

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. 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, a 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 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.

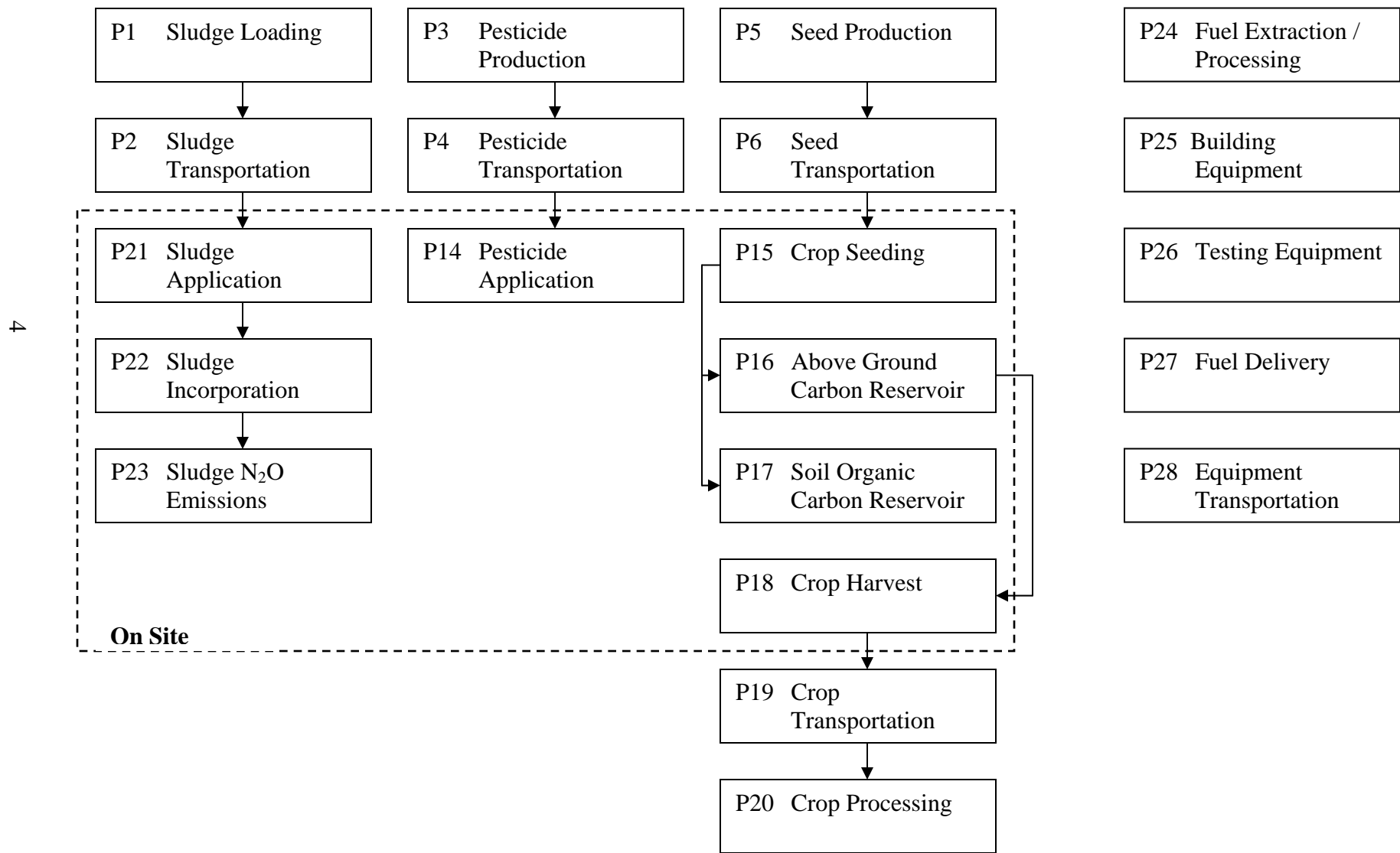
Some emissions are expected over the course of the project due to sludge transportation and application, however these emissions are negligible compared to the amount of GHGs reduced through the project. Since sludge application eliminates the need for fertilizer application, the related energy inputs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

