate offsets for the year in which they are used.

Each year of the project, the Accredited Professional Advisor will assess the nitrogen application practices relative to the baseline. Any increased emissions from additional nitrogen application passes relative to the baseline will be calculated and subtracted from the net GHG Statement for the farm. The methods for accounting for additional passes are explained with examples in **APPENDIX F**: Additional Fuel Pass Method**.**

4.1.1 Quantification Approach

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

Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and at each performance level on farms. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are summed across the analytical units to derive the emission reduction claim for the farm for the year. The calculations sequence for each crop type, using the conventional approach, is as follows:

(1) The CO_2e emissions in the baseline and project conditions are calculated using functional units of kilograms CO_2e per kilogram of crop produced on a dry matter basis. In the equations, the crop type will be referred to as crop i, representing the understanding that each project (farm) may consist of a number of crops.
(2) The baseline condition (in this case, the conventional baseline) is expressed for each crop type as the three year average kg CO_2e per kg of crop produced, or if applying one of the dynamic baselines, a one year measurement of the kg CO_2e per kg of crop produced for each crop type (see **APPENDIX D**: Dynamic Baseline Quantification Approaches for description of dynamic baseline quantification).
(3) Within a single EcoDistrict and a single 4R management level, project condition emissions are calculated for each crop type on an annual basis using the same functional units.
(4) The sum of emissions from synthetic nitrogen fertilizer and crop residue (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 type. These emissions are then added to emissions associated with manure application, which are not multiplied by the reduction modifier.
(5) The CO_2e reduction for each project crop type is calculated as the difference between the baseline emissions intensity and project emissions intensity (as calculated in Step 4 above) (kg CO_2e per kg crop produced).
(6) To derive the total emission reductions (kg CO_2e) for each crop type, multiply the reduction in Step 5 above by the total mass of crop produced (kg crop produced) in the project.
(7) If applicable, emissions reductions from multiple crop types are summed.
(8) If applicable, emissions reductions from crops in each 4R management level and each EcoDistrict are summed.
(9) Emissions from additional fuel use are subtracted from the above result to calculate total project emission reductions (see **APPENDIX F**: Additional Fuel Pass Method for more information on quantification of additional fuel use).

In certain project configurations, the implementation of the 4R Plan may result in increased fossil fuel consumption from additional fertilizer applications (e.g., a split application) compared to management in the baseline scenario. If this occurs, the incremental project emissions from the distribution of fertilizer (Fertilizer and Lime Distribution) **must be included** in the total project emissions intensity. In order to ensure the GHG statement is conservative, emission offsets cannot be generated for reducing the number of field passes during the project.

4.1.2 Net Emission Reductions

Net emissions reductions are the reductions resulting from a comparison of project and baseline emissions for all sources and sinks (SSs) included in the quantification. In cases where the SS is subject to a carbon price, the emission from the SS is quantified and reported but does not contribute to the offset-eligible emission reduction calculation in section 4.1.3 Offset Eligible Emission Reductions.

Net emission reductions must be calculated using the equation below:

$$\textbf{Net Emission Reductions} = \textbf{Emissions}_{\textbf{Baseline}} - \textbf{Emissions}_{\textbf{Project}}$$

Where baseline emissions are:

$$\text{Emissions Intensity}_{\text{Baseline}} = [\sum_{\text{crop i}} [(\text{Emissions}_{\text{Manure use, i}} + \text{Emissions}_{\text{Manure Soil Crop Dyn, i}} + \text{Emissions}_{\text{Urea}} + \text{Emissions}_{\text{Other Fert and Lime Use, crop i}} + \text{Emissions}_{\text{Other Fert Soil Crop Dyn, crop I}})/ \text{Crop Mass}_{\text{Baseline i}}] * GWP_{N2O}$$

Baseline emissions sources including the following:

Emissions Intensity $_{Baseline}$	=	Sum of the emissions under the baseline condition divided by baseline crop mass
	=	Crop i Index number for tracking crop types within an EcoDistrict and within a performance level
	+	Emissions from manure under SS P8/B8 Fertilizer and Lime Use
	+	Emissions from manure under SS P13/B13 Soil Crop Dynamics
	+	Emissions from Urea SS B8/P8 carbon dioxide
	+	Emissions from inorganic fertilizer and crop residues and under SS P7 Fertilizer and Lime Use
	+	Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics
	/	Crop Mass determined in the baseline for all crops based on a three year average, adjusted to a dry matter basis (conventional approach)
	*	GWP_{N2O} Global warming potential value for N_2O

Where project emissions are calculated according to the following:

$$\text{Emissions Intensity}_{\text{Project}} = [\sum_{\text{crop i}} [\text{Emissions}_{\text{Manure Use, i}} + \text{Emissions}_{\text{Manure Soil Crop Dyn, i}} + \text{Emissions}_{\text{Urea}} + ((\text{Emissions}_{\text{Other Fert and Lime Use, crop i}} + \text{Emissions}_{\text{Other Fert Soil Crop Dyn, crop I}}) * RM_{PL}) / \text{Crop Mass}_{\text{Project i}}] * GWP_{N2O}$$

Project emission sources including the following:

Emissions Intensity $_{Project}$	=	Sum of the emissions under the project condition divided by project crop mass
	=	Crop i Index number for tracking crop types within an EcoDistrict and within a performance level
	+	Emissions from manure under SS P8/B8 Fertilizer and Lime Use
	+	Emissions from manure under SS P13/B13 Soil Crop Dynamics
	+	Emissions from Urea SS B8/P8 carbon dioxide
	+	Emissions from inorganic fertilizer and crop residues and under SS P7 Fertilizer and Lime Use
	+	Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics
	*	RM_{PL} Emission reduction modifier of 0.85 and 0.75, which corresponds to the implementation of Basic or Intermediate/Advanced 4R Plans, respectively

/ Crop Mass determined in the project for all crops, adjusted to a dry matter basis

* GWP_{N2O} Global warming potential value for N_2O

The dynamic baseline approach outlined in section 1.5 Flexibility Mechanisms can be applied in this protocol. See APPENDIX D: Dynamic Baseline Quantification Approaches for equations required under the dynamic baseline approaches.

Emission factors for fuels can be found in the Carbon Offset Emission Factors Handbook and applicable Global Warming Potential values in the Standard for Completing Greenhouse Gas Compliance and Forecasting Reports Part 1 Section 8.

The following calculations can be used to calculate crop mass on a dry matter basis:[19]

$\text{Crop Mass}_{\text{dry matter basis}}$	=	$\text{Wet Mass}_{\text{sample}} \times \%DM$
		(**All Quantification calculations in Table 8 using crop mass values must be conducted on a dry matter basis)**
%DM	=	$(\text{Dry Mass}_{\text{sample}} / \text{Wet Mass}_{\text{sample}}) \times 100\%$
%DM	=	Per cent dry matter of the crop
$\text{Wet Mass}_{\text{sample}}$	=	Wet mass, or harvest mass, of the bin sample used collected to determine bin moisture content
$\text{Dry Mass}_{\text{sample}}$	=	Mass of the bin sample used to determine bin moisture content after it has been dried

Emission reductions are reported in tonne CO2e. Applicable equations may need to apply the global warming potential for the gas as well as the unit conversion below:

0.001	**=**	**Conversion factor, kilograms to tonnes.**	**$tCO_2e/kgCO_2e$**

4.1.3 Offset Eligible Emission Reductions

Reductions of emissions that are not subject to a carbon price are eligible for emission offsets; reductions of emissions that are subject to a carbon price are not eligible for emission offsets. Projects (or all eligible subprojects) that quantify offset eligible emission reductions must also quantify and report on priced emission reductions as per this section.

Offset eligible emission reductions are calculated from a comparison of project and baseline emissions for all sources and sinks excluding emissions that are subject to a carbon price.

$$\text{Offset Eligible Emission Reductions*} = [\sum_{\text{EcoDistrict } j} \sum_{\text{4R management level } k} \sum_{\text{crop } i} (\text{Emissions Intensity}_{\text{Non-priced Baseline}} - \text{Emissions Intensity}_{\text{Non-priced Project}}) * \text{Crop Mass}_{\text{Project}}] - \text{Emissions}_{\text{Fert and Lime Dist}}$$

where:

EcoDistrict j = Index number for tracking EcoDistrict types

$4R_{\text{Management Level } k}$ = Index number for tracking 4R management performance levels, within an EcoDistrict

Crop i = Index number for tracking crop types within an EcoDistrict and within a performance level

$\text{Emissions Intensity}_{\text{Non-priced Baseline}}$ = Sum of the emissions under the baseline condition divided by baseline crop mass

$\text{Emissions Intensity}_{\text{Non-priced Project}}$ = Sum of the emissions under the project condition divided by project crop mass

[19] Further description of methodologies to determine crop mass on a dry matter basis, including methodologies for drying crop bin samples can be found in the following source: United States Department of Agriculture Natural Resources Conservation Service, 2007, Dry Matter Determination.

Crop Mass $_{Project}$ = Dry basis project crop mass for crop i

Emissions$_{Fert\ and\ Lime\ Dist}$ = Emissions under source/sink (SS) P7 Fertilizer and Lime Distribution (On Site)

Emission reductions are reported in tonne CO2e. Applicable equations may need to apply the global warming potential for the gas as well as the unit conversion below:

0.001	**=**	**Conversion factor, kilograms to tonnes.**	**$tCO_2e/kgCO_2e$**

*Rounding of the GHG Statement by subproject is not allowed in the data management systems or the Aggregated Project Reporting Sheets (APRS). Subprojects must quantify at least 4 significant digits, per the Standard.

4.1.4 Priced Emission Reductions

Emissions that are subject to a carbon price are not eligible for emission offsets. Projects (or all eligible subprojects) must quantify and report on reductions of emissions that are subject to any carbon price.

Priced emission reductions are calculated from a comparison of project and baseline emissions for all sources and sinks.

$$\textbf{Priced Emissions Reductions} = \textbf{Emissions}_{\textbf{Priced Baseline}} - \textbf{Emissions}_{\textbf{Priced Project}}$$

where:

Emissions $_{Priced\ Baseline}$ = None.

and

Emissions $_{Priced\ Project}$ = None.

Table 8: Quantification Methodology for Conventional Application of this Protocol.

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
P7 - Fertilizer and Lime Distribution	$Emissions_{Fert\ and\ Lime\ Dist} = \sum (Vol.\ Fuel * (EF\ Fuel_{Ext\ and\ prod\ CO2} + EF\ Fuel_{Comb\ CO2}))\ ;\ \sum (Vol.\ Fuel * (EF\ Fuel_{Ext\ and\ prod\ CH4} + EF\ Fuel_{Comb\ CH4}) * GWP_{CH4})\ ;\ \sum (Vol.\ Fuel * (EF\ Fuel_{Ext\ and\ prod\ N2O} + EF\ Fuel_{Comb\ N2O}) * GWP_{N2O})$					
	$Emissions_{Fert\ and\ Lime\ Dist}$	kg of CO_2e;	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	L / m^3 / other	Measured	As per fuel volume determination methods provided in Appendix F	Quarterly reconciliation	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small
	Carbon Dioxide Emissions Factor for Extraction and Production of Each Type of Fuel / $EF\ Fuel_{Ext\ and\ prod\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Carbon Dioxide Emissions Factor for Combustion of Each Type of Fuel / $EF\ Fuel_{Comb\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	CH_4 Emissions Factor for Extraction and Production of Each Type of Fuel / $EF\ Fuel_{Ext\ and\ prod\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Methane Emissions Factor for Combustion of Each Type of Fuel / $EF\ Fuel_{Ext\ and\ prod\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Global Warming Potential for Methane / GWP_{CH4}	Unitless	Estimated	Refer to Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in Carbon Offset Emission Factors Handbook and the Standard for Completing Greenhouse Gas Compliance and Forecasting Reports.
	Nitrous Oxide Emissions Factor for Extraction and	kg N_2O per L /	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Production of Each Type of Fuel / EF $Fuel_{Ext\ and\ prod\ N2O}$	m^3 / other				
	Nitrous Oxide Emissions Factor for Combustion of Each Type of Fuel / EF $Fuel_{Comb\ N2O}$	kg N_2O per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Global Warming Potential for Nitrous Oxide / GWP_{N2O}	Unitless	Estimated	Refer to Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in Carbon Offset Emission Factors Handbook and the Standard for Completing Greenhouse Gas Compliance and Forecasting Reports
B8/P8 - Fertilizer and Lime Use	$Emissions_{Manure\ Use,\ crop\ i} = N_{Manure\ \ crop\ i} * (EF_{ECO} * RF\_NS_{k=ON,m} * RF\_CS_m) * MolarRatio$					
	Manure Use Emissions – $Emissions_{Manure\ Use,\ crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Manure Nitrogen Use per Crop i — $N_{Manure\ crop\ i}$	kg N	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 $e^{(0.00558*P-7.701)}$ where P is the long-term mean precipitation from May 1 to October 31 for ecodistrict i. Also integrates influence of texture, tillage, and topography	Annually	The value associated with EF_{Eco} is to be determined based on the EcoDistrict the farm is located in. The EF_{Eco} value for each EcoDistrict is listed in Appendix A. As per the approach used in Canada's National Inventory Report 2022 quantification method.
	Ratio factor for organic N source k=ON in cropping system m —$RF\_NS_{k=ON,m}$	unitless	Estimated	For organic nitrogen sources use factor 0.84 for annual cropping systems, and 1.00 for perennial systems	Annually	As per Canada's 2022 National Inventory Report quantification report Table A3.4–30
	Ratio factor for cropping system (annual or perennial) —RF_CS_m	unitless	Estimated	For annual cropping systems use factor 1.00, and 0.19 for perennial systems	Annually	As per Canada's 2022 National Inventory Report quantification report Table A3.4–30
	MolarRatio	kg N_2O/kg N	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2. MolarRatio = 44/28

