QUANTIFICATION PROTOCOL FOR MECHANICAL PULP SLUDGE UTILIZATION PROJECTS RELATED TO AGRICULTURAL APPLICATION

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1.0 Project and Methodology Scope and Description

The opportunities for generating carbon offsets with this protocol arise mainly from the direct and indirect reduction of atmospheric greenhouse gases (GHG) through the application of mechanical pulp mill sludge on agricultural land as opposed to the previous practices of incineration or landfilling the waste material.

1.1 Protocol Scope and Description

The carbon offsets from this protocol will be based on the quantification of increased carbon stocks and decreased GHGs resulting from the application of pulp sludge to agricultural land as opposed to its incineration or placement in a landfill. Sludge application significantly increases crop yields and residues on agricultural land thus increasing the carbon reservoir (both above ground and below ground). The carbon reservoirs store and accumulate carbon rather than releasing greenhouse gases to the atmosphere. The sludge is traditionally a discarded by-product of the pulp mill and at baseline is incinerated or put in landfills which are practices that produce GHGs.

This protocol can theoretically be applied to all mechanical pulp mills spreading sludge on all agricultural land and crop types across the province, however more research may need to be done on sludge application to crop types other than forage and grain crops. This protocol can be used as a generic template for proponents to follow to meet the measurement, monitoring, and GHG quantification requirements. Due to the complexity and variability of farming and cropping systems, the comparison approach has been adopted for this protocol. The comparison approach uses actual measurements of parameters from a control group to compare with the project. Emissions or removals from the control group are monitored throughout the project and compared with the emissions from the project site. Project developers will need to establish a baseline condition by maintaining a control group representing business as usual practices. An assurance factor, based on existing data from previous research, will be included in the quantification. **FIGURE 1.1** and **FIGURE 1.2** describe typical project and baseline conditions as a flow diagram, respectively.

Some emissions are expected over the course of the project due to sludge transportation and application, however these emissions are negligible compared to the amount of GHGs reduced through the project. Since sludge application eliminates the need for fertilizer application, the related energy inputs and GHG emissions would be avoided.

Protocol Approach:

This protocol can be used as a general template for project proponents to follow. The amount of sludge applied by each mill will equal a set “reduction coefficient” equal to the difference from the baseline of GHGs reduced through its use. Baseline emissions for each project area will be determined through the use of control groups following identical farming and cropping practices. This protocol is focused on increased carbon biomass and soil carbon storage resulting from sludge land application; other protocols will cover other aspects of carbon offsets for the mill, and could be used in conjunction with this protocol.

Figure 1.1. Process Flow Diagram for Project Condition – Agricultural Sludge Utilization