#### **Protocol Approach:**

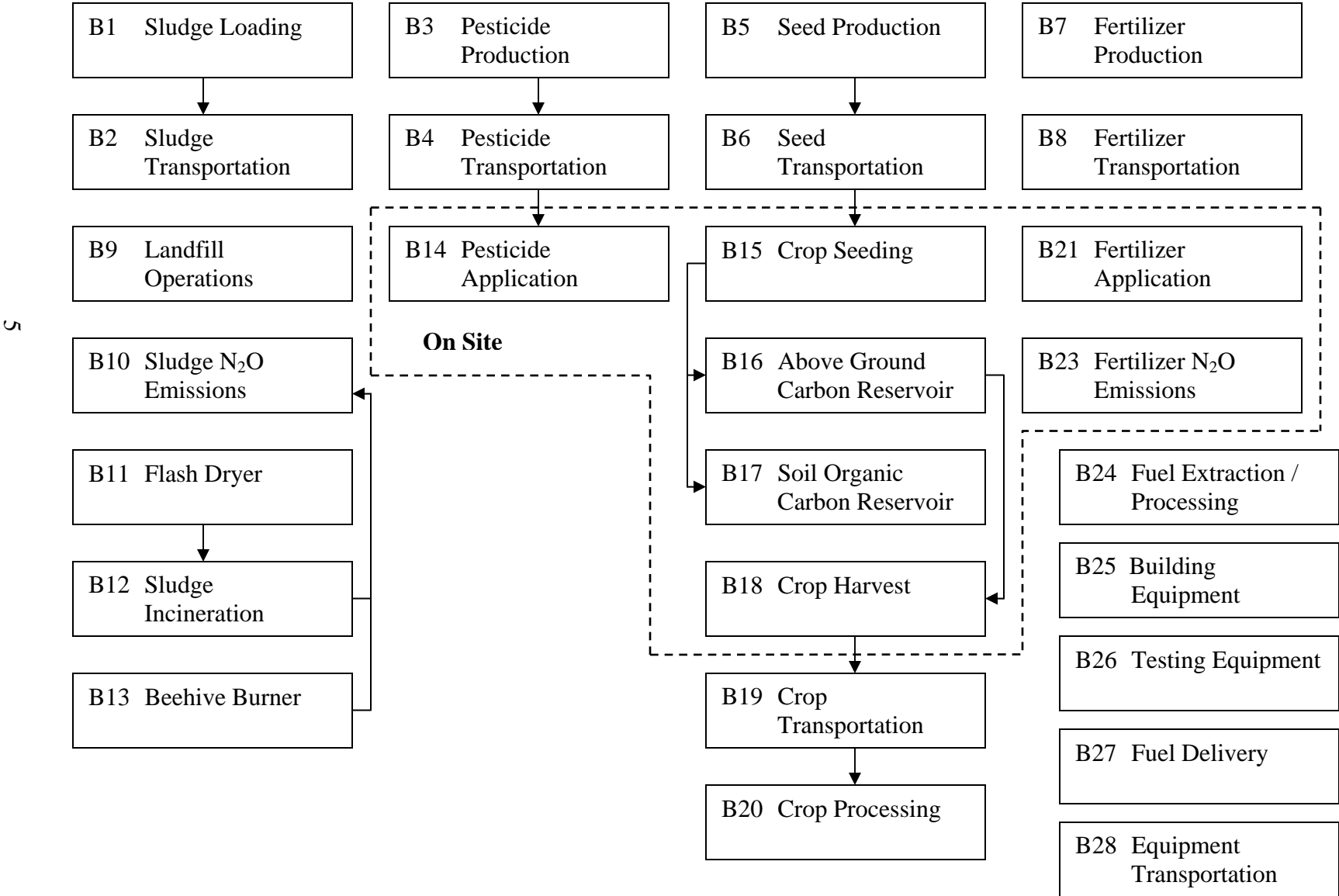
This protocol can be used as a general template for project proponents to follow. The amount of sludge applied by each mill will equal a set “reduction coefficient” equal to the difference from the baseline of GHGs reduced through its use. Baseline emissions for each project area will be determined through the use of control groups following identical farming and cropping practices. This protocol deals with emission reductions from utilization of sludge for agricultural application. Business as usual practices for sludge

handling includes drying, incineration, and beehive burner combustion. Emissions from these practices are avoided through utilization of sludge by agricultural application. A further reduction in GHG reductions are achieved by increased soil carbon storage. This protocol is focused on emissions avoidance, increased 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 the Project Condition – Agricultural Sludge Utilization**