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B8/P8 -Fertilizer and Lime Use	$Emissions_{Other\ Fert\ and\ Lime\ Use,\ crop\ i} = N_{FN\ crop} * (EF_{ECO} * RF\_CS_{m}) * MolarRatio$					
	Other (inorganic fertilizer) Fertilizer and Lime Use Emissions - $Emissions_{Other\ Fert\ and\ Lime\ Use,\ crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen Fertilizer Use per Crop i — $N_{FN\ crop\ i}$	kg N	Measured	Direct measurement during application	Continuous	Direct measurement as the most accurate method
	Emission Factor Related to Local Soil and Climatic Conditions — EF_{Eco}	kg N_2O - N / kg N	Estimated	Calculated using $e^{(0.00558*P-7.701)}$ where P is the long-term mean precipitation from May 1 to October 31 for ecodistrict i. Also integrates influence of texture, tillage, and topography	Annually	The value associated with EF_{Eco} is to be determined based on the EcoDistrict the farm is located in. The EF_{Eco} value for each EcoDistrict is listed in Appendix A. As per the approach used in Canada's National Inventory Report 2022 quantification method
	Ratio factor for cropping system (annual or perennial) —RF_CS_m	unitless	Estimated	For annual cropping systems use factor 1.00, and 0.19 for perennial systems	Annually	As per Canada's 2022 National Inventory Report quantification report Table A3.4–30
	MolarRatio	kg N_2O/kg N	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2. MolarRatio = 44/28
B8/P8 -Fertilizer and Lime Use	$Urea\ CO_2\ Emission = \Sigma(M_{Urea,i} \times EF_{Urea}) * MolarRatio$					
	Annual C emissions from urea application CO_2Emission	tonne CO_2	N/A	N/A	Annually	As per Canada's 2022 National Inventory Report quantification report
	Annual amount of urea fertilization $M_{Urea,i}$	tonne Urea	Measured	Direct measurement during application	Annually	As per Canada's 2022 National Inventory Report quantification report

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emission factor EF_{Urea}	tonne C /tonne Urea	Estimated	Ratio factor 0.20	N/A	As per Canada's 2022 National Inventory Report quantification report
	MolarRatio	tonne CO_2/ tonne C	N/A	N/A	N/A	This molar ratio fraction converts carbon to carbon dioxide based on the molecular weight of CO_2 and C. MolarRatio = 44/12
B13/P13 - Soil and Crop Dynamics	$Emissions_{Manure\ Soil\ and\ Crop\ Dyn,\ crop\ i} = ((N_{Manure\ crop\ i} * FRAC_m * EF_{VD}) + (N_{Manure\ crop\ i} * FRAC_L * EF_L)) * MolarRatio$					
	Manure Soil and Crop Dynamics Emissions – $Emissions_{Manure\ Soil\ and\ Crop\ Dyn,\ crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Manure nitrogen per crop i— N_{Manure}	kg N	Measured	Direct measurement during application	Continuous	Direct measurement is the most accurate method
	Fraction of Manure nitrogen Applied to Soils that Volatizes as NH_3-N and NO_x-N — $FRAC_m$	unitless	Estimated	Default factor for dairy 0.11 and swine 0.13. Default factor set at 0.21 for manure other than dairy and swine.	Annually	As per Canada's 2022 National Inventory Report quantification report
	Emission Factor for Nitrous Oxide from Nitrogen Redeposited after Volatilization — EF_{VD}	kg N_2O - N / kg N	Estimated	Default factor set at 0.005 kg N_2O - N / kg N	Annually	As per Canada's 2022 National Inventory Report quantification report and 2006 IPCC Guidelines
	Fraction of Nitrogen Lost in Leachate — $FRAC_L$	unitless	Estimated	Calculated using 0.3247*P/PE-0.0247, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area	Monthly	The $FRAC_{leach}$ value for each EcoDistrict within Alberta is listed in Appendix A. As per Canada's 2022 National Inventory Report quantification method. For irrigated fields, use a $FRAC_L$ = 0.3

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emission Factor for Nitrous Oxide from Leachate — EF_L	kg N_2O - N / kg N	Default	Default factor set at 0.0075 kg N_2O - N / kg N	Annually	As per Canada's 2022 National Inventory Report quantification report and 2006 IPCC Guidelines
	MolarRatio	kg N_2O/kg N	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2. MolarRatio = 44/28
B13/P13 - Soil and Crop Dynamics	$Emissions_{Other\ Soil\ and\ Crop\ Dyn,\ crop\ i} = ((N_{res\ crop\ i} * EF_{ECO} * RF\_NS_{k=ON,m} * RF\_CS_m) + (N_{VD\ crop\ I} * EF_{VD}) + (N_{L\ crop\ i} * EF_L)) * MolarRatio$					
	Other (crop residue) Soil and Crop Dynamics Emissions – $Emissions_{Other\ Soil\ and\ Crop\ Dyn,\ crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually — $N_{res,\ crop\ i}$	kg N	Calculated	Calculated as per the equation given below	Annually	As per Canada's National Inventory Report quantification process
	Emission Factor Related to Local Soil and Climatic Conditions — EF_{Eco}	kg N_2O - N / kg N	Estimated	Calculated using $e^{(0.00558*P-7.701)}$ where P is the long-term mean precipitation from May 1 to October 31 for ecodistrict i. Also integrates influence of texture, tillage, and topography	Annually	The value associated with EF_{Eco} is to be determined based on the EcoDistrict the farm is located in. The EF_{Eco} value for each EcoDistrict is listed in APPENDIX A: Annual ecodistrict emission factors for Alberta. As per the approach used in Canada's National Inventory Report 2022 quantification method.
	Ratio factor for organic N source k=ON in cropping system m —$RF\_NS_{k=ON,m}$	unitless	Estimated	For crop residue in annual cropping systems use 0.84 and 1.00 for perennial systems	Annually	As per Canada's 2022 National Inventory Report quantification report Table A3.4–30
	Ratio factor for cropping system (annual or perennial) —RF_CS_m	unitless	Estimated	For annual cropping systems use factor 1.00, and 0.19 for perennial systems	Annually	As per Canada's 2022 National Inventory Report quantification report Table A3.4–30

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Nitrogen from Volatilization and Re-deposition of NH_3 and NO_x per Crop i— $N_{VD, crop\ i}$	kg N	Calculated	Calculated as per the equation given below	Annually	As per the approach used in Canada's National Inventory Report 2022 quantification method.
	Emission Factor for Nitrous Oxide from Nitrogen Redeposited after Volatilization — EF_{VD}	kg N_2O - N / kg N	Estimated	Default factor set at 0.005 kg N_2O - N / kg N	Annually	As per the approach used in Canada's National Inventory Report 2022 quantification method and 2006 IPCC Guidelines
	Nitrogen Leaching of NO_2 - N and NO_3- N per Crop i— $N_{L, crop\ i}$	kg N	Calculated	Calculated as per the equation given below	Annually	As per Canada's 2022 National Inventory Report quantification process
	Emission Factor for Nitrous Oxide From Leachate — EF_L	kg N_2O - N / kg N	Default	Default factor set at 0.0075 kg N_2O - N / kg N	Annually	As per Canada's 2022 National Inventory Report quantification report and 2006 IPCC Guidelines
	MolarRatio	kg N_2O/kg N	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2. MolarRatio = 44/28
B13/P13 - Soil and Crop Dynamics	$N_{res\ crop\ i} = Crop\ Mass_{crop\ i} * (1/\ Yield\ Ratio) * FRAC_{renew\ crop\ i} * ((R_{AG\ crop\ i} * N_{AG\ crop\ i}) + (R_{BG\ crop\ i} * N_{BG\ crop\ i}))$					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per Crop i—$N_{res\ crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Harvested Annual Dry Matter Production for Crop i — Crop $Mass_{crop\ i}$	kg DM	Measured	Direct measurement	Annually	Direct measurement is the most accurate method
	Fraction of Total Dry Matter Production that is Harvested – Yield Ratio	unitless	Estimated	This value is determined using the Table B.1 in APPENDIX B: Crop Residue Nitrogen Factors. The value is from the fifth column (Yield_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
	Fraction of Total Area Under Crop i that is Renewed Annually — $FRAC_{renew\ crop\ i}$	unitless	Estimated	For annual crops $FRAC_{renew}$ = 1	Annually	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
						IPCC review of its methodologies). Value set at one to reflect that only annuals are allowed in project condition
	Ratio of Above-Ground Residues Dry Matter to Harvested Production for Crop i — $R_{AG\ crop\ i}$	unitless	Estimated	This value is determined using the Table B.1 in APPENDIX B: Crop Residue Nitrogen Factors.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 i — $N_{AG\ crop\ i}$	kg N / kg DM	Estimated	This value is determined using the Table B.1 in APPENDIX B: Crop Residue Nitrogen Factors. 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 i— $R_{BG\ crop\ i}$	unitless	Estimated	This value is determined using the Table B.1 in APPENDIX B: Crop Residue Nitrogen Factors.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
	Nitrogen Content of Below-Ground Residues for Crop i — $N_{BG\ crop\ i}$	kg N / kg DM	Estimated	This value is determined using the Table B.1 in APPENDIX B: Crop Residue Nitrogen Factors. 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
	$N_{VD\ crop\ i} = (N_{Fert\ crop\ i} * FRAC_f)$					

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B13/P13 - Soil and Crop Dynamics	Indirect Emissions of Nitrogen from Volatilization and Re-deposition of NH_3 and NO_x per Crop i — $N_{VD\ crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen Fertilizer Use per Crop i— $N_{fert\ ,\ crop\ i}$	kg N	Estimated	Direct measurement	Annually	Direct measurement is the most accurate method
	Fraction of Synthetic Fertilizer Nitrogen Applied to Soils that Volatizes as NH_3^- and NO_x-N — $FRAC_f$	unitless	Estimated	Default factor set at 0.06 for commercial fertilizer	Annually	As per Canada's 2022 National Inventory Report quantification report
	$N_{L\ crop\ i} = (N_{Fert\ crop\ i} + N_{res,\ crop\ i}) * FRAC_L$					
	Indirect Emissions of Nitrogen from Leaching per Crop i — $N_{L\ crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen Fertilizer Use per Crop i— $N_{Fert\ crop\ i}$	kg N	Measured	Direct measurement	Continuous	Direct measurement is the most accurate method
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per Crop i— $N_{res\ ,\ crop\ i}$	kg N	Calculated	Calculated as per the equation above	Annually	As per Canada's 2022 National Inventory Report quantification process
	Fraction of Nitrogen Lost in Leachate — $FRAC_L$	unitless	Estimated	Calculated using 0.3247*P/PE-0.0247, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area	Monthly	The $FRAC_{leach}$ value for each EcoDistrict within Alberta is listed in Appendix A. As per Canada's 2022 National Inventory Report quantification method. For irrigated fields, use a $FRAC_L = 0.3$

i - Rochette *et al,* 2008A, Estimation of N_2O emissions from agricultural soils in Canada. II. 1990-2005 Inventory. Canadian Journal of Soil Science. 88: 655-669, Rochette *et al*, 2008B, Estimation of N_2O emissions from agricultural soils in Canada. I. Development of a country-specific methodology. Canadian Journal of Soil Science. 88: 641-654 and Rochette, *et al.* 2018 Soil nitrous oxide emissions from agricultural soils in Canada: Exploring relationships with soil, crop and climatic variables. Agriculture, Ecosystems & Environment, 254, 69-81.