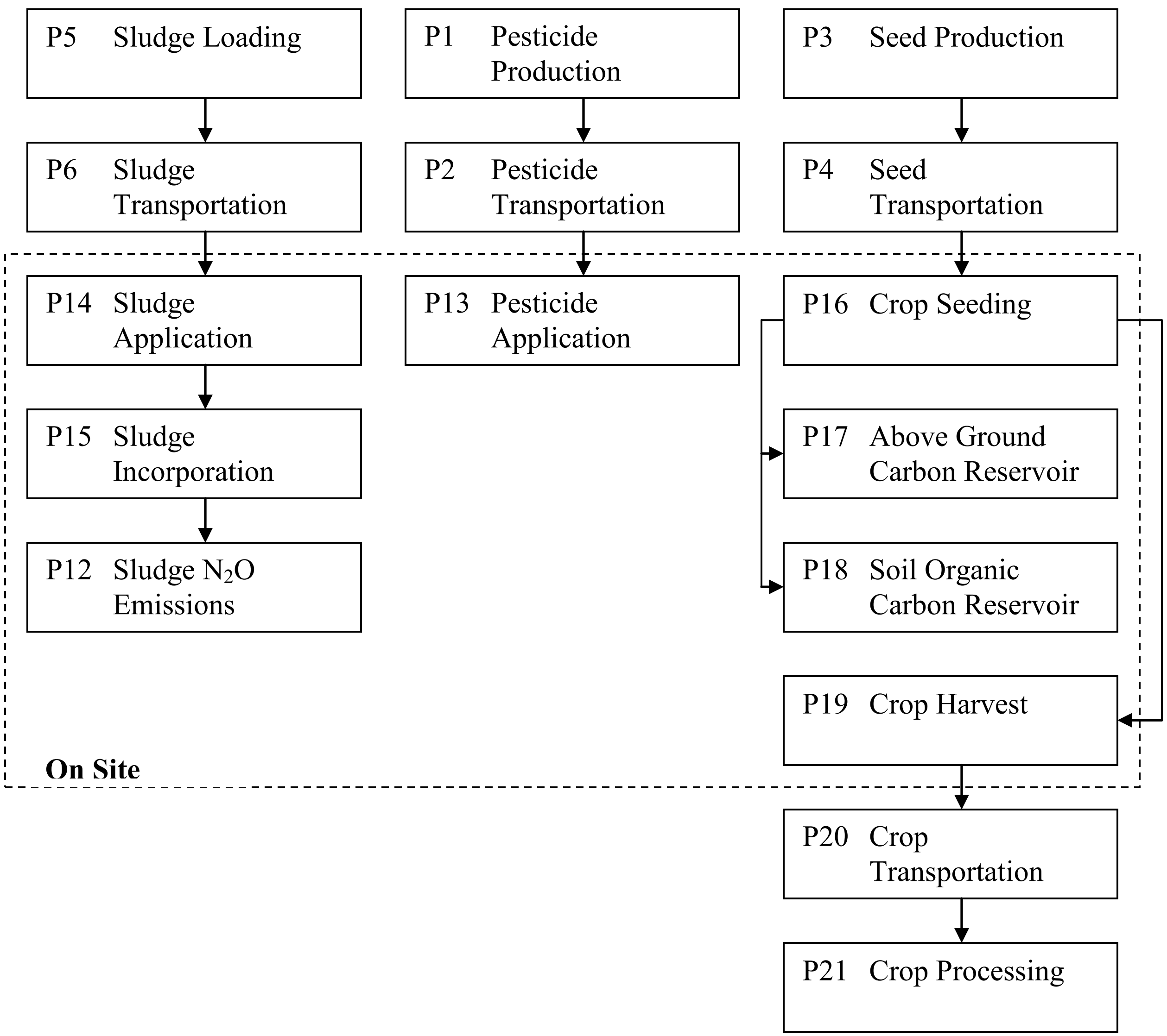
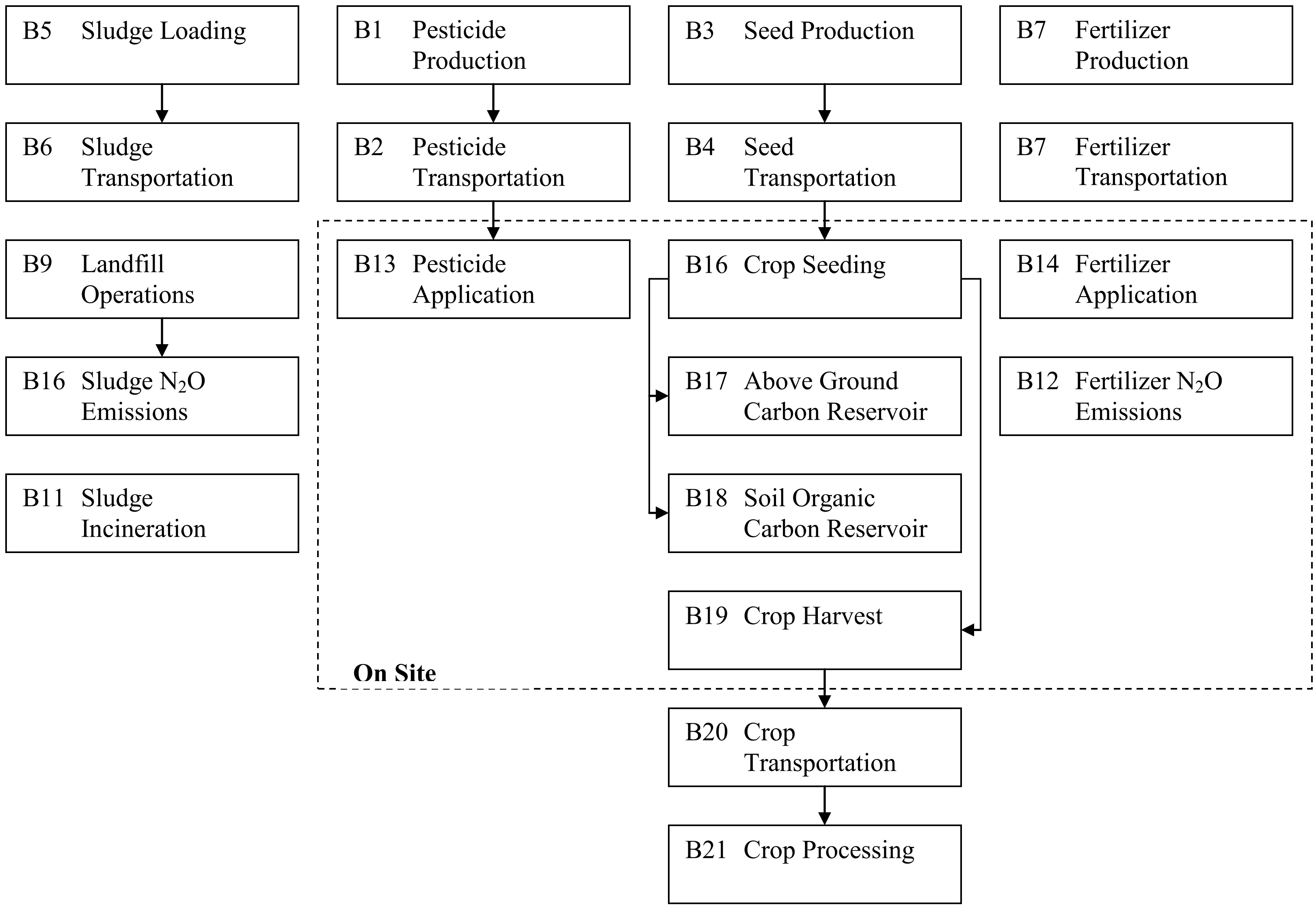


Figure 1.2. Process Flow Diagram for Baseline Conditions – Agricultural Sludge Utilization.



Protocol Applicability: This protocol is applicable to all mechanical pulp mills in Alberta that are producing sludge and applying it according the established guidelines.

In order for a project to gain carbon offsets under this protocol, the project proponent must demonstrate that it meets the protocol requirements and produce sufficient evidence to indicate that:

1. The sludge was stored and spread in the approved method described in the Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999) as confirmed by affirmation from the project developer and farm records.

2. The project must meet sludge land application guidelines established under the Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999).

3. The quantification of reductions achieved by the project is based on actual comparison measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol using approved control groups representing business as usual farming and cropping practices.

4. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System (Specified Gas Emitters Regulation – Offset Credit Project Guidance Document 2008).