**Figure 1.2. Process Flow Diagram for the Baseline Condition – Agricultural Sludge Utilization.**



**Protocol Applicability:**

This protocol is applicable to all mechanical pulp mills in Alberta that are producing sludge and applying it according to 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, spread and incorporated 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) and this protocol as confirmed by affirmation from the project developer and farm records.
  - a. Mechanical pulp sludge should be stockpiled in a manner that prevents contamination of any surface watercourses and groundwater. The stockpile should not be located on land which has a slope greater than 9%. Not more than a quantity sufficient for one application of sludge should be stored at a designated application area at any time.
  - b. Any method of spreading sludge that results in an even application to soil may be used. Conventional tractor pulled manure spreaders and truck mounted spreaders which have an auger type flinger at the back to dispense the sludge are recommended. Following the contours of the land to minimize soil disturbance is also recommended.
  - c. Roto-tillers or tandem (double) discs are the most useful implements for incorporation.
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). Sludge should not be applied to:
  - a. Organic soil
  - b. Soil with a C:N ratio greater than 40:1
  - c. Soil which has an EC greater than 6 dS/m
  - d. Soil which has a SAR greater than 8
  - e. An area where the slope exceeds 15%
  - f. Soil in low lying areas that have saturated soil conditions for more than six consecutive weeks
  - g. An area where the seasonally high watertable is within 1.5 meters of the soil surface
  - h. Frozen soil unless it can be incorporated within 72 hours of application

The recommended distance from residences or watercourses on land with 0 to 3% slopes is 15 meters, 30 meters on land with 3 to 9% slopes and 50 meters on land with 9 to 15% slopes.

3. The quantification of reductions achieved by all new projects are based on actual comparison measurements 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.
  - a. A control strip is to be established in each parcel of land designated for sludge application. Ideally the control strip will be located in the middle of the land area and be a minimum of 10 meters wide and run the entire length of the area to account for landscape variability. No sludge should be applied in the control strip.
4. The minimum number of samples was taken as indicated in this protocol. The number of samples required may increase with increased variability in landscape topography and should be assessed by qualified personnel. All sample locations should be geo referenced and data quality management procedures followed.
5. The quantification of reductions achieved between 2002 and 2008 are based on quantification calculations and approved data sources (see Section 2.5.2 – Contingent Data – of this protocol).
6. 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 and avoided emissions from no longer incinerating or landfilling sludge. This protocol can be combined with other protocols where multiple projects are undertaken by the pulp mill to reduce overall GHG emissions.
2. If no control strip was established before sludge application, the protocol user may apply the quantification approach described in Section 2.5.2 – Contingent Data.
3. 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:

|   |  |
|---|--|
| Affected Greenhouse Gas Source, Sink or Reservoir   | GHG source, sink or reservoir influenced by a project activity, through changes in market demand or supply for associated products or services, or through physical displacement. An affected GHG source, sink or reservoir is generally off the project site (ANSI/ISO/ASQ E14064-2:2006(E)).   |
| 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.  |
| Control Strip                                       | A parcel of land (minimum 10 m wide) which is sampled as the standard or baseline and compared with an area treated with sludge.   |
| Controlled Greenhouse Gas Source, Sink or Reservoir | GHG source, sink or reservoir whose operation is under the direction and influence of the greenhouse gas project proponent through financial, policy, management or other instruments. A controlled GHG source, sink or reservoir is generally on the project site (ANSI/ISO/ASQ E14064-2:2006(E)).  |
| 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).   |

Related Greenhouse Gas Source, Sink or Reservoir GHG source, sink or reservoir that has material or energy flows into, out of, or within the project. A related GHG source, sink or reservoir is generally upstream or downstream from the project, and can be either on or off the project site. It may also include activities related to design, construction and decommissioning of the site (ANSI/ISO/ASQ E14064-2:2006(E)).