5. Data Management

Documentation (documents and records) is a key element to emission offset project development, verification, and meeting Alberta Emission Offset System and Regulation requirements. The types of document and records required to demonstrate that an emission offset project meets regulatory and protocol requirements can vary by project. It is the project developer's responsibility to ensure they are meeting all protocol requirements and clearly document how they are going to meet protocol and system requirements in the emission offset project plan, offset project report, and supported by any data management systems including each 4R Plan.

The verification process relies heavily on the quality and availability of documentation to support each emission reduction. Projects are verified to meet requirements outlined in the Standard for Validation, Verification and Audit to a reasonable level of assurance, which means that objective evidence of project implementation is required to make an emission offset claim. Reasonable assurance means the verifier is able to reach a positive finding on the accuracy and correctness of the GHG Statement. Attestation is not considered objective evidence and is not accepted under reasonable level of assurance engagements.

In order to support the verification and any supplemental government reviews or reverifications, the emission offset 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, and dated.
- All records must be maintained in an orderly manner.
- All documents must be retained in accordance to regulatory requirements.
- Electronic and paper documentation are both satisfactory.
- Copies of records should be stored to prevent loss of data.

In the case of aggregated projects, the farm enterprise owner/operator and the emission offset project developer/aggregator must both maintain and retain records as required above for all emission reduction claims.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location. The greater the rigour of a management system for the data, the more easily verification can be conducted for the project.

5.1 Documents

Documentation in the form of documents and records is a key element to project development. Documents are required to demonstrate that a project meets program criteria, eligibility, baseline eligibility and project offset quantification requirements. Examples of documents include offset project plan, the 4R Plan(s), established procedures, specifications, drawings, regulations, standards, guidelines, training certificates etc. These documents must include a list of records available to a reviewer that demonstrate the system and protocol criteria have been met. The offset project documents should also indicate how the records will be managed (i.e., retention, storage and access).

Documents may be stand-alone or interdependent but must be complete. Documents may be subject to change or periodic update. The project developer must be able to demonstrate that the relevant version of a document is being used. Older versions applicable to specific GHG statements must be retained as part of the project documentation as per section 31(6) of the Regulation.

In addition to the criteria outlined in this protocol, the emission offset project developer is required to provide documents to show that offset criteria in the Standard for Greenhouse Gas Emission Offset Project Developers have been met

The offset project plan must be specific and detail the documentation requirements for the project. The verification process relies heavily on the quality and availability of documentation and the project plan must be clear on the types of documentation that will be available. The project developer will need to provide a reviewer with objective evidence of project implementation.

Documents and records are required to be:

- legible, identifiable and traceable,
- centrally located,
- dated,
- easily located (easily searched), and
- orderly; and prevented from loss.

Project developers are required to retain copies of all required records and any additional records needed to support greenhouse gas statements. The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily verification will be conducted for the project.

5.2 Records

Records prove completion of the project as planned. Records include but are not limited to invoices, contracts, metered results, maintenance logs, calculations, databases, photographs, calibration records, farm record sheets, components of the 4R Plans, soil testing results, etc. Where the emission offset project developer is different from the person or entity implementing the activity, both must maintain sufficient records to support the offset project and any emission reduction claims. If the emission offset project developer or farm and/or farmed fields ownership changes, sufficient records to support the emission offset project must be provided to the new owner to support any previous claims. Records may be requested anytime per Regulation, and must be provided upon request. Table 9 outlines the minimum general records needed to support this protocol.

5.2.1 General Records Requirements

Table 9: General Records Requirements

Record Requirement	Examples of Records	Why Required
Ownership of the emission reduction	• Land title certificate or rental agreement for each farmed field being claimed in the project for the first year the field is included. • Confirmation of annual check against land titles to determine if ownership for the property has changed. • If ownership has changed, a new land title certificate or rental agreement must be obtained. • If a single lease agreement is used for multiple project years, the agreement must be valid over this time span.	To confirm emission reduction ownership
Right to transact on offset credits	• Contract between the project developer/aggregator and farm operator for the assignment of the emission reduction rights. This includes agreement to provide access to data needed to quantify the GHG statement for the farm enterprise.	To confirm the right to transact on emission offsets
Confirmation of annual Farm Enterprise Boundary by the Accredited Professional Advisor	• Measurement of farm enterprise boundary size using imagery such as satellite data or aerial photos or county maps. • Annual check of additions or removals of land title certificates under the farm enterprise boundary. • Annual check of additions or removals between the farm enterprise and other parties. • Copy of Business number for farm enterprise. • Annual Aggregated Project Planning Sheet (APPS) submitted inti the registry for the cropping year.	To confirm the entire farm enterprise is included in the offset project To confirm that new lands added or removed to the farm enterprise boundary are recorded in the annual APPS submitted to the registry, and appropriately handled according to protocol requirements
Locations of the Farm Enterprise included in Project	• Legal land location(s) (Alberta Township System and additional boundary file or central GPS coordinates) within the farm enterprise boundary. • EcoDistrict location(s) within the farm enterprise boundary, determined using the tool[ii] provided by Alberta Agriculture and Rural Development.	Entire Farm Enterprise Boundary must be included in the project management system EcoDistrict locations required for emission reductions accounting

Record Requirement	Examples of Records	Why Required
Use of Irrigation if applicable	• Supporting documentation for water usage on the field by farm operator including two of the following: ▪ Water use records. ▪ Photo evidence with GPS time stamp showing equipment used including model information. ▪ Crop insurance records noting use of irrigation. ▪ Air photo or satellite imagery showing pivots. ▪ Alberta Irrigation Program documents. ▪ Detailed farm maps showing coverage of irrigation networks over project fields including type and model numbers for equipment being used. OR • Sign off by the Accredited Professional Advisor who reviewed and collected supporting documentation that confirm the irrigation practice. • Copy of supporting documentation reviewed by Accredited Professional Advisor.	Irrigation impacts N_2O emissions from agricultural soils Irrigation status required to properly calculate project emission reductions
Accredited Professional Advisor credentials	• Confirmation that the Accredited Professional Advisor has successfully completed the Fertilizer Canada 4R Nutrient Stewardship Courses (1-3) and NERP course (APA Certificate). • Proof of Accredited Professional Advisor's registration as a member of the Alberta Institute of Agrologists. • Confirmation from the AIA Membership Directory (website) that the Accredited Professional Advisor meets the requirements of the Area of Practice Standard for Greenhouse Gas Assessment and Management Practice. The record must be a screen shot or print out of the member directory, showing the name of the individual and include GHG Assessment and Management Practice, and the date the member search was conducted. The date of the search must precede any work conducted by the member on the project.	To ensure that the participants of this protocol have training and credentials required
Annual submissions of the Aggregated Project Planning Sheet(s) – APPS, and Annual specific Aggregated Project Reporting Sheet – APRS	• The APPS is required for aggregation of two or more projects undertaking the same project activity but being bundled into one larger project in the system. A subproject is tracked at the quarter section level and any sections of the farm must be included as part of each project. • Due to the dynamic nature of farm enterprises, the **annual submission of the APPS is required for all farms** participating in this protocol. There are deadlines associated with APPS submissions and if an APPS is not submitted for a vintage year, the farms are unable to make a claim for that vintage year. • The APPS provides evidence for the crediting start date for farms participating in an aggregated project in the system and allows for any added or removed lands to be reflected annually. • The APRS is required for all aggregated projects that are making a greenhouse gas emission reduction claim. The	To ensure the project developer is actively managing farms, and verifier is able to review the farms/ subprojects listed in and being quantified in the project

Record Requirement	Examples of Records	Why Required
	APRS documents eligibility or ineligibility for all farm subprojects and their verified emission offset claim by vintage year.	

ii - The EcoDistrict must be specified to determine the appropriate factor to quantify N_2O emissions for the field. EcoDistrict maps are available from the Canadian National Soil Database (NSDB).

5.2.2 Baseline Considerations

The baseline N_2O emissions are calculated per mass of crop type produced as the average over the three years prior to project implementation.[20] It is not required that the same fields are farmed with a particular crop type in the baseline and project condition, since crops will be rotated. Three years of baseline data are needed for any crop type included in the project (using the conventional baseline approach).

Direct evidence is required to substantiate the mass of nitrogen inputs for each crop type for each of the three years used to derive the baseline emissions of N_2O per mass of crop produced. Records requirements for the conventional baseline are noted in Table 10.

Table 10: Conventional Baseline Records Requirements

Record Requirement	Examples of Records	Why Required
Types of crops grown in the three years used to establish the baseline	• Farm records indicating the crop type grown for each field in the project. One of the following: ▪ AFSC records, hail insurance records by field. ▪ Signed records from a crop advisor that show the type of crop grown by field. ▪ Seed purchase receipts.	To establish the crop types in the baseline and project
Crop mass (by crop) grown for each of the three years used to establish the baseline	• Selection of one of the acceptable crop mass determination methods, as provided by the protocol in Table 12. • Supporting documentation to accompany the selected acceptable crop mass determination, as described in Table 12.	For GHG quantification
Mass of nitrogen fertilizer applied by crop type across the full farm in each of the three years used for the baseline	• Invoices showing nutrient composition and quantity of fertilizer purchased. One of the following: ▪ Farm log of fertilizer application masses and dates by field. ▪ Custom application receipts indicating fertilizer mass and application dates.	For purposes of preparing the 4R Plan Total mass of nitrogen for GHG quantification
Quantity, composition and application date of manure applied by field for each year in the baseline	• Manure Management Plans including either manure analysis or referenced manure nutrient values as outlined in section section 3.1: 4R Plan Development. One of the following: ▪ Farm records indicating the manure applied by field. ▪ Custom application records indicating the manure applied by field.	For GHG quantification
Baseline calculation records	• Set of baseline calculations signed off by project developer and Accredited Professional Advisor.	Baseline calculations

[20] Refer to Section 1.5 and 4.0 for details on flexibility of the 3 years required, and what to do if new crop types are introduced to the project.

Record Requirement	Examples of Records	Why Required
	• Years used to calculate baseline values. • Supporting documentation describing baseline quantification, including calculations and factors used. • If non-consecutive years are chosen for development of conventional baseline for a crop (and the crop was grown in un-used years), trend data on extreme weather events to demonstrate how the year is excluded will be required.	required for project verification

i - Custom manure applicators or operators who apply, transfer or receive more than 500 tonnes of manure per year must keep records for a minimum of 5 years and must conduct soil tests. For more information, see Manure management guidelines and legislation (https://www.alberta.ca/manure-management-guidelines-and-legislation.aspx) and Manure Management Record Keeping Regulations.

5.2.3 Project Records Requirements

Note that management zones become more detailed with increasing 4R performance levels. Project records will at minimum contain the information provided in Table 11.