Protocol Flexibility:
Flexibility in applying the quantification protocol is provided to project developers in two ways.

1. This protocol applies to the reduction of atmospheric GHGs by land application of sludge, which is a single aspect of pulp mill operations. This protocol can be combined with other protocols where multiple projects are undertaken by the pulp mill to reduce overall GHG emissions.

2. Site specific emission factors may be substituted for the generic emission factors used in this protocol document. Emission factors must be verifiable and/or obtained from a credible reference.

This quantification protocol is written for the Mechanical Pulp Mill Sludge Utilization project developer. Some familiarity with, or general understanding of the operation of pulp mills and farming practices is expected.

1.2 Glossary of New Terms:

Assurance Factor: The assurance factor accounts for the risk and magnitude of carbon sequestration reversal due to fire, drought, pest and other disturbances. This factor accounts for the average number of reversal events anticipated over a 20 year period. The assurance factor accounts for the reversal event across all of the years that the project is eligible to receive credits for carbon sequestration. This prevents any liability accruing with credits for sludge utilization projects due to the risk of reversal. A conservative assurance factor of 90% was applied based on extensive research and operational measurements. The assurance factor may need to be adjusted as more data becomes available.

Carbon Sequestration: The process of increasing the carbon stored in a reservoir other than the atmosphere.

Carbon stock: The quantity of carbon held within a reservoir at a specified time, expressed in units of mass.

Functional Equivalence: The project and the baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (i.e. sequestration of carbon on a given land area) for comparison between the project and baseline activity (refer to the Project Guidance Document for the Alberta Offset System for more information).

Reservoir: A physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a greenhouse gas removed from the atmosphere by a greenhouse gas sink or a greenhouse gas captured from a greenhouse gas source. Examples of reservoirs include trees, soil, oil and gas reservoirs, and oceans.

Pulp Sludge: A traditionally discarded by-product created by the operations of mechanical pulp mills. Mechanical pulp sludge consists primarily of water, wood fiber, biomass, and residual process and wastewater treatment chemicals (mainly nutrients such as nitrogen and phosphorus). Sludge improves the nutrient status and physical properties of soil resulting in enhanced plant growth.

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

Sources and sinks (SS's) were identified for the project by reviewing the seed protocol document and relevant process flow diagrams. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

The emissions produced for the project will differ due to variations in sludge application rates and properties, farm management and cropping practices, climatic conditions, and soil chemical and physical properties. A measurement comparison approach of affected carbon reservoirs will establish the additional carbon stored by the project.

Based on the process flow diagrams provided in **FIGURE 1.1** and **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1**.