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.

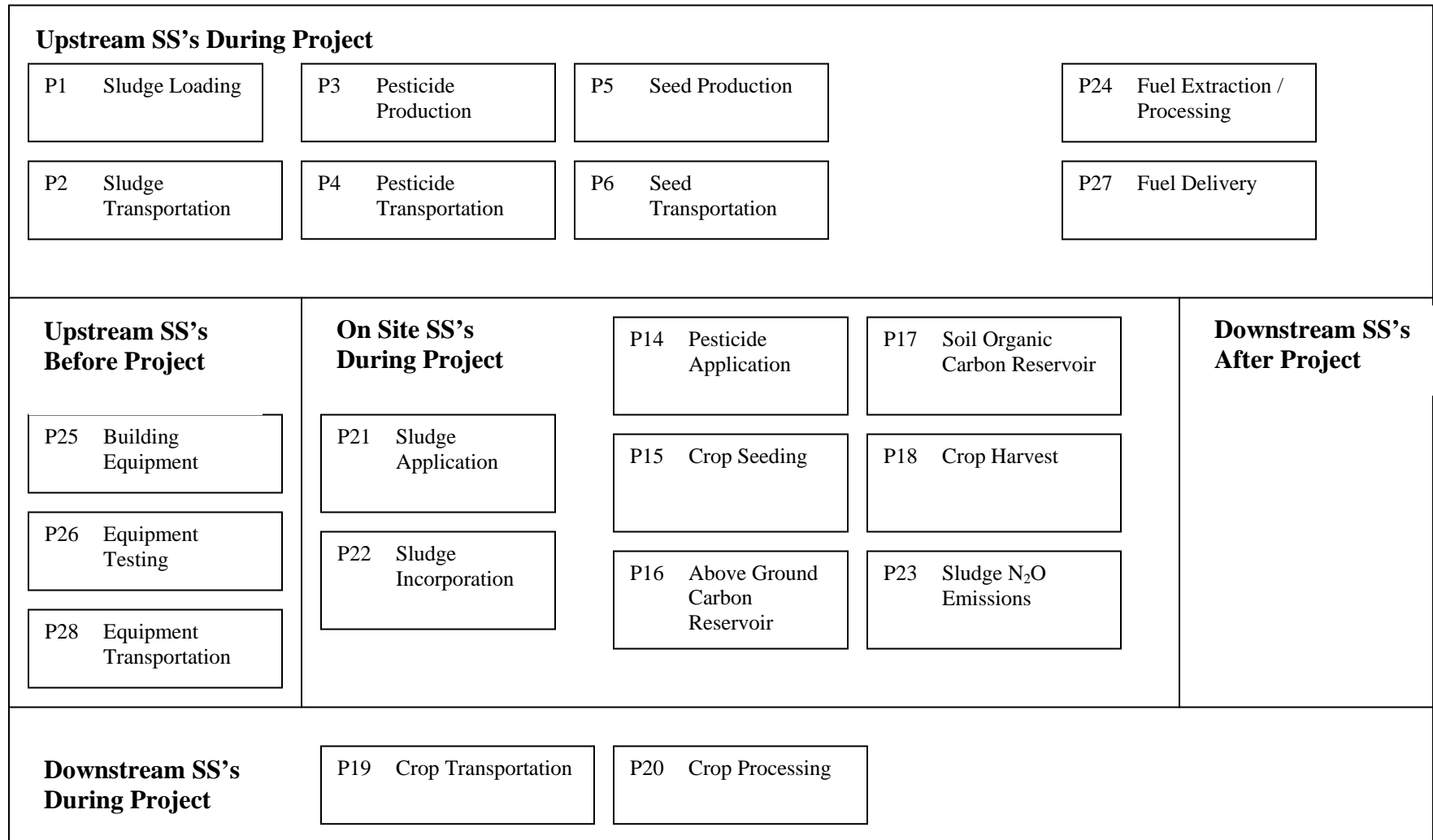
### 2.1 Identification of Sources and Sinks (SS's) for the Project