Table 11: Project Condition Records Requirements

Record Requirement	Examples of Records	Why Required
Locations and area of each 4R management zone (fields/sub-fields) enrolled in the project [i]	• EcoDistrict location of each field/management zone determined using the tool[ii] provided by Alberta Agriculture and Rural Development. Both of the following: ▪ Legal land location (Alberta Township System and project boundary file and central GPS coordinates) of each management zone. ▪ Specific location, area and boundaries of each 4R management zone using satellite data or aerial photos.	Key input to 4R Plan To ensure the fields/subfields are in the same EcoDistrict
Crop type grown for each management zone[iii]	• Farm records indicating the crop type grown for each management zone in the project (including indication of fields that were managed under ineligible crop types such as perennial production or summerfallow for that cropping year). One of the following: ▪ AFSC records, hail insurance records. ▪ Signed Accredited Professional Advisor records of field observations for each field in the project. The Accredited Professional Advisor must have reviewed and collected supporting farm records that confirm the types of crops/field activities for that year. These records must be maintained in a format that is readily available for verifiers to inspect.	Key input to 4R Plan Establish that the crop is grown in the project year
4R practices by management zone	• 4R Plan signed by Accredited Professional Advisor showing performance level BMPs applied to all management units. ▪ 4R Plan detailing source BMPs by management zone, including the composition of fertilizers applied. ▪ 4R Plan detailing rate BMP by management zone, based on annual soil testing and nutrient application recommendations. ▪ 4R Plan detailing place BMP by management zone, including % band concentration calculations.	To confirm that the proper reduction modifier is being applied in GHG emission reduction calculations Ensure the proper BMPs are

	▪ 4R Plan detailing time BMP by management zone, including fertilizer application dates.	implemented in each performance level
Available nitrogen	• Accredited Professional Advisor sign off on records outlining soil sampling methodology, sampling dates, sample handling, and location from which samples were collected. This information must be specific to 4R management zones. Soil sampling and nitrogen rate recommendations must be made at the intensity described below: ▪ Annual soil testing for each field at the basic 4R implementation level, or ▪ Annual soil testing required for each management zone at the intermediate 4R implementation level, or ▪ Annual soil testing required for each sub-field management zone at the advanced 4R implementation level. And • If soil testing cannot be completed for a given year (this is allowed a maximum of once in a crediting period for each farm enterprise), the following information is required: ▪ Description of extreme soil or climatic soil conditions preventing soil sampling (weather trend data, time stamped photos of soil surface, etc.). ▪ Description of alternate tools used to develop fertilizer recommendations without soil sampling data. • 4R Plan records indicating anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year).	Key input to 4R Plan
Quantity, composition and application date of nitrogen fertilizer applied by crop type included in the project	• 4R Plan indicating the recommended quantity and composition of fertilizer for each management zone in the project, based on soil sampling, assessment of nitrogen from manure soil amendments in the previous year, assessment of nitrogen from crop residue remaining from the previous year, yield goal, and field conditions in the previous year (e.g., crop residue from a hail event). • Invoices showing quantity and composition of fertilizer purchased. • Reconciled total of purchased nitrogen amounts with amounts applied by crop type and/or remaining in storage (in order to support reconciliation this includes a record of nitrogen amounts applied to crop types declared ineligible under this protocol). One of the following: ▪ Farm log of fertilizer application dates by management zone (including manure), or ▪ Custom application receipts indicating fertilizer application dates.	Assess conformance to the 4R Plan Total mass of nitrogen is used for GHG quantification
Soil temperature readings	In cases where fall nitrogen application occurs according to the 4R Plan, the following records are required: • Sign off from the Accredited Professional Advisor that the fertilizer application occurred in accordance to the 4R Plan and protocol requirements. • Soil temperature readings (at a depth of five centimeters or deeper) showing three consecutive days where the soil is less than 10º Celsius, or	To ensure that fall soil applications occur according to requirements of the protocol.

	• Soil temperature calculations (using the equation provided in Section 3.1) showing five consecutive days where the soil temperature is calculated to be less than 10° Celsius.	
Fertilizer placement equipment	• Annual provision of date stamped photos of fertilizer banding or spreading and incorporation equipment. • Evidence that application equipment was calibrated to the equipment manufacturer's specifications prior to fertilizer application. One of the following: ▪ Width of fertilizer openers and spacing to determine the per cent band concentration[iv], or ▪ Invoices or a letter from custom fertilizer application that indicates the type of opener and row spacing for each field.	Assess conformance to the 4R Plan
Quantity, composition and application date of manure applied by field	• Manure management records including either manure analysis or referenced manure nutrient values as outlined in Section 3.1 above. • Laboratory analysis results determining manure nutrient content or reference to appropriate manure nutrient values as outlined in Section 3.1 above. • Sign off from the Accredited Professional Advisor of nitrogen content of the applied manure. One of the following: ▪ Farm records indicating mass of manure applied by field, or ▪ Confined Feeding Operation records or custom application records indicating mass of manure applied by field.	Assess conformance to the 4R Plan Total mass of nitrogen is used for GHG quantification
Crop mass by crop type, dry matter basis (for each EcoDistrict and 4R performance level)	• Estimation of crop yield at the field level, which is used for evaluating the 4R Plan (not used for GHG quantification). • Conventional baseline or dynamic baseline one: ▪ Selection of one of the acceptable crop mass determination methods used for GHG quantification. ▪ Supporting documentation according to the selected crop mass determination method (see Table 12). • If using dynamic baseline two: ▪ Calculations showing crop mass data derived from the five-year rolling averages published by Agriculture Financial Services Corporation (AFSC). ▪ Reference to each crop type (including irrigated or dryland) and crop variety used to calculate project crop yields with AFSC five-year rolling average data. ▪ AFSC risk area used to calculate project crop yields.	Field level monitoring is used for evaluating the 4R Plan Crop mass is used for GHG quantification
Additional supporting farm records	• Farm records noting any extraordinary situations, such as remaining crop residue related to crop damage from hail, flooding, pest infestations, etc. • In the case of crop failure: ○ Crop insurance records (if applicable), and/or ○ Independent agronomist or Accredited Professional Advisor assessment documentation. • Farm records indicating which fields contained crops or management systems ineligible for credit production under this protocol (e.g., summerfallow, grazing, ineligible crops) or had	To support proof of 4R Plan implementation or describe variances from the 4R Plan

	ineligible fertilizers applied which resulted in the ineligibility of the fields under this protocol for the year. • Listing of fields/subfields in Aggregated Project Reporting Sheet (APRS) with zero carbon claimed and documents why ineligible for the year.	
Confirmation that 4R Plan was conformed to by the farm operator	• Annual sign off from the Accredited Professional Advisor that the 4R Plan was conformed to, including fields under ineligible crops or ineligible management (e.g., summerfallow, grazed fields, or use of fertilizers ineligible under the protocol). • Description of situations where 4R was not conformed to and why.	Implementation Sign off by Accredited Professional Advisor
Additional field passes	• Accredited Professional Advisor analysis of additional equipment passes required per 4R management unit as a result of implementation of the 4R Plan. *Method A: Documented Fuel Use Method* • Sale receipts including specification of fuel type. • Fuel logs and or equipment use logs indicating date and fuel usage associated with additional passes. *Method B: Additional Pass Method* • Area and location (supported with aerial photos or satellite data) of 4R management units receiving additional passes.	Emissions associated with fuel usage from additional passes part of overall project emissions reductions claims

i - It is not required that the same fields are farmed with a particular crop type in the baseline and project condition, since crops will be rotated.
ii - The EcoDistrict must be specified to determine the appropriate factor to quantify N_2O emissions for the filed. EcoDistrict maps are available from the Canadian National Soil Database (NSDB).
iii - There is no need to record different crop varieties.
iv - For specialty crops where the fertilizer application may be separate from seeding equipment, a date-stamped photo of the fertilizer spacing for that field.
v - Manure management records are a requirement for larger operations in Alberta under the *Agricultural Operation Practices Act*. The records need to document who manure is sold or given to and where it's being applied and at what rate. Nutrient content of the manure is required as well.

Table 12: Crop Mass Determination Methods Records Requirements

Record Requirement	Examples of Records	Why Required
Mobile weighing devices	• Calibration report (digital printouts) demonstrating that equipment has been calibrated to manufacturer specifications, by a qualified third party, prior to harvest. • A weight log of each load[21]. • A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day. • The calibration report will be made available to the verifier to assess the proper procedures are followed.	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Fixed scale	• Calibration report demonstrating that equipment has been calibrated to manufacturer specifications, by a qualified third party, prior to harvest. • A weight log of each load[22]. • A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

[21] In the event the weight log is less than the project claim, the weight log shall prevail.
[22] In the event the weight log is less than the project claim, the weight log shall prevail.

	each crop type, a minimum of three crop moisture tests are taken from each field per day. • The calibration report will be made available to the verifier to assess proper procedures are followed.	
Commercial-scale certified by Industry Canada with accompanying scale tickets (i.e., elevator or grain processors)	• Scale tickets for each truck load that specifies load mass and crop type for each load. • Scale tickets that show the truck loads that link to the moisture test. • Scale company and location. • Moisture determination result from each load in a moisture log.	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

Bin Volume	• Copy of method and calculations used to calculate bin volume measurements.
	• A third party sign off will be made available reporting the bin is empty and recorded in a bin log before harvest (Accredited Professional Advisor or their representative check); this must include photo, time stamped evidence.
	• Bin moisture test result(s) or average for the bin.
	• The following sources can be used to calculate the bin volume dimensions and crop mass (dry matter basis, according to moisture logs above):
	    • Agriculture and Rural Development. March 2002. Round Bin Volume Calculator.
	    • Saskatchewan Crop Insurance Corporation. Interactive Bin Calculator.
	    • Manitoba Agricultural Services Corporation. MASC Insurance Calculators.
	• All crop at harvest needs to go into an empty bin, meaning crop mass at harvest needs to be segregated from any existing crop from the year before.
	• The bin log and moisture log will be made available to the verifier upon request.
		To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

Flexibility mechanism 5: Combine-mounted yield monitors	• Calibration report or evidence demonstrating that equipment has been calibrated to manufacturer specifications for each crop type, prior to harvest; and/or report of yield monitor data cleaned using an appropriate post processing software. • A weight log of each load. • A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day, **or** • Records and lab results of destructive lab testing to obtain moisture from crop. Provide evidence of lab certification and a methodology that complies with national or provincial standards. • Confirmation under seal from Accredited Professional Advisor of all application of this flexibility mechanism to generate yield data.	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

5.3 Record Keeping

Projects must be supported with data of sufficient quality to fulfill the quantification requirements and be substantiated by records.

In support of this requirement project data must be managed in a manner that substantiates that:

- Emissions and reductions that have been recorded pertain to the offset project.

- All emissions and reductions that should have been recorded have been recorded.
- Emissions and reductions quantification has been recorded appropriately and counted once.
- Emissions and reductions have been recorded in the correct reporting period.
- Emissions and reductions have been recorded in the appropriate category.
- An auditable data management system.

Based on these requirements, data must be quantifiable, measurable and verifiable using replicable means. That is, any independent reviewer should be able to reach the same conclusions using evidence-supported data.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements.

Where the project developer is different from the party implementing the activity, as in the case of an aggregated project; the individual farmer and the aggregator, must all 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 regulator upon request.

Table 13: Responsibilities for Data Collection and Retention

Entity	Data Collection and Retention Responsibilities
Farm Operator	Work with the Accredited Professional Advisor to develop the 4R Plan and commits to implementation on an annual basis for the duration of the crediting period. Perform the BMPs in accordance with the 4R Plan Provide copies of farm records and documentation to the project developer/aggregator. The farm operator must retain original records.
Project Developer/ Aggregator	The project developer has primary responsibility for record keeping and record coordination to support project implementation and due diligence, and will be the primary information source for third party verification and/or government reviews. The project developer is required to collect and manage copies of farm records and supporting documentation outlined above.
Accredited Professional Advisor	Review and sign off on baseline condition and any calculations in the 4R Plan. Design, conduct annual soil testing and nitrogen recommendations, and sign off on the 4R Plans. Ensure the described farm enterprise boundary remains accurate throughout the project and that all nitrogen inputs and crop mass are accounted for within the farm enterprise boundary. Annual sign off that the 4R Plan was implemented.

In order to support the third-party verification and any government review, 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 seven years after the end of the project crediting period.
- Electronic and paper documentation are both satisfactory.
- Copies of records should be stored in two locations to prevent loss of data.

5.4 Site Visits

A risk-based sample size of farms site visits is required for verification, per the Standard for Validation, Verification and Audit, and all farms should be visited at least once over the life of the project. Verifiers will 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.

5.5 Quality Assurance/Quality Control (QA/QC) Considerations

QA/QC procedures are applied to ensure that all measurements and calculations have been made correctly. Emission offset project developers remain responsible for clearly providing evidence and information that support their emission offset project meet all rules and requirements of the system, regulation, and protocol. QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly.