Figure 2.1. Project Element Life Cycle Chart – Agricultural Sludge Utilization

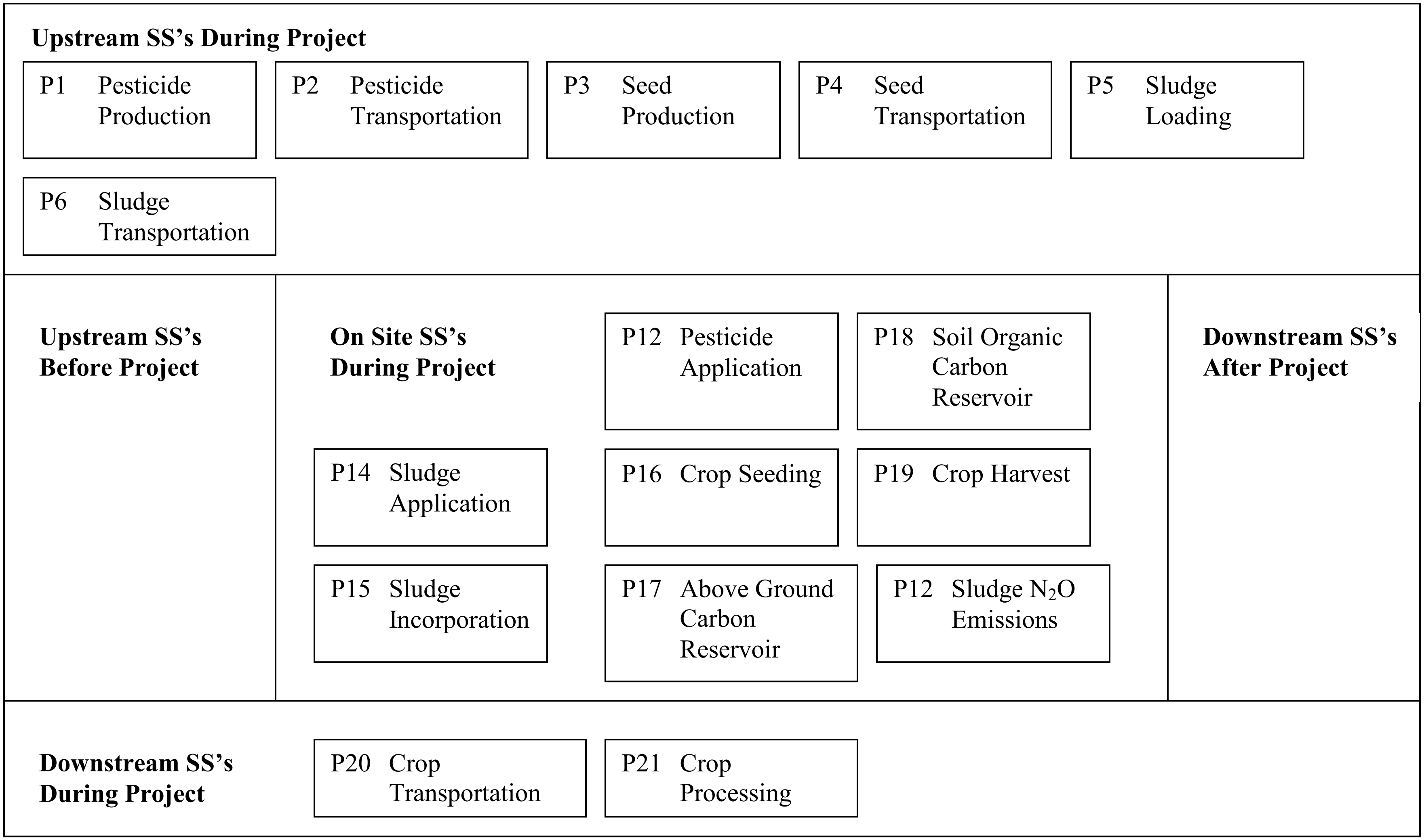


Table 2.1. Project SS's for Agricultural Sludge Application

SS	Description	Controlled, Related or Affected
	Upstream SS's during Project Operation	
P1 Pesticide Production	Pesticide Production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be evaluated for the project equivalent.	Related
P2 Pesticide Transportation	Pesticide may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used evaluate the project equivalent emissions.	Related
P3 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 evaluated for the project equivalent.	Related
P4 Seed Transportation	Seed may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the project equivalent emissions.	Related
P5 Sludge Loading	Sludge will be loaded from bunkers into trucks for delivery to the site. The related energy inputs for fuelling this equipment are captured under this SS, for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment and the number of loads would be used to evaluate functional equivalence with baseline condition.	Related
P6 Sludge Transportation	Sludge will be hauled to the site by truck. Distance travelled and number of loads will be tracked to evaluate the project equivalent emissions.	Related
	Onsite SS's during Project Operation	
P12 Sludge N_2O Emissions	N_2O -N emissions from nitrogen in the Sludge	Controlled
P13 Pesticide Application	Emissions associated with spreading pesticide.	Controlled
P14 Sludge Application	Sludge would be distributed on the field to achieve a uniform application rate. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
P15 Sludge Incorporation	Sludge would be incorporated after application using farm equipment. The related energy inputs for fuelling this equipment would be based on type of equipment used, application rate, and area covered.	Controlled
P 16 Crop Seeding	Seed would need to be distributed on the field. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
P17 Above Ground Carbon Reservoir	Carbon will accumulate in the above ground biomass from sequestration in plant tissue. Yield and carbon content from the produced crop would be measured to evaluate above ground carbon accumulation. The extent of this accumulation would need to be tracked and compared to untreated areas to establish the project condition.	Controlled

Table 2.1. (Concluded) Project SS's for Agricultural Sludge Application.

P18 Soil Organic Carbon Reservoir	Carbon will be added to the soil through addition of carbon in the sludge matrix. Carbon will also accumulate in the below ground organic materials as a result of root biomass development and crop decomposition. The soil carbon content prior to and after sludge addition will be tracked.	Controlled
P19 Crop Harvest	Crops would need to be harvested and transported from the field to storage. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
Downstream SS's during Project Operation		
P20 Crop Transportation	Crops would need to be transported from storage to the market. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Related
P21 Crop Processing	Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the baseline condition.	Related

2.2 Identification of Baseline

The baseline condition is considered to be business as usual farming and cropping practices without land application of sludge.

The emissions produced at baseline will differ for each project due to variations in farm management and cropping practices, climatic conditions, and soil chemical and physical properties. A representative control group along with pre-application measurements will establish the baseline condition.

The baseline condition is defined, including the relevant SS's and processes, as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.2**