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 |
|---|---|---------------------------------|
| <b>Upstream SS's during Project Operation</b> |   |                                 |
| P1 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                         |
| P2 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                         |
| P3 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                         |
| P4 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                         |
| P5 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                         |
| P6 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                         |
| P24 Fuel Extraction / Processing              | Each of the fossil fuels used throughout the on-site component of the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked. | Related                         |
| P27 Fuel Delivery                             | Each of the fuels used throughout the on site component of the project will need to be transported. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling stations as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.                 | Related                         |
| <b>Onsite SS's during Project Operation</b>   |   |                                 |
| P14 Pesticide Application                     | Emissions associated with spreading pesticides. Type of equipment used and the area covered would be used to evaluate emissions from this activity.   | Controlled                      |
| P21 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                      |
| P22 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                      |

|   |  |            |
|---|--|------------|
| P23 Sludge N <sub>2</sub> O Emissions           | N <sub>2</sub> O -N emissions from nitrogen in the sludge after land application and incorporation. It is important to track the amount of nitrogen emitted after application and in subsequent years to compare with synthetic fertilizers.   | Controlled |
| P 15 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 |
| P16 Above Ground Carbon Reservoir               | Carbon will accumulate in the above ground biomass from sequestration in plant tissue. Yield from the produced crop would be measured and carbon content would be estimated based on previous research to evaluate above ground carbon accumulation. The extent of this accumulation would need to be tracked and compared to untreated areas to determine the extent of above ground carbon sequestration.  | Controlled |
| P17 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 to a depth of 30 cm.  | Controlled |
| P18 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 |
| <b>Downstream SS's during Project Operation</b> |  |            |
| P19 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    |
| P20 Crop Processing                             | Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the baseline condition.   | Related    |
| <b>Other</b>                                    |  |            |
| P25 Building Equipment                          | Equipment may need to be built either on site or off site. This includes all 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    |
| P26 Equipment testing                           | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using 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    |
| P28 Equipment Transportation                    | 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    |

## 2.2 Identification of Baseline

The baseline condition is considered to be sludge disposal using incineration and landfilling methods and 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 sludge disposal methods, 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 soil condition. **TABLE 2.2** identifies all possible baseline approaches and provides justification for the selected comparison based baseline scenario.

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.