Some standard QA/QC procedures include, but are not limited to:

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

6. References

Agriculture and Agri-Food Canada. 2015. The National Soil DataBase (NSDB). https://sis.agr.gc.ca/cansis/nsdb/index.html

Agriculture and Rural Development. Round Bin Volume Calculator. March 2002. https://www.agric.gov.ab.ca/app19/calc/volume/roundbin.jsp

Alberta Agriculture and Rural Development. 2008. Alberta Farm Fertilizer Information and Recommendation Manager (AFFIRM). https://www.alberta.ca/alberta-farm-fertilizer-information-and-recommendation-manager.aspx

Alberta Agriculture and Rural Development. 2008. Alberta's Nutrient Management Planning Guide. https://open.alberta.ca/publications/7086752

Alberta Environment and Protected Areas. 2023. Standard for Greenhouse Gas Emission Offset Project Developers. https://open.alberta.ca/publications/standard-for-greenhouse-gas-emission-offset-project-developers-version-3

Alberta Environment and Protected Areas. 2023. Standard for Validation, Verification and Audit. https://open.alberta.ca/publications/standard-for-validation-verification-and-audit-version-5

Alberta Environment and Protected Areas. 2023. Carbon Offset Emission Factors Handbook. https://open.alberta.ca/publications/carbon-offset-emission-factors-handbook-version-3

Fertilizer Canada. 2015. GrowZone: NERP Training Program. https://fertilizercanada.ca/wp-content/uploads/2015/07/NERP-Training-Program-English.pdf

Climate Check. 2009. Decision Paper for Nitrous Oxide Emission Reduction Protocol. Prepared for Climate Change Central and Canadian Fertilizer Institute.

Environment and Climate Change Canada. 2022. 1990-2020 National Inventory Report. Greenhouse Gas sources and sinks in Canada. https://publications.gc.ca/site/eng/9.506002/publication.html

Environmentally Sustainable Agriculture Tracking Survey Report, University of Alberta, August 2021. https://www.ualberta.ca/resource-economics-environmental-sociology/media-library/research/project-reports/documents/pr-21-03-final.pdf

International Plant Nutrition Institute. 2011. The 4Rs: Right Source, Right Rate, Right Time, Right Place.

IPSOS REID. 2014. 2014 Environmentally Sustainable Agriculture Tracking Survey Summary Report. Prepared for the Government of Alberta.

Janzen HH, Beauchemin KA, Bruinsma Y, Campbell CA, Desjardins RL, Ellert BH, and Smith EG, 2003, The fate of nitrogen in agroecosystems: An illustration using Canadian estimates, Nutrient Cycling in Agroecosystems 67:85–102

Koehler-Munro, K., Montgomery, K.M., Goddard, T.W., Brierley, J.A., Kryzanowski, L.M. 2005. Soil Temperature Dynamics of Adjacent Catenas on Farmland in the Black Soil Zone. Proceedings of the Alberta Soil Science Workshop. February 14-16, 2005. Calgary. Pp. 177-182.

Manitoba Agricultural Services Corporation. MASC Insurance Calculators. https://www.masc.mb.ca/masc.nsf/calculator_agriinsurance.html

Rochette, P., Liang, C., Pelster, D., Bergeron, O., Lemke, R., Kroebel, R., MacDonald D., Yan, W., Flemming, C. 2018. Soil nitrous oxide emissions from agricultural soils in Canada: Exploring relationships with soil, crop and climatic variables. Agriculture, Ecosystems & Environment, 254, 69-81.

Rochette, P., Worth, D. E., Huffman, E. C., Brierley, J. A., Mcconkey, B. G., Yang, J., Hutchinson, J.J., Desjardins, R.L., Lemke, R., Gameda, S. 2008(A). Estimation of N_2O emissions from agricultural soils in Canada. II. 1990-2005 Inventory. Canadian Journal of Soil Science. 88: 655-669.

Rochette, P., Worth, D. E., Lemke, R. L., McConkey, B. G., Pennock, D. J., Wagner-Riddle, C., Desjardins, R. J. 2008(B). Estimation of N_2O emissions from agricultural soils in Canada. I. Development of a country-specific methodology. Canadian Journal of Soil Science. 88: 641-654.

Saskatchewan Crop Insurance Corporation. Interactive Bin Calculator. https://www.scic.ca/crop-insurance/other-program-resources/cropconnect/help-bin-calculator

Saskatchewan Ministry of the Environment. 2012. Greenhouse Gas Source Emissions under Three Protocols. Prepared by Cecil N Nagy, Department of Bioresource Policy, Business and Economics, University of Saskatchewan, Saskatoon, Saskatchewan.

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.

Snyder, C.S., T.W. Bruulsema, T.L. Jensen, and P.E. Fixen. 2009. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture Ecosyststems and Environment 133:247-26.

Statistics Canada. 2003. Agriculture 2001 Census.

United States Department of Agriculture Natural Resources Conservation Service. 2007. Dry Matter Determination. Prepared by Tamilee Nennich of Texas A&M University and Larry Chase of Cornell University.

APPENDIX A: Annual ecodistrict emission factors for Alberta

TABLE A-1: Annual ecodistrict emission factors for Alberta including the effects of topography, soil texture, and non-growing season emissions and ecodistrict leaching factors.

Ecodistrict	Irrigation type	Tillage type	Emission Factor (kg N_2O-N/kg N)	Leaching Factor (kg N Leached / kg N Applied)
244	No Irrigation	Conventional Tillage	0.014	0.178
244	No Irrigation	Conservation Tillage	0.010	0.178
244	Irrigation	Conventional Tillage	0.043	0.178
244	Irrigation	Conservation Tillage	0.031	0.178
583	No Irrigation	Conventional Tillage	0.009	0.165
583	No Irrigation	Conservation Tillage	0.007	0.165
583	Irrigation	Conventional Tillage	0.030	0.165
583	Irrigation	Conservation Tillage	0.022	0.165
584	No Irrigation	Conventional Tillage	0.011	0.150
584	No Irrigation	Conservation Tillage	0.008	0.150
584	Irrigation	Conventional Tillage	0.045	0.150
584	Irrigation	Conservation Tillage	0.032	0.150
586	No Irrigation	Conventional Tillage	0.005	0.159
586	No Irrigation	Conservation Tillage	0.004	0.159
586	Irrigation	Conventional Tillage	0.018	0.159
586	Irrigation	Conservation Tillage	0.013	0.159
587	No Irrigation	Conventional Tillage	0.002	0.157
587	No Irrigation	Conservation Tillage	0.001	0.157
587	Irrigation	Conventional Tillage	0.007	0.157
587	Irrigation	Conservation Tillage	0.005	0.157
588	No Irrigation	Conventional Tillage	0.008	0.145
588	No Irrigation	Conservation Tillage	0.006	0.145
588	Irrigation	Conventional Tillage	0.034	0.145
588	Irrigation	Conservation Tillage	0.025	0.145
589	No Irrigation	Conventional Tillage	0.004	0.153
589	No Irrigation	Conservation Tillage	0.003	0.153
589	Irrigation	Conventional Tillage	0.014	0.153
589	Irrigation	Conservation Tillage	0.010	0.153
590	No Irrigation	Conventional Tillage	0.008	0.163
590	No Irrigation	Conservation Tillage	0.006	0.163
590	Irrigation	Conventional Tillage	0.028	0.163
590	Irrigation	Conservation Tillage	0.020	0.163
591	No Irrigation	Conventional Tillage	0.011	0.191
591	No Irrigation	Conservation Tillage	0.008	0.191
591	Irrigation	Conventional Tillage	0.028	0.191
591	Irrigation	Conservation Tillage	0.020	0.191
592	No Irrigation	Conventional Tillage	0.010	0.175
592	No Irrigation	Conservation Tillage	0.007	0.175
592	Irrigation	Conventional Tillage	0.031	0.175
592	Irrigation	Conservation Tillage	0.022	0.175
593	No Irrigation	Conventional Tillage	0.010	0.180

593	No Irrigation	Conservation Tillage	0.008	0.180
593	Irrigation	Conventional Tillage	0.030	0.180
593	Irrigation	Conservation Tillage	0.022	0.180
594	No Irrigation	Conventional Tillage	0.011	0.183
594	No Irrigation	Conservation Tillage	0.008	0.183
594	Irrigation	Conventional Tillage	0.031	0.183
594	Irrigation	Conservation Tillage	0.023	0.183
595	No Irrigation	Conventional Tillage	0.011	0.166
595	No Irrigation	Conservation Tillage	0.008	0.166
595	Irrigation	Conventional Tillage	0.036	0.166
595	Irrigation	Conservation Tillage	0.026	0.166
596	No Irrigation	Conventional Tillage	0.007	0.165
596	No Irrigation	Conservation Tillage	0.005	0.165
596	Irrigation	Conventional Tillage	0.023	0.165
596	Irrigation	Conservation Tillage	0.017	0.165
597	No Irrigation	Conventional Tillage	0.008	0.174
597	No Irrigation	Conservation Tillage	0.006	0.174
597	Irrigation	Conventional Tillage	0.024	0.174
597	Irrigation	Conservation Tillage	0.018	0.174
598	No Irrigation	Conventional Tillage	0.011	0.185
598	No Irrigation	Conservation Tillage	0.008	0.185
598	Irrigation	Conventional Tillage	0.028	0.185
598	Irrigation	Conservation Tillage	0.021	0.185
599	No Irrigation	Conventional Tillage	0.010	0.176
599	No Irrigation	Conservation Tillage	0.007	0.176
599	Irrigation	Conventional Tillage	0.030	0.176
599	Irrigation	Conservation Tillage	0.022	0.176
600	No Irrigation	Conventional Tillage	0.007	0.181
600	No Irrigation	Conservation Tillage	0.005	0.181
600	Irrigation	Conventional Tillage	0.020	0.181
600	Irrigation	Conservation Tillage	0.014	0.181
609	No Irrigation	Conventional Tillage	0.015	0.220
609	No Irrigation	Conservation Tillage	0.011	0.220
609	Irrigation	Conventional Tillage	0.031	0.220
609	Irrigation	Conservation Tillage	0.022	0.220
610	No Irrigation	Conventional Tillage	0.010	0.184
610	No Irrigation	Conservation Tillage	0.007	0.184
610	Irrigation	Conventional Tillage	0.028	0.184
610	Irrigation	Conservation Tillage	0.020	0.184
611	No Irrigation	Conventional Tillage	0.010	0.166
611	No Irrigation	Conservation Tillage	0.008	0.166
611	Irrigation	Conventional Tillage	0.035	0.166
611	Irrigation	Conservation Tillage	0.026	0.166
612	No Irrigation	Conventional Tillage	0.006	0.173
612	No Irrigation	Conservation Tillage	0.004	0.173

612	Irrigation	Conventional Tillage	0.019	0.173
612	Irrigation	Conservation Tillage	0.014	0.173
615	No Irrigation	Conventional Tillage	0.005	0.220
615	No Irrigation	Conservation Tillage	0.004	0.220
615	Irrigation	Conventional Tillage	0.010	0.220
615	Irrigation	Conservation Tillage	0.007	0.220
616	No Irrigation	Conventional Tillage	0.004	0.217
616	No Irrigation	Conservation Tillage	0.003	0.217
616	Irrigation	Conventional Tillage	0.007	0.217
616	Irrigation	Conservation Tillage	0.005	0.217
617	No Irrigation	Conventional Tillage	0.007	0.216
617	No Irrigation	Conservation Tillage	0.005	0.216
617	Irrigation	Conventional Tillage	0.015	0.216
617	Irrigation	Conservation Tillage	0.011	0.216
618	No Irrigation	Conventional Tillage	0.006	0.186
618	No Irrigation	Conservation Tillage	0.004	0.186
618	Irrigation	Conventional Tillage	0.016	0.186
618	Irrigation	Conservation Tillage	0.012	0.186
619	No Irrigation	Conventional Tillage	0.007	0.226
619	No Irrigation	Conservation Tillage	0.005	0.226
619	Irrigation	Conventional Tillage	0.013	0.226
619	Irrigation	Conservation Tillage	0.009	0.226
622	No Irrigation	Conventional Tillage	0.007	0.233
622	No Irrigation	Conservation Tillage	0.005	0.233
622	Irrigation	Conventional Tillage	0.012	0.233
622	Irrigation	Conservation Tillage	0.009	0.233
623	No Irrigation	Conventional Tillage	0.010	0.236
623	No Irrigation	Conservation Tillage	0.007	0.236
623	Irrigation	Conventional Tillage	0.017	0.236
623	Irrigation	Conservation Tillage	0.013	0.236
625	No Irrigation	Conventional Tillage	0.007	0.239
625	No Irrigation	Conservation Tillage	0.005	0.239
625	Irrigation	Conventional Tillage	0.012	0.239
625	Irrigation	Conservation Tillage	0.009	0.239
626	No Irrigation	Conventional Tillage	0.008	0.239
626	No Irrigation	Conservation Tillage	0.006	0.239
626	Irrigation	Conventional Tillage	0.015	0.239
626	Irrigation	Conservation Tillage	0.011	0.239
629	No Irrigation	Conventional Tillage	0.009	0.217
629	No Irrigation	Conservation Tillage	0.006	0.217
629	Irrigation	Conventional Tillage	0.019	0.217
629	Irrigation	Conservation Tillage	0.014	0.217
630	No Irrigation	Conventional Tillage	0.007	0.208
630	No Irrigation	Conservation Tillage	0.005	0.208
630	Irrigation	Conventional Tillage	0.016	0.208