Figure 2.2. Baseline Element Life Cycle Chart – Agricultural Sludge Utilization

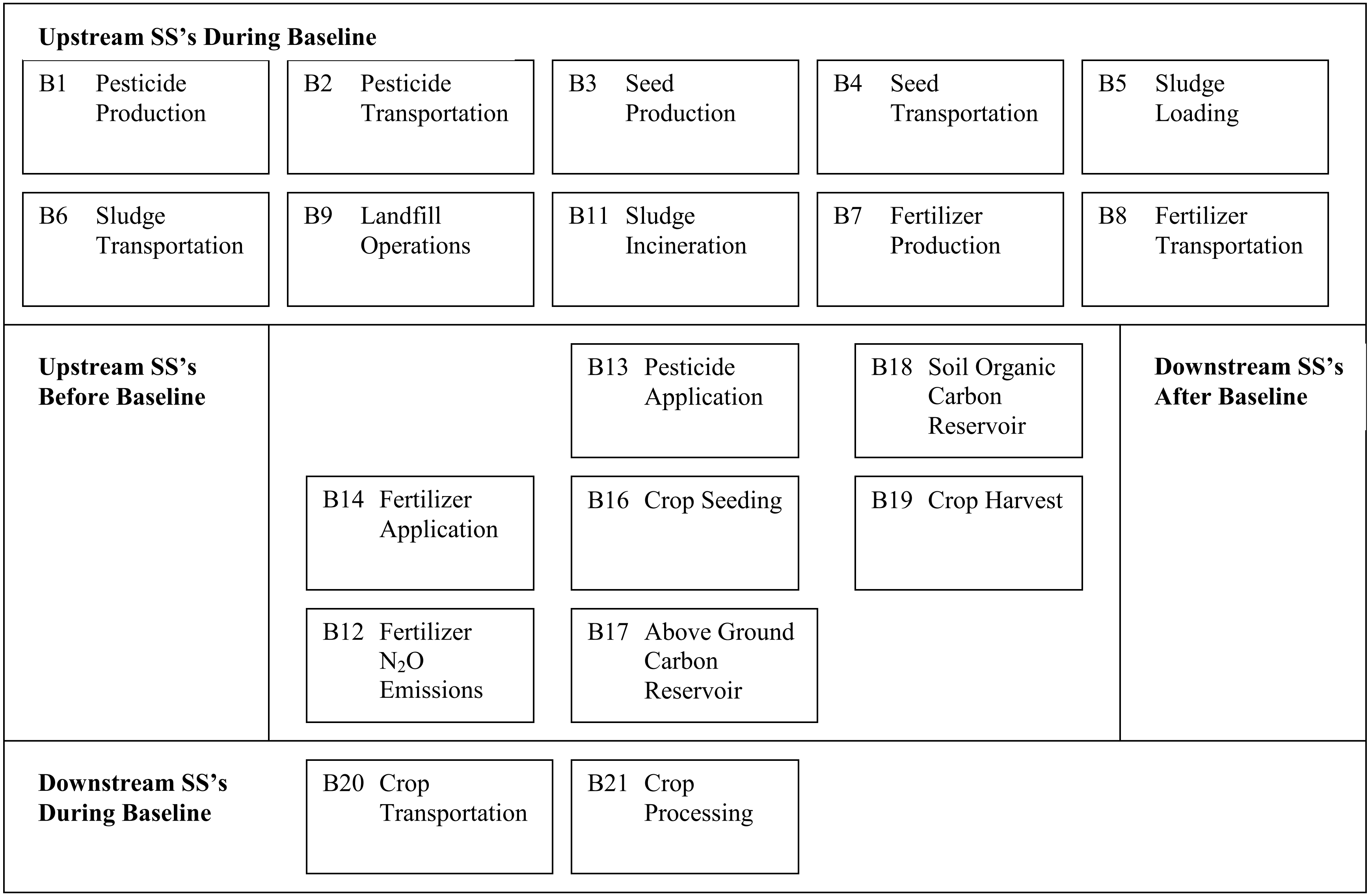


Table 2.2. Baseline SS's for Agricultural Sludge Applications.

SS	Description	Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Pesticide Production	Pesticide production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be evaluated for the baseline equivalent.	Related
B2 Pesticide Transportation	Pesticide may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used evaluate the baseline equivalent emissions.	Related
B3 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 evaluated for the baseline equivalent.	Related
B4 Seed Transportation	Seed may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used evaluate the baseline equivalent emissions.	Related
B5 Sludge Loading	Sludge will be loaded from bunkers into trucks for delivery to the landfill site. The related energy inputs for fuelling this equipment are captured under this SS, for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment and the number of loads would be used to evaluate functional equivalence with project condition.	Related
B6 Sludge Transportation	Sludge may be transported to a landfill. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the baseline emissions.	Related
B7 Fertilizer Production	Fertilizer production may have energy requirements such as natural gas, diesel and electricity. Quantities and types for each of the energy requirements would be used to determine baseline emissions.	Related
B8 Fertilizer Transportation	Fertilizer may need to be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the baseline equivalent emissions.	Related
B9 Landfill Operations	Sludge may be disposed of in a landfill. Quantities and types for each of the energy inputs would be tracked to calculate baseline emissions.	Related
B10 Sludge N_2O Emissions	N_2O emissions from baseline scenarios of landfilling , incineration or burning	Related
B11 Sludge Incineration	Sludge may be disposed through incineration. Greenhouse gas emissions may occur that are associated with the operation and maintenance of the incinerator. Quantities and types for each of the energy inputs would be tracked to calculate baseline emissions.	Related

Table 2.2. (Concluded) Baseline SS's for Agricultural Sludge Applications.

Onsite SS's during Baseline Operation		
B12 Fertilizer N_2O Emissions	Annual direct N_2O -N emissions from synthetic fertilizer nitrogen applied to soils, kg N yr^{-1}	Related
B13 Pesticide Application	Emissions associated with spreading pesticide.	Controlled
B14 Fertilizer Application	Fertilizer would be distributed on the field to achieve a uniform application rate. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
B16 Crop Seeding	Seed would need to be distributed on the field. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
B17 Above Ground Carbon Reservoir	Carbon will accumulate in the above ground biomass from sequestration in plant tissue. Yield and carbon content from the produced crop would be measured to evaluate above ground carbon accumulation. The extent of this accumulation would need to be tracked and compared to treated areas to establish the baseline condition.	Controlled
B18 Soil Organic Carbon Reservoir	Carbon will be added to the soil through addition of carbon in the sludge matrix. Carbon will also accumulate in the below ground organic materials as a result of root biomass development and crop decomposition. The soil carbon content prior to and after sludge addition will be tracked.	Controlled
B19 Crop Harvest	Crops would need to be harvested and transported from the field to storage. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
Downstream SS's during Baseline Operation		
B20 Crop Transportation	Crops would need to be transported from storage to the market. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Related
B21 Crop Processing	Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the project condition.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided the American National Standard – Greenhouse Gases Part 2 – Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (ANSI/ISO/ASQ E14064-2, 2006). The justification for the exclusion or conditions upon which SS's may be excluded is provided. All other SS's listed previously are included. This information is summarized in **TABLE 2.3**.

Table 2.3. Comparisons of SS's for Agricultural Sludge Applications.