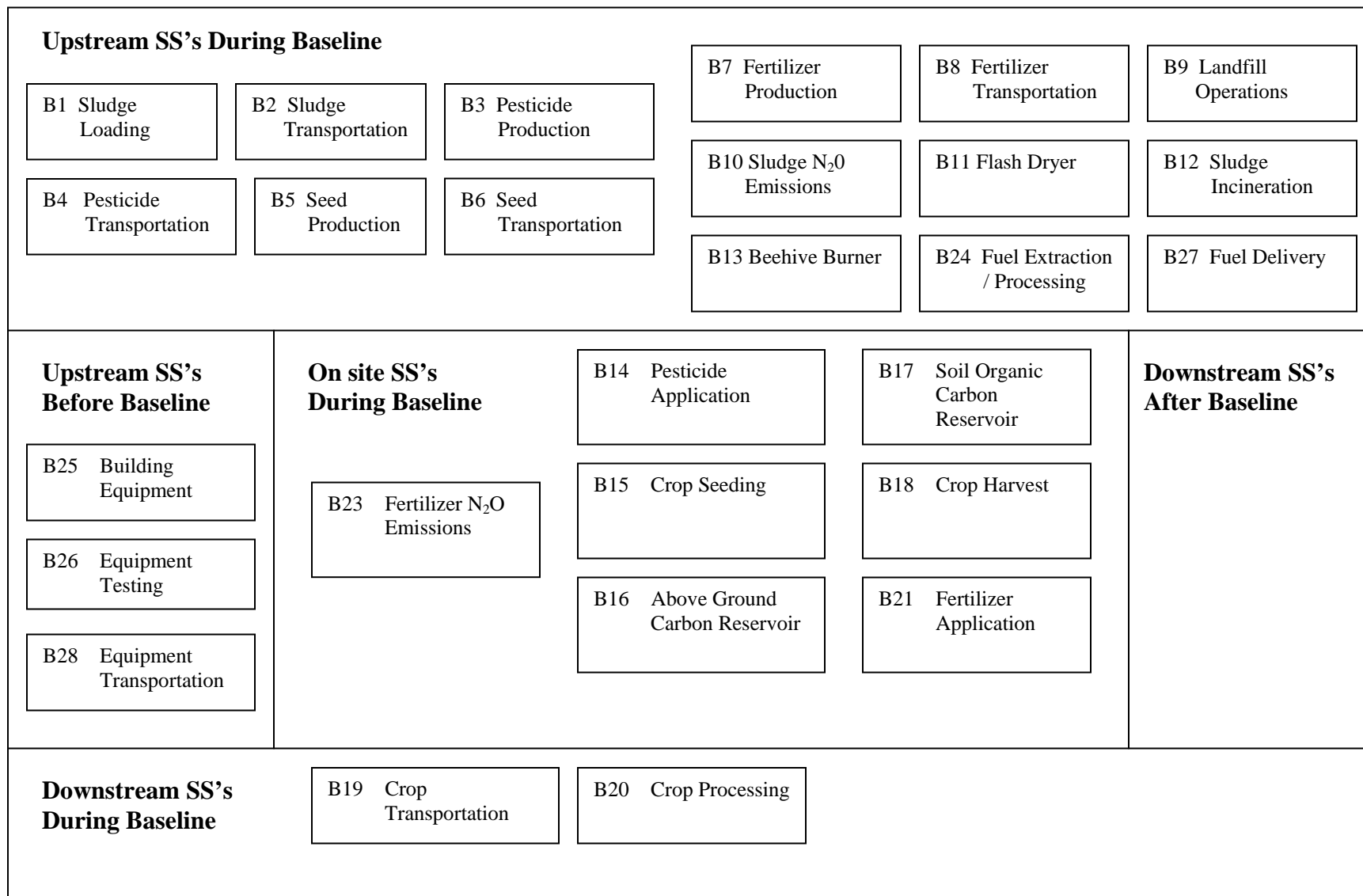
**Table 2.2. Identification of Possible Baseline Quantification Approaches**

| <b>Baseline Options</b>     | <b>Description</b>  | <b>Static / Dynamic Baseline</b> | <b>Accept or Reject and Justify</b>   |
|-----------------------------|---|----------------------------------|---|
| <b>Historic Benchmark</b>   | Typically site-specific and can be constructed to reflect reductions in a base period (such as the average emissions of the previous three years).                                      | Dynamic                          | Reject: The amount of sludge being land applied is variable each year and this method would not give an accurate estimate of the amount of carbon being sequestered above or below ground due to variability. |
| <b>Performance Standard</b> | Assumes the typical emissions profile for the industry or sector is a reasonable representation of the baseline.  | Dynamic                          | Reject: Each mechanical mill operator has different processes and operating procedures thus an industry baseline is not reasonable.   |
| <b>Comparison Based</b>     | Actual measurements of parameters from a control group to compare with the project.   | Dynamic                          | Accept: Actual measurements produce the most accurate and reliable results and can not be discounted by variability.  |
| <b>Projection Based</b>     | Projections of reductions in the future can use a variety of techniques, from simple straight line growth assumptions to complex models.  | Dynamic                          | Reject: There are too many variables that would need to be input into a model such as soil type, landscape variability, climate factors, crop species, farming and management practices, etc.                 |
| <b>Adjusted Baseline</b>    | Takes into account current practice levels of a particular project and specified that the same baseline is used for all projects of a certain type, regardless of historical practices. | Dynamic                          | Reject: There are no well documented current practice levels and too much variability associated with the baseline for an adjusted baseline.  |

### **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 controlled, related or affected are provided in **TABLE 2.3**.

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



**Table 2.3. Baseline SS's for Agricultural Sludge Applications.**

| SS   | Description   | Controlled, Related or Affected |
|--|---|---------------------------------|
| <b>Upstream SS's during Baseline Operation</b> |   |                                 |
| B1 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                         |
| B2 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                         |
| B3 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                         |
| B4