630	Irrigation	Conservation Tillage	0.012	0.208
631	No Irrigation	Conventional Tillage	0.006	0.166
631	No Irrigation	Conservation Tillage	0.004	0.166
631	Irrigation	Conventional Tillage	0.021	0.166
631	Irrigation	Conservation Tillage	0.015	0.166
650	No Irrigation	Conventional Tillage	0.005	0.177
650	No Irrigation	Conservation Tillage	0.004	0.177
650	Irrigation	Conventional Tillage	0.016	0.177
650	Irrigation	Conservation Tillage	0.012	0.177
678	No Irrigation	Conventional Tillage	0.006	0.211
678	No Irrigation	Conservation Tillage	0.004	0.211
678	Irrigation	Conventional Tillage	0.013	0.211
678	Irrigation	Conservation Tillage	0.009	0.211
679	No Irrigation	Conventional Tillage	0.005	0.178
679	No Irrigation	Conservation Tillage	0.004	0.178
679	Irrigation	Conventional Tillage	0.016	0.178
679	Irrigation	Conservation Tillage	0.012	0.178
680	No Irrigation	Conventional Tillage	0.004	0.175
680	No Irrigation	Conservation Tillage	0.003	0.175
680	Irrigation	Conventional Tillage	0.012	0.175
680	Irrigation	Conservation Tillage	0.009	0.175
681	No Irrigation	Conventional Tillage	0.007	0.204
681	No Irrigation	Conservation Tillage	0.005	0.204
681	Irrigation	Conventional Tillage	0.017	0.204
681	Irrigation	Conservation Tillage	0.013	0.204
683	No Irrigation	Conventional Tillage	0.003	0.198
683	No Irrigation	Conservation Tillage	0.002	0.198
683	Irrigation	Conventional Tillage	0.008	0.198
683	Irrigation	Conservation Tillage	0.006	0.198
684	No Irrigation	Conventional Tillage	0.009	0.207
684	No Irrigation	Conservation Tillage	0.006	0.207
684	Irrigation	Conventional Tillage	0.020	0.207
684	Irrigation	Conservation Tillage	0.015	0.207
686	No Irrigation	Conventional Tillage	0.004	0.163
686	No Irrigation	Conservation Tillage	0.003	0.163
686	Irrigation	Conventional Tillage	0.016	0.163
686	Irrigation	Conservation Tillage	0.012	0.163
687	No Irrigation	Conventional Tillage	0.004	0.159
687	No Irrigation	Conservation Tillage	0.003	0.159
687	Irrigation	Conventional Tillage	0.013	0.159
687	Irrigation	Conservation Tillage	0.010	0.159
688	No Irrigation	Conventional Tillage	0.005	0.161
688	No Irrigation	Conservation Tillage	0.004	0.161
688	Irrigation	Conventional Tillage	0.018	0.161
688	Irrigation	Conservation Tillage	0.013	0.161

692	No Irrigation	Conventional Tillage	0.009	0.204
692	No Irrigation	Conservation Tillage	0.006	0.204
692	Irrigation	Conventional Tillage	0.022	0.204
692	Irrigation	Conservation Tillage	0.016	0.204
703	No Irrigation	Conventional Tillage	0.007	0.206
703	No Irrigation	Conservation Tillage	0.005	0.206
703	Irrigation	Conventional Tillage	0.017	0.206
703	Irrigation	Conservation Tillage	0.012	0.206
708	No Irrigation	Conventional Tillage	0.006	0.199
708	No Irrigation	Conservation Tillage	0.005	0.199
708	Irrigation	Conventional Tillage	0.017	0.199
708	Irrigation	Conservation Tillage	0.012	0.199
727	No Irrigation	Conventional Tillage	0.008	0.197
727	No Irrigation	Conservation Tillage	0.006	0.197
727	Irrigation	Conventional Tillage	0.021	0.197
727	Irrigation	Conservation Tillage	0.015	0.197
728	No Irrigation	Conventional Tillage	0.005	0.168
728	No Irrigation	Conservation Tillage	0.003	0.168
728	Irrigation	Conventional Tillage	0.017	0.168
728	Irrigation	Conservation Tillage	0.012	0.168
729	No Irrigation	Conventional Tillage	0.004	0.148
729	No Irrigation	Conservation Tillage	0.003	0.148
729	Irrigation	Conventional Tillage	0.015	0.148
729	Irrigation	Conservation Tillage	0.011	0.148
730	No Irrigation	Conventional Tillage	0.005	0.157
730	No Irrigation	Conservation Tillage	0.004	0.157
730	Irrigation	Conventional Tillage	0.019	0.157
730	Irrigation	Conservation Tillage	0.014	0.157
731	No Irrigation	Conventional Tillage	0.005	0.185
731	No Irrigation	Conservation Tillage	0.004	0.185
731	Irrigation	Conventional Tillage	0.015	0.185
731	Irrigation	Conservation Tillage	0.011	0.185
732	No Irrigation	Conventional Tillage	0.006	0.193
732	No Irrigation	Conservation Tillage	0.004	0.193
732	Irrigation	Conventional Tillage	0.016	0.193
732	Irrigation	Conservation Tillage	0.011	0.193
737	No Irrigation	Conventional Tillage	0.006	0.186
737	No Irrigation	Conservation Tillage	0.005	0.186
737	Irrigation	Conventional Tillage	0.019	0.186
737	Irrigation	Conservation Tillage	0.014	0.186
738	No Irrigation	Conventional Tillage	0.005	0.158
738	No Irrigation	Conservation Tillage	0.004	0.158
738	Irrigation	Conventional Tillage	0.022	0.158
738	Irrigation	Conservation Tillage	0.016	0.158
739	No Irrigation	Conventional Tillage	0.003	0.141

739	No Irrigation	Conservation Tillage	0.002	0.141
739	Irrigation	Conventional Tillage	0.012	0.141
739	Irrigation	Conservation Tillage	0.009	0.141
740	No Irrigation	Conventional Tillage	0.006	0.182
740	No Irrigation	Conservation Tillage	0.004	0.182
740	Irrigation	Conventional Tillage	0.018	0.182
740	Irrigation	Conservation Tillage	0.013	0.182
743	No Irrigation	Conventional Tillage	0.005	0.141
743	No Irrigation	Conservation Tillage	0.003	0.141
743	Irrigation	Conventional Tillage	0.023	0.141
743	Irrigation	Conservation Tillage	0.017	0.141
744	No Irrigation	Conventional Tillage	0.006	0.173
744	No Irrigation	Conservation Tillage	0.005	0.173
744	Irrigation	Conventional Tillage	0.022	0.173
744	Irrigation	Conservation Tillage	0.016	0.173
746	No Irrigation	Conventional Tillage	0.006	0.186
746	No Irrigation	Conservation Tillage	0.004	0.186
746	Irrigation	Conventional Tillage	0.018	0.186
746	Irrigation	Conservation Tillage	0.013	0.186
750	No Irrigation	Conventional Tillage	0.007	0.155
750	No Irrigation	Conservation Tillage	0.005	0.155
750	Irrigation	Conventional Tillage	0.031	0.155
750	Irrigation	Conservation Tillage	0.023	0.155
769	No Irrigation	Conventional Tillage	0.005	0.143
769	No Irrigation	Conservation Tillage	0.004	0.143
769	Irrigation	Conventional Tillage	0.025	0.143
769	Irrigation	Conservation Tillage	0.018	0.143
771	No Irrigation	Conventional Tillage	0.005	0.123
771	No Irrigation	Conservation Tillage	0.004	0.123
771	Irrigation	Conventional Tillage	0.034	0.123
771	Irrigation	Conservation Tillage	0.024	0.123
777	No Irrigation	Conventional Tillage	0.003	0.143
777	No Irrigation	Conservation Tillage	0.002	0.143
777	Irrigation	Conventional Tillage	0.015	0.143
777	Irrigation	Conservation Tillage	0.011	0.143
779	No Irrigation	Conventional Tillage	0.006	0.142
779	No Irrigation	Conservation Tillage	0.004	0.142
779	Irrigation	Conventional Tillage	0.030	0.142
779	Irrigation	Conservation Tillage	0.022	0.142
781	No Irrigation	Conventional Tillage	0.011	0.137
781	No Irrigation	Conservation Tillage	0.008	0.137
781	Irrigation	Conventional Tillage	0.059	0.137
781	Irrigation	Conservation Tillage	0.043	0.137
786	No Irrigation	Conventional Tillage	0.005	0.132
786	No Irrigation	Conservation Tillage	0.004	0.132

786	Irrigation	Conventional Tillage	0.032	0.132
786	Irrigation	Conservation Tillage	0.023	0.132
787	No Irrigation	Conventional Tillage	0.006	0.108
787	No Irrigation	Conservation Tillage	0.004	0.108
787	Irrigation	Conventional Tillage	0.050	0.108
787	Irrigation	Conservation Tillage	0.037	0.108
788	No Irrigation	Conventional Tillage	0.006	0.112
788	No Irrigation	Conservation Tillage	0.005	0.112
788	Irrigation	Conventional Tillage	0.049	0.112
788	Irrigation	Conservation Tillage	0.036	0.112
790	No Irrigation	Conventional Tillage	0.004	0.111
790	No Irrigation	Conservation Tillage	0.003	0.111
790	Irrigation	Conventional Tillage	0.029	0.111
790	Irrigation	Conservation Tillage	0.021	0.111
791	No Irrigation	Conventional Tillage	0.005	0.124
791	No Irrigation	Conservation Tillage	0.004	0.124
791	Irrigation	Conventional Tillage	0.034	0.124
791	Irrigation	Conservation Tillage	0.025	0.124
793	No Irrigation	Conventional Tillage	0.005	0.113
793	No Irrigation	Conservation Tillage	0.004	0.113
793	Irrigation	Conventional Tillage	0.041	0.113
793	Irrigation	Conservation Tillage	0.030	0.113
797	No Irrigation	Conventional Tillage	0.006	0.117
797	No Irrigation	Conservation Tillage	0.004	0.117
797	Irrigation	Conventional Tillage	0.045	0.117
797	Irrigation	Conservation Tillage	0.033	0.117
798	No Irrigation	Conventional Tillage	0.006	0.145
798	No Irrigation	Conservation Tillage	0.004	0.145
798	Irrigation	Conventional Tillage	0.027	0.145
798	Irrigation	Conservation Tillage	0.020	0.145
799	No Irrigation	Conventional Tillage	0.005	0.132
799	No Irrigation	Conservation Tillage	0.004	0.132
799	Irrigation	Conventional Tillage	0.030	0.132
799	Irrigation	Conservation Tillage	0.022	0.132
800	No Irrigation	Conventional Tillage	0.010	0.139
800	No Irrigation	Conservation Tillage	0.007	0.139
800	Irrigation	Conventional Tillage	0.056	0.139
800	Irrigation	Conservation Tillage	0.041	0.139
801	No Irrigation	Conventional Tillage	0.007	0.173
801	No Irrigation	Conservation Tillage	0.005	0.173
801	Irrigation	Conventional Tillage	0.025	0.173
801	Irrigation	Conservation Tillage	0.018	0.173
802	No Irrigation	Conventional Tillage	0.006	0.131
802	No Irrigation	Conservation Tillage	0.004	0.131
802	Irrigation	Conventional Tillage	0.036	0.131