SS	Baseline (C,R,A)	Project (C,R,A)	Include or Exclude from Quantification	Justification for Exclusion
Upstream SS's				
B1 Pesticide Production	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practices are covered under proposed greenhouse gas regulations. Further, the baseline and project conditions are functionally equivalent.
P1 Pesticide Production	N/A	Related	Exclude	
B2 Pesticide Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
P2 Pesticide Transportation	N/A	Related	Exclude	
B3 Seed Production	Related	N/A	Exclude	Excluded as these SS's are not relevent to the project as the emissions from these practices are covered under proposed greenhouse gas regulations. Further, the baseline and project conditions are functionally equivalent.
P3 Seed Production	N/A	Related	Exclude	
B4 Seed Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
P4 Seed Transportation	N/A	Related	Exclude	
B5 Sludge Loading	Related	N/A	Exclude	Excluded as the emissions from sludge loading are negligible due to short haul distances.
P5 Sludge Loading	N/A	Related	Exclude	Excluded as the emissions from sludge loading are negligible due to short haul distances.
B6 Sludge Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible due to very short haul distances.
P6 Sludge Transportation	N/A	Related	Exclude	Exclude as the emissions from transportation in the project (one time application) are functionally equivalent to the fertilizer transportation and application over five years (five time application) in the baseline.
B7 Fertilizer Production	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emission from these practices are covered under proposed greenhouse gas regulations.
P8 Fertilizer Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible.
B9 Landfill Operations	Related	N/A	Exclude	Excluded as covered under other aspects of carbon offsets for the mill.

Table 2.3. (Continued) Comparisons of SS's for Agricultural Sludge Applications.

SS	Baseline (C,R,A)	Project (C,R,A)	Include or Exclude from Quantification	Justification for Exclusion
B10 Sludge N_2O Emissions	Related	N/A	Exclude	Excluded as covered under other aspects of carbon offsets for the mill.
B11 Sludge Incineration	Related	N/A	Exclude	Excluded as covered under other aspects of carbon offsets for the mill.
Onsite SS's				
B12 Fertilizer N2O Emissions	Related	N/A	Include	N/A
P12 Sludge N_2O Emissions	N/A	Controlled	Include	N/A
B13 Pesticide Application	N/A	Controlled	Exclude	Excluded as the as the emissions from application are negligible and likely functionally equivalent to the baseline scenario.
P13 Pesticide Application	Controlled	N/A	Exclude	
P14 Sludge Application	N/A	Controlled	Exclude	Excluded as the baseline and project conditions are functionally equivalent.
P15 Sludge Incorporation	N/A	Controlled	Exclude	
B14 Fertilizer Application	Controlled	N/A	Exclude	Excluded as emissions from fertilizer application are functionally equivalent to sludge application.
B16 Crop Seeding	Controlled	N/A	Exclude	Excluded as the emissions from crop seeding are likely functionally equivalent to the baseline scenario.
P16 Crop Seeding	N/A	Controlled	Exclude	
B17 Above Ground Carbon Reservoir	Controlled	N/A	Include	N/A
P17 Above Ground Carbon Reservoirs	N/A	Controlled	Include	
B18 Soil Organic Carbon Reservoir	Controlled	N/A	Include	N/A
P18 Soil Organic Carbon Reservoir	N/A	Controlled	Include	

Table 2.3. (Concluded) Comparisons of SS's for Agricultural Sludge Applications.

B19 Crop Harvest	Controlled	N/A	Exclude	Excluded as the emissions from crop harvesting are likely functionally equivalent to the baseline scenario.
P19 Crop Harvest	N/A	Controlled	Exclude	
Downstream SS's				
B20 Crop Transportation	Controlled	N/A	Exclude	Excluded as the emissions from crop transportation are negligible and likely functionally equivalent to the baseline scenario.
P20 Crop Transportation	N/A	Controlled	Exclude	
B21 Crop Processing	Controlled	N/A	Exclude	Excluded as the emissions from crop processing are likely functionally equivalent to the baseline scenario.
P21 Crop Processing	N/A	Controlled	Exclude	

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in TABLE 2.4, below. A listing of relevant emission factors is provided in Appendix A. These calculation methodologies serve to complete the following equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{N20 Fertilizer Emissions}} + ((-\text{Emissions}_{\text{carbon sequestration}}) \times \text{Assurance Factor})$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{N20 Sludge Emissions}} + ((-\text{Emissions}_{\text{carbon sequestration}}) \times \text{Assurance Factor})$$

Where:

$\text{Emission}_{\text{Baseline}}$ = sum of emissions under the baseline condition

$\text{Emissions}_{\text{N20 Fertilizer Emissions}}$ = Emissions under B12 (Fertilizer N_2O emissions)

$\text{Emissions}_{\text{carbon sequestration}}$ = Sequestration under SS B18 (Soil Organic Carbon Reservoir) + SS B17 (Above Ground Carbon Reservoir)

Assurance Factor = Factor to account for reversals (Appendix B)

$\text{Emissions}_{\text{Project}}$ = sum of emissions under the project condition

$\text{Emissions}_{\text{carbon sequestration}}$ = Sequestration under SS P18 (Soil Organic Carbon Reservoir) + SS P17 (Above Ground Carbon Reservoir)

$\text{Emissions}_{\text{N20 Fertilizer Emissions}}$ = Emissions under P12 (Sludge N_2O emissions)

Assurance Factors are provided in Appendix B.

Table 2.4. Quantification Procedures – Agricultural Sludge Utilization

Project SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured/ Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
P18 Soil Organic Carbon Reservoir (Emission reductions from soil carbon addition and accumulations, Mg CO_2e/ha/yr)	Soil bulk density	g/cm^3	Measured using core sample of known volume and dry weight	Collect sample to depth of incorporation using bulk density sampler and dry to constant weight	5 individual checks in treated area to confirm bulk density before sludge application and at end of credit period	Pre-application and after 5-6 year period and/or prior to re-application	Representative sample to account for variability in depth of incorporation and receiving soil characteristics
	Soil organic carbon	%	Measured	LECO total combustion of carbon to CO_2 and analysis by infrared detector	2 treatment sections within each 64 ha area (or smaller) each with 8 randomly selected sample locations composited for one grab sample	Analysis of each sample collected	For calculation of soil organic carbon content in sludge treated
	Area treated	ha	Measured	Field survey or map	N/A	Annually or chosen credit interval	For determination of total credit
P17 Above Ground Carbon Reservoir (Emission reductions resulting from increased biomass production, Mg CO_2e/ha/yr)	Crop live tissue weight	Live tissue kg/ha	Live tissue weight determination from representative treated area	Measurement of total wet weight and moisture content from representative sludge treated area	5 randomly selected 1 m^2 frames representing the 64 ha treated area	Annually	For calculation of biomass production related to carbon fixing
	organic carbon content of live tissue collected	%	Measured carbon content of dry plant tissue collected	LECO total combustion of carbon to CO_2 and analysis by infrared detector	As required by method	Analysis of each sample collected	For calculation of live tissue carbon content of sludge treated area

Sequestration $_{\text{above ground carbon reservoir}}$ = (Live tissue weight / Area collected x Area treated x Carbon content $_{\text{bulk sample}}$ x Conversion Factor $_{C\text{-}CO2}$)
Sequestration $_{\text{below ground carbon reservoir}}$ = SOC% x bulk density (g/cm^3) x sample depth (cm)

Table 2.4. (Continued) Quantification Procedures – Agricultural Sludge Utilization

Baseline SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured/ Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
B18 Soil Organic Carbon Reservoir (Emission reductions from soil carbon addition and accumulations, Mg CO_2e/ha/yr)	Soil bulk density	g/cm^3	Measured using core sample of known volume and dry weight	Collect sample to depth of incorporation using bulk density sampler and dry to constant weight	3 individual checks in the control strip to confirm bulk density before sludge application and at end of credit period	Pre-application and after 5-6 year period and/or prior to re-application	Representative sample to account for variability in depth of incorporation and receiving soil characteristics
	Soil organic carbon	%	Measured	LECO total combustion of carbon to CO_2 and analysis by infrared detector	3 randomly selected, GPS referenced sample locations within each control area composited and analyzed for SOC	Analysis of each sample collected	For calculation of soil organic carbon content in sludge treated area
	Area treated	ha	Measured	Field survey or map	N/A	Initial survey of treated area	For determination of total credit
B17 Above Ground Carbon Reservoir (Emission reductions resulting from increased biomass production, Mg CO_2e/ha/yr)	Crop live tissue weight	Live tissue kg/ha	Live tissue weight determination from representative treated area	Measurement of total wet weight and moisture content from representative sludge treated area	5 randomly selected 1 m^2 frames representing the 64 ha treated area	Annually	For calculation of biomass production related to carbon fixing
	organic carbon content of live tissue collected	%	Measured carbon content of dry plant tissue collected	LECO total combustion of carbon to CO_2 and analysis by infrared detector	As required by method	Analysis of each sample collected	For calculation of live tissue carbon content of sludge treated area

Sequestration $_{\text{above ground carbon reservoir}}$ = (Live tissue weight / Area collected x Area treated x Carbon content $_{\text{bulk sample}}$ x Conversion Factor $_{\text{C-CO2}}$)

Sequestration $_{\text{below ground carbon reservoir}}$ = SOC% x bulk density (g/cm^3) x sample depth (cm)

Table 2.4. (Concluded) Quantification Procedures – Agricultural Sludge Utilization

Project and Baseline SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured/ Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
P12 N_2O Emissions related to sludge application	CO_2e/ha	Mg N/ha	Measure total nitrogen content of applied sludge	Estimated from IPCC guidelines for N_2O emissions for sludge organic N additions	Composite sample of sludge necessary for total nitrogen analysis	Grab sample representing applied sludge N content	Determine N_2O -N emissions from N inputs to sludge applied soils
B12 Fertilizer N_2O Emissions associated with Synthetic Fertilizer Use	N_2O emissions from fertilizer application to soils	T CO_2e/ha	Annual amount of synthetic fertilizer applied to soils (kg N/yr)	Total N by LECO furnace	As required by method	Analysis of each sample collected	To determine N_2O emissions related to business as usual practices using inorganic fertilizers

Emissions $_{\text{N2O emissions sludge}}$ = N_2O-N emissions from N inputs from sludge

Emissions $_{\text{fertilizer N2O emissions from synthetic fertilizer}}$ = kg N_2O-N/ha x EF_1