802	Irrigation	Conservation Tillage	0.026	0.131
804	No Irrigation	Conventional Tillage	0.004	0.108
804	No Irrigation	Conservation Tillage	0.003	0.108
804	Irrigation	Conventional Tillage	0.030	0.108
804	Irrigation	Conservation Tillage	0.022	0.108
805	No Irrigation	Conventional Tillage	0.005	0.089
805	No Irrigation	Conservation Tillage	0.004	0.089
805	Irrigation	Conventional Tillage	0.058	0.089
805	Irrigation	Conservation Tillage	0.042	0.089
806	No Irrigation	Conventional Tillage	0.005	0.087
806	No Irrigation	Conservation Tillage	0.003	0.087
806	Irrigation	Conventional Tillage	0.054	0.087
806	Irrigation	Conservation Tillage	0.039	0.087
809	No Irrigation	Conventional Tillage	0.006	0.088
809	No Irrigation	Conservation Tillage	0.004	0.088
809	Irrigation	Conventional Tillage	0.059	0.088
809	Irrigation	Conservation Tillage	0.043	0.088
811	No Irrigation	Conventional Tillage	0.009	0.094
811	No Irrigation	Conservation Tillage	0.007	0.094
811	Irrigation	Conventional Tillage	0.091	0.094
811	Irrigation	Conservation Tillage	0.066	0.094
812	No Irrigation	Conventional Tillage	0.006	0.096
812	No Irrigation	Conservation Tillage	0.004	0.096
812	Irrigation	Conventional Tillage	0.060	0.096
812	Irrigation	Conservation Tillage	0.044	0.096
814	No Irrigation	Conventional Tillage	0.006	0.087
814	No Irrigation	Conservation Tillage	0.004	0.087
814	Irrigation	Conventional Tillage	0.065	0.087
814	Irrigation	Conservation Tillage	0.048	0.087
815	No Irrigation	Conventional Tillage	0.003	0.087
815	No Irrigation	Conservation Tillage	0.002	0.087
815	Irrigation	Conventional Tillage	0.036	0.087
815	Irrigation	Conservation Tillage	0.026	0.087
818	No Irrigation	Conventional Tillage	0.005	0.100
818	No Irrigation	Conservation Tillage	0.004	0.100
818	Irrigation	Conventional Tillage	0.048	0.100
818	Irrigation	Conservation Tillage	0.035	0.100
821	No Irrigation	Conventional Tillage	0.004	0.086
821	No Irrigation	Conservation Tillage	0.003	0.086
821	Irrigation	Conventional Tillage	0.045	0.086
821	Irrigation	Conservation Tillage	0.033	0.086
823	No Irrigation	Conventional Tillage	0.004	0.088
823	No Irrigation	Conservation Tillage	0.003	0.088
823	Irrigation	Conventional Tillage	0.052	0.088
823	Irrigation	Conservation Tillage	0.038	0.088

828	No Irrigation	Conventional Tillage	0.004	0.093
828	No Irrigation	Conservation Tillage	0.003	0.093
828	Irrigation	Conventional Tillage	0.048	0.093
828	Irrigation	Conservation Tillage	0.035	0.093
829	No Irrigation	Conventional Tillage	0.003	0.094
829	No Irrigation	Conservation Tillage	0.002	0.094
829	Irrigation	Conventional Tillage	0.033	0.094
829	Irrigation	Conservation Tillage	0.024	0.094
833	No Irrigation	Conventional Tillage	0.005	0.088
833	No Irrigation	Conservation Tillage	0.004	0.088
833	Irrigation	Conventional Tillage	0.062	0.088
833	Irrigation	Conservation Tillage	0.046	0.088
836	No Irrigation	Conventional Tillage	0.004	0.089
836	No Irrigation	Conservation Tillage	0.003	0.089
836	Irrigation	Conventional Tillage	0.045	0.089
836	Irrigation	Conservation Tillage	0.033	0.089
837	No Irrigation	Conventional Tillage	0.004	0.093
837	No Irrigation	Conservation Tillage	0.003	0.093
837	Irrigation	Conventional Tillage	0.042	0.093
837	Irrigation	Conservation Tillage	0.031	0.093
838	No Irrigation	Conventional Tillage	0.003	0.095
838	No Irrigation	Conservation Tillage	0.002	0.095
838	Irrigation	Conventional Tillage	0.033	0.095
838	Irrigation	Conservation Tillage	0.024	0.095
1016	No Irrigation	Conventional Tillage	0.004	0.174
1016	No Irrigation	Conservation Tillage	0.003	0.174
1016	Irrigation	Conventional Tillage	0.013	0.174
1016	Irrigation	Conservation Tillage	0.009	0.174
1018	No Irrigation	Conventional Tillage	0.005	0.160
1018	No Irrigation	Conservation Tillage	0.004	0.160
1018	Irrigation	Conventional Tillage	0.021	0.160
1018	Irrigation	Conservation Tillage	0.016	0.160
9593	No Irrigation	Conventional Tillage	0.010	0.192
9593	No Irrigation	Conservation Tillage	0.008	0.192
9593	Irrigation	Conventional Tillage	0.025	0.192
9593	Irrigation	Conservation Tillage	0.018	0.192
9607	No Irrigation	Conventional Tillage	0.010	0.165
9607	No Irrigation	Conservation Tillage	0.008	0.165
9607	Irrigation	Conventional Tillage	0.032	0.165
9607	Irrigation	Conservation Tillage	0.024	0.165
9609	No Irrigation	Conventional Tillage	0.009	0.220
9609	No Irrigation	Conservation Tillage	0.006	0.220
9609	Irrigation	Conventional Tillage	0.017	0.220
9609	Irrigation	Conservation Tillage	0.013	0.220
9687	No Irrigation	Conventional Tillage	0.004	0.170

9687	No Irrigation	Conservation Tillage	0.003	0.170
9687	Irrigation	Conventional Tillage	0.015	0.170
9687	Irrigation	Conservation Tillage	0.011	0.170
9787	No Irrigation	Conventional Tillage	0.006	0.112
9787	No Irrigation	Conservation Tillage	0.004	0.112
9787	Irrigation	Conventional Tillage	0.048	0.112
9787	Irrigation	Conservation Tillage	0.035	0.112

APPENDIX B: Crop Residue Nitrogen Factors

Table B-1: Crop Residue Factors from Holos Methodology (based on IPCC methods and modified for Canadian conditions and protocol)

Crop	Moisture Content (w/w)	Nitrogen Content of Above-Ground Residues (kg N / kg)	Nitrogen Content of Below-Ground Residues (kg N / kg)	Relative Dry Matter Allocation: Fraction of Total Dry Matter Production that is Harvested (unitless)	Relative Dry Matter Allocation: Ratio of Above-Ground Residue Dry Matter to Harvested Production (unitless)	Relative Dry Matter Allocation: Ratio of Below-Ground Residue Dry Matter to Harvested Production (unitless)
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
Lentils	0.13	0.010	0.01	0.28	0.52	0.20
Mixed Grains	0.12	0.006	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
Sugar Beets	0.80	0.029	0.01	0.76	0.19	0.05
Timothy Hay	0.13	0.015	0.015	0.40	0.10	0.50
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 HH, Beauchemin KA, Bruinsma Y, Campbell CA, Desjardins RL, Ellert BH, and Smith EG, 2003, The fate of nitrogen in agroecosystems: An illustration using Canadian estimates, Nutrient Cycling in Agroecosystems 67:85–102

* If the seed crop is treated like an annual crop and meets the 4R eligibility criteria for the performance level chosen, then a new annual crop is seeded the next year under 4R Plan requirements, it would qualify under the protocol.

APPENDIX C: Impact of the Project Activity on Downstream Crop-Related Emissions

A study was commissioned by Saskatchewan Environment to assess the impact on crop transportation and handling GHG emissions due to possible increases in grain/oilseed production as a result of implementation of the Protocol. Cecil Nagy at the Department of Bioresource Policy, Business and Economics at the University of Saskatchewan conducted the analysis.

Methods

To conduct the analysis, crop district data from Statistics Canada and Saskatchewan Agriculture and Food (crop production (tonnes) for 14 crops produced in Saskatchewan and area seeded (ha) for those crops) were used for the base production levels. Mr. Nagy was asked to assess the impact on downstream handling/transportation emissions from changes in production (tonnes) by soil zone for yield increases from 5 per cent to 30 per cent using the five-year average yield and seeded area as the base data for each crop district. Mr. Nagy assessed emission sources from truck, rail and lake transportation along with grain handling for each of the areas, in relation to major terminals for grain/oilseed collection.

The estimate of the change in downstream GHG emissions is the sum of the tonne-kilometres by mode of transportation times the GHG emission coefficient for the mode of transportation plus GHG from handling facilities for the amount of crop shipped to a domestic or export destination. The change in production by crop, times the share of production going to the domestic or export market, times the share to each market destination, given the mode(s) of transportation involved, times the total kilometres by mode, times the GHG coefficient, results in the transportation emissions.

The GHG from grain handling is estimated as the amount of grain handled for export or domestic markets times the number of times the grain is handled. For grain shipped by train it is times four and for truck transport it is times two. The coefficients used to estimate GHG emissions are presented in Table G-1 below. The grain handling coefficient is estimated as the amount of electricity needed to move the grain to storage, turn the grain once and load the grain onto trucks or rail cars. Estimates of the amount of electricity needed are 1.27 KWh per tonne using electric motors typically used in a grain terminal (Kenkel, 2008). The emission coefficient for electricity generation in Saskatchewan (2008 estimate) from Environment Canada is 710 g CO_2e per KWh which gives an estimate of 0.90 kg CO_2e per tonne of grain.

Table C-1: GHG Coefficients for Transport and Handling

Mode	Coefficient	Units
Train[1]	16.98	kg CO_2e / 1000 tonne-Km
Truck[2]	88.6	kg CO_2e /1000 tonne-Km
Lake[1]	10	kg CO_2e /1000 tonne-Km
Elevator[3]	0.90	kg CO_2e / tonne

The Environmental Footprint of Surface Freight Transportation, Lawson Economics Research Inc., 2007
Estimate from the Draft Intermodal Protocol.
Dr. Nagy's estimate from Environment Canada electricity coefficient and electricity use estimate.

Results and Conclusions

The analysis and subsequent review by the technical working group for the protocol, determined that even with a 30% increase in yield, the impact on the project reductions would be less than material. Table C-2 shows the emissions on a per hectare basis of varying increases in yield.

Table C-2: GHG Emissions from Adoption of the Protocol (CO_2e tonnes per hectare) Five-Year Production Averages*

	5%	10%	15%	20%	25%	30%
Brown	0.0040	0.0080	0.0120	0.0160	0.0201	0.0241
Dark Brown	0.0040	0.0080	0.0120	0.0160	0.0201	0.0244
Thin Black	0.0037	0.0074	0.0112	0.0149	0.0186	0.0225
Thick Black	0.0040	0.0080	0.0120	0.0160	0.0200	0.0241
Gray	0.0045	0.0091	0.0136	0.0182	0.0227	0.0274

*Estimated as the seeded hectares to crops for which the protocol would be adopted.

Based on these results, the technical working group deemed the impact immaterial and the exclusion of the crop transportation/handling emissions from the quantification to be justified. The approach used in analyzing the downstream emission impacts was conservative due to the following two factors:

(1) It is highly unlikely that growers would see a 30% increase in yields as a result of implementing the 4R Nutrient Plan; modest yield increases are more likely (5 to 7% increases) due to more efficient use of nitrogen; and,

(2) The analysis assumes that the yield increases of, for example 30%, would have to occur consistently for all crops in the district, and further, the adoption of the Protocol on 100% of all the seeded acres in the soil zones within the district.

Based on the analysis, the technical working group felt confident that the downstream emissions sources could be excluded.

References

Canadian Grain Commission. 2012. Canadian Grain Exports and Exports of Canadian Grain & Wheat Flour, Canadian Grain Commission.

Kenkel, P. 2008. Grain Handling and Storage Costs in Country Elevators. Department of Agricultural Economics, Oklahoma State University. P 11.

Statistics Canada. 2012. Table 404-0021 Rail transportation, origin and destination of commodities, annual.

APPENDIX D: Dynamic Baseline Quantification Approaches

One of the two approaches given below may be used to quantify the estimated emission reductions achieved by the project without the need for consideration of historical parameters. Both of these approaches use a dynamic baseline approaches quantify the emissions that likely would have occurred in the project year, had the 4R Plan not been implemented. Under both approaches, the dynamic baseline is recalculated each year using the estimated project emissions and the conservative reduction modifier as inputs.