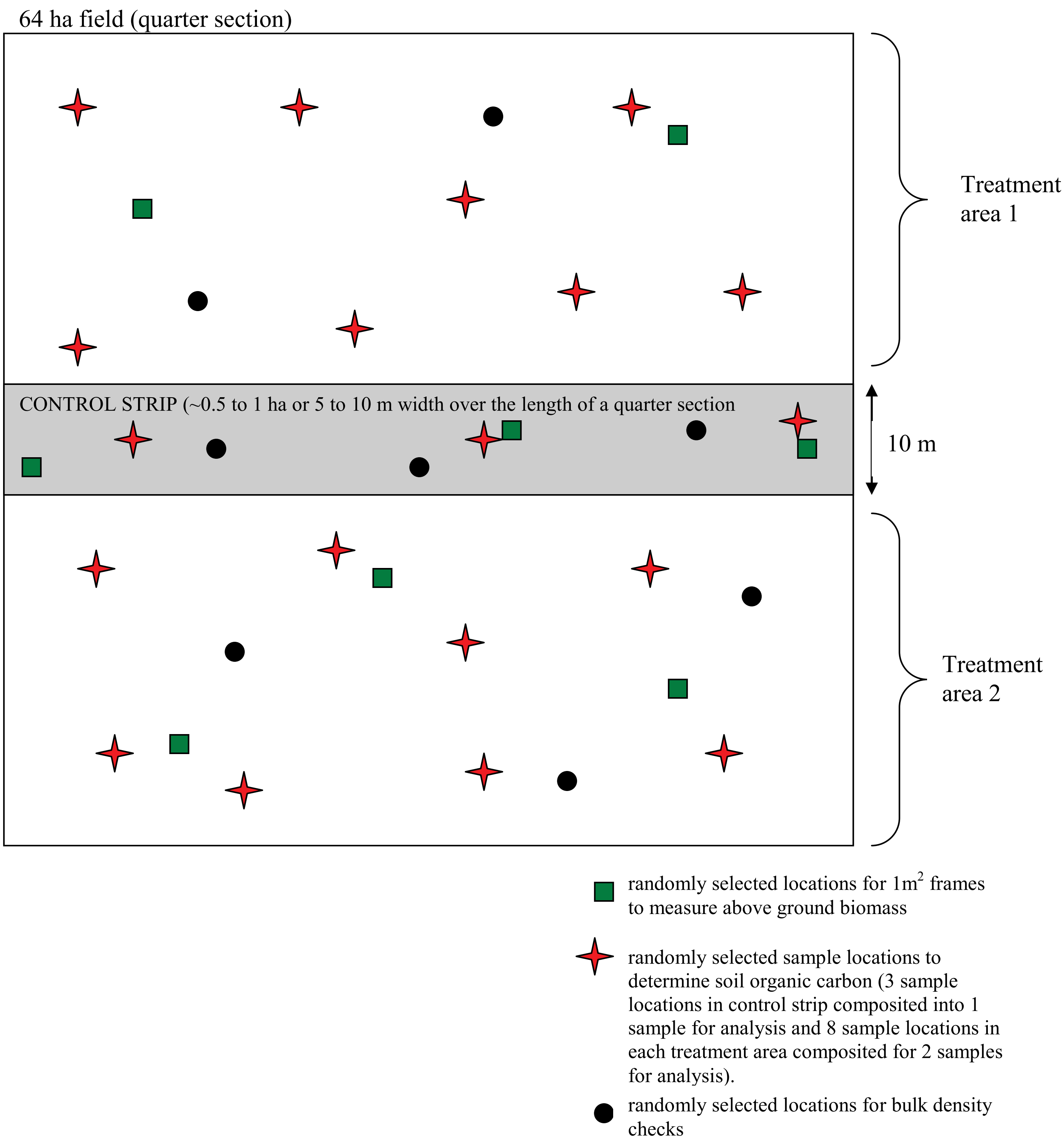


Figure 2.3. Diagram representing optimum sampling conditions. For land units of irregular shapes, modifications to this plan may be necessary, however, the basic elements of the sampling scheme described should be maintained.

2.6 Management of Data Quality

Since this protocol is a measurement based comparison approach, data quality management must include field measurements, and data from the sampling and related analytical work. Procedures will be established for measurements completed and sampling and analytical techniques for the baseline and project scenarios.

2.6.1 Record Keeping

Record keeping will include:

a) Sample location, timing and qualified individuals conducting the work.
b) Written logs of all field measurements and observations.
c) Electronic files of all raw and calculated data.
d) Blanks, duplicates, and internal standard tracking for all analytical data.
e) All records to be available for review and audit.

2.6.2 Quality Assurance/Quality Control Practices

a) Establish minimum experience standards for personnel conducting field measurements, sampling and analysis.
b) Check data integrity of field measurements by performing random checks.
c) Confirm estimated data with confirming measurements.
d) Maintain database of analytical standards and unknowns.
e) Recalculate data to ensure no mathematical errors have been made.

Appendix A. Conversion and Emission Factors Used

<u>Fuel Use – Sludge Transportation</u>

g CO_2/ L fuel used = 2730
g CH_4/L fuel used = 0.15
g N_2O/L fuel used = 0.08

Fuel Economy factors

Diesel heavy truck = 33.6L/100 km
Greenhouse Gas Potential
$CO_{2e} = N_2O \times 310$
$CO_{2e} = CH_4 \times 21$

Source:
Environment Canada, Canada's 2004 Greenhouse Gas Inventory

<u>N2O emissions from fertilizer/sludge applications</u>

$N_2O\text{direct} = N_2O\text{-}N_{\text{inputs}} \times EF_1$
Where
$N_2O\text{-}N_{\text{inputs}} = F_{SN} + F_{ON}$
F_{SN} = annual amount of synthetic fertilizer applied to soils kg N yr^{-1}
F_{ON} = organic N additions applied to soil through sludge addition
EF1 = emission factor for N2O emissions from N inputs
Kg N20-N (kg N input)$^{-1}$ default value = 0.01

Source :
IPCC Guidelines for National Gas Inventories, 2006

Appendix B. Relevant Assurance Factors

Development of Assurance Factors

An assurance factor will account for the average risk of reversal for all agricultural sludge utilization projects. Since the effects of increasing the carbon reservoir would be measured during the credit allocation period, the assurance factor will be assessed on a site specific basis.

Based on the analysis of available data from 15 years of research of sludge utilization on agricultural land, a reasonable assurance factor would exceed 90%. For the purposes of this protocol and until more operational data is available, a 90 % assurance factor was deemed reasonable.