Using a dynamic baseline allows project developers who do not have sufficient data or data of appropriate quality for the three-year conventional baseline for farms to participate on a go forward basis. To account for increased uncertainty associated with decreased availability of on-farm baseline data, dynamic baseline approaches have a discount factor applied to calculated project emissions. In order to be eligible for use of a dynamic baseline, projects must also provide proof that nitrogen application rates have not exceeded recommendations for each crop. To provide this assurance, Accredited Professional Advisors will use a variety of information sources such as soil testing reports, field history, current crop, soil amendments from the previous year, and historic knowledge of regional soils and cropping systems to ensure reasonable and conservative nitrogen fertilizer rate recommendations. These requirements are currently built into the body of the protocol and associated records requirements. Once a baseline approach is chosen, project developers cannot switch between the conventional and dynamic baseline approaches. In Dynamic Baseline One, crop mass for the current project year is determined by the acceptable yield methods outlined in Table 12: Crop Mass Determination Methods Records Requirements of the protocol. Dynamic Baseline One has a five per cent discount factor applied to it. In Dynamic Baseline Two default crop mass data is derived from the five-year rolling averages published by Agriculture Financial Services Corporation. Dynamic Baseline Two has a 10 per cent discount factor applied to it.

In the case of catastrophic crop failure (owing to drought, frost, hail, weed infestation, etc.), the total mass of crop produced may be decreased to the extent that project emissions per mass of crop exceed baseline emissions. In this event, the fields/crops would be excluded from credit production under this protocol for that year.

If the Dynamic Baseline One approach has been employed, project developers cannot switch back to the Dynamic Baseline Two. Users of Dynamic Baseline Two must switch to use of Dynamic Baseline One within two years (see section 1.3 Protocol Applicability). Both dynamic baseline approaches are conservative in the sense that they result in fewer credits being generated, on average, than when a conventional baseline is used. Dynamic Baseline Two is the most conservative approach with the application of a 10% discount factor.

The basis for applying a dynamic baseline approach in this protocol is justified by other accepted protocols in the Alberta offset system where measurement or estimation of variables in the project condition (for example, wind projects where electricity produced, or conservation cropping where volume of carbon dioxide sequestered or land fill gas projects where volume of landfill gas collected) are used for estimating emissions that would have occurred in the baseline condition.

A dynamic baseline is favoured over a conventional, historic baseline approach in many protocols because the business-as-usual externalities that cannot be otherwise controlled are removed from consideration. The most significant externalities in this Protocol are related to growing conditions and weather related events. Changes in growing conditions from year to year are not relevant under a dynamic baseline approach because both the baseline and the project emissions are calculated from measurements and estimates from the same year.

Dynamic Baseline One - Quantification Approach

Calculating the baseline emissions for each crop type (tCO_2e) using the present years data. Steps are outlined in 4.1.1 Quantification Approach of the Protocol. Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and each performance level on the farm. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are then summed across the analytical units to derive the GHG claim for the farm. Note that emissions associated with manure application are considered to be consistent in the baseline and project condition, so no emission reductions are applied to manure nitrogen application in the dynamic baseline.

Emission Reduction	**=**	**$[\sum_{EcoDistrict\ j} \sum_{4R\ management\ level\ k} (Emissions\ Reduction_{crop\ i})] - Emissions_{Fert\ and\ Lime\ Dist}$**
$Emissions\ Reduction_{crop\ i}$	=	$DF * [\sum_{crop\ i} [Emissions_{Other\ Fert\ and\ Lime\ Use,\ i} + Emissions_{Other\ Soil\ Crop\ Dyn,\ i}] * (1-RM_{PL})] * GWP_{N2O}$
Discount Factor (DF)	=	0.95 (5% discount factor) for Dynamic Baseline One
Other factors	=	See Section 4.1.1

Dynamic Baseline Two - (Default Crop Mass) Quantification Approach

With application of a 10 per cent discount factor, the Dynamic Baseline Two quantification approach is more conservative in terms of the number of credits generated in comparison to both the conventional baseline and the Dynamic Baseline One approach. The difference between this approach and the Dynamic Baseline One is that five-year average yields published by the Agriculture Financial Services Corporation (AFSC) of Alberta are used as a proxy for crop mass values from the farm. Crop yields from this source are organized by crop type and AFSC risk area.[23] The appropriate regional risk area shapefile can be obtained from Alberta Agriculture and Rural Development. Dynamic Baseline Two can be used for a maximum of two years. After the two year maximum, project developers using Dynamic Baseline Two must switch to Dynamic Baseline One.

The quantification approach for Dynamic Baseline Two is as follows:

(1) Obtain the appropriate shapefile for AFSC risk zones from ARD and develop rule set for allocating EcoDistricts to risk zones.

(2) Multiply the five-year average yield for the EcoDistrict by risk zone by the area cropped to determine the crop mass.

For example, using a five-year average yield of 1600 kg/ha, for canola grown on 500 ha of land the calculation would be as follows:

Crop Mass$_{crop}$	**=**	**Five-year average Yield $_{crop\ i}$ * Cropped Area**
	=	1600 kg/ha * 500 ha
	=	800,000 kg of canola

Calculate the baseline emissions for each crop type (tCO_2e), using the present years nitrogen input data and the crop mass value calculated above. Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and at each performance level on farms. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are then summed across the analytical units to derive the GHG claim for the farm.

Emission Reduction	**[$\sum_{EcoDistrict\ j} \sum_{4R\ management\ level\ k}$ (Emissions Reduction$_{crop\ i}$)] - Emissions $_{Fert\ and\ Lime\ Dist}$**
Emissions Reduction$_{crop\ i}$	[DF * $\sum_{crop\ i}$ [Emissions$_{Other\ Fert\ and\ Lime\ Use,\ i}$ + Emissions$_{Other\ Soil\ Crop\ Dyn,\ i}$ * (1-RM$_{PL}$)]] *GWP$_{N2O}$
Discount Factor (DF)	0.90 (10% discount factor) for Dynamic Baseline Two
Other factors	See Section 4.1.1

[23] Five-year rolling averages for yield by risk management zone are published annually by Agriculture Financial Services Corporation.

APPENDIX E: The 4R Practices

Canada's fertilizer industry has a vested interest in managing products to protect the environment and has developed an approach to nutrient management which provides farmers with a variety of science-based beneficial management practices (BMPs) to ensure the right source of fertilizer is applied at the right rate, right time and right place.

Examples of Beneficial Management Practices to mitigate these risks include the following:

Table E-1: The 4R Practices

Practice	Examples
Right Source: Using the right product to meet crop needs	• Ammonium-based formulations • Slow/controlled release fertilizers • Inhibitors • Stabilized nitrogen
Right Rate: Matching the right amount of fertilizer to crop needs	• Soil Testing • Yield Goal Analysis • Crop Removal Balance • Nutrient Management Planning • Plant Tissue Analysis • Applicator Calibration • Crop Scouting • Record Keeping • Variable Rate Application Technology
Right Time: Making nutrients available when crops need them	• Application Timing • Controlled Release Technologies • Inhibitors • Fertilizer Product Choice
Right Place: Keep nutrients where crops can use them	• Application Method • Incorporation of Fertilizer • Buffer Strips • Conservation Tillage • Cover Cropping • On-Farm Fertilizer Storage

APPENDIX F: Additional Fuel Pass Method

The Accredited Professional Advisor (APA) will assess and document nitrogen fertilizer application practices prior to project implementation as part of developing the initial 4R Plan. As part of this assessment, the APA will establish and document the number of field passes typically used by the grower for nitrogen fertilizer application prior to project implementation.

Each year of the project, the APA will assess the nitrogen application practices relative to the baseline. Any increased GHG emissions from additional nitrogen application passes relative to the baseline will be calculated and subtracted from the GHG Statement for the farm. Two methods for accounting for additional passes are available as outlined below.

Method A: Documented Fuel Use Method

This method can be used when there is sufficient documented evidence of the farm fuel used in the additional passes to apply nitrogen fertilizer to accurately calculate the additional GHGs released by the operation. Documentation may include fuel use logs and/or equipment use logs that can be clearly traced to the additional operations. Documented evidence of additional fuel usage must apply specifically to field use (excluding road use and personal vehicles). The method is as follows:

- Document which fields received additional passes.
- Document the fuel type, volume of fuel used in the additional passes, and the method used to calculate fuel use.
- Multiply the total volume of fuel used by the emission factors provided in Table 12 of the protocol.
- Subtract the GHG value in kgCO2e from the GHG Statement for the farm, as described in Section 4.1.1 of the Protocol.

Method B: Additional Pass Method

This method is based on the number of additional passes used rather than direct estimate of fuel consumption. To be conservative, the default value of 5.23 litres per hectare (band fertilizer with coulters), which is four to six times higher fuel use than the other methods, will be used in all cases under Method B, regardless of the type of equipment used (see Table K-1). Under this methodology it is assumed that diesel fuel is used. An additional 10 per cent fuel usage is added to ensure conservativeness of the estimate resulting from this scenario.

Vol. Fuel	**=**	**1.10* Fuel Use_{diesel} * $\sum_{\text{Mgmt unit } l}$ [$\text{Pass}_{area\ l}$ * $\text{Pass}_{quantity\ l}$]**
Vol. Fuel	=	Volume of diesel fuel used during extra field passes
1.10	=	10 per cent increase in total fuel usage for conservativeness
Fuel Use_{diesel}	=	Fuel usage factor (diesel) for each extra pass. Value set at 5.23 litres of diesel per hectare
Mgmt unit l	=	Index number for management units which received extra field passes as a result of 4R Plan implementation
Pass_{area}	=	Area that received extra field passes
$\text{Pass}_{quantity}$	=	Number of extra passes on each field

- Document which fields received additional passes.
- Document the area of each field that received additional passes.
- Multiply the area of each field by the number of additional passes.
- Sum the additional pass hectares from all fields to get the total pass-hectares for the farm.
- Multiply the total pass hectares for the farm by the default fuel use factor of 5.23 litres of fuel per hectare. Multiply this value by the total number of hectares which received extra passes on the farm. This will result in a calculation of extra L of fuel used in the project condition. Add an extra 10 per cent fuel usage (multiply by 1.10).
- Multiply the total volume of fuel used by the emission factors provided in Table 8 of the protocol.
- Subtract the GHG value in kgCO2e from the GHG Statement for the farm, as described in Section 4.1.1.

Example Calculations

Prior to project implementation, a grower with 1000 hectares of cereals and oilseeds applies all fertilizer nitrogen at time of seeding. As part of his improved practices under his 4R Plan, he switches from a one to a two pass system by applying 75% of his recommended nitrogen rate on his wheat fields at time of seeding and in crop banding the remaining 25% post emergent. In Year 1 of the project he follows this practice on 400 hectares of wheat with the remainder of his cropped area in a one-pass system.

Method A

Total fuel consumption for the second pass was calculated from fuel logs at 750 litres. 750 litres of fuel will therefore be used for calculation of $\text{Emissions}_{\text{Fert and Lime Dist}}$ with the quantification methodology provided in Table 8.****

Method B

Calculating additional hectare-passes

400 ha X 1 = 400 ha-pass

Calculating the fuel usage from the additional pass

400 ha-pass x 5.23 L fuel per hectare = 2092 L of extra fuel used

2092 L of extra fuel x 1.10 = 2301.20 L of extra fuel (diesel)

2301.20 L of diesel fuel will therefore be used for calculation of $Emissions_{Fert\ and\ Lime\ Dist}$ emissions with the quantification methodology provided in Table 8.

Justification and Recommendation for the Additional GHG Pass Coefficient

Mr. Lawrence Papworth, at the Alberta Agriculture and Rural Development AgTech Centre, developed a chart on possible post emergent fertilizer application methods. Lawrence indicated a coulter would have to be used to band granular, liquid or anhydrous NH_3 and the main power use is the draft of the coulter, which means that fuel use would be the same for all of them. Knife openers could be used to band fertilizer in row crops but it isn't common. Lawrence added the high clearance sprayer option because they are quite common on farms. Producers can use sprayers that apply micronutrients on post emergent specialty crops. The values in the chart are based on operating power units efficiently.

Table F-1: Fuel Usage Calculations for a Variety of Additional Pass Methods

Type of Operation	Fuel Use (gallons/acre)	Fuel Use (litres/acre)	Fuel Use (litres/hectare)
Spreading granular fertilizer	0.16	0.60	1.48
Dribble liquid fertilizer	0.16	0.61	1.50
Band fertilizer with coulters	0.56	2.11	5.23
Broadcast or dribble liquid fertilizer (high clearance sprayer)	0.11	0.42	1.03

References

Iowa State University. 2005. Ag Decision Maker: Fuel Required for Field Operations. File A3-27.

Government of Saskatchewan. 2015. 2014-15 Farm Machinery Custom and Rental Rate Guide.

National Sustainable Agriculture Information Service. 2007. Conserving Fuel on the Farm.

Virginia State University. 2014. Predicting Tractor Diesel Fuel Consumption. Publication 442-073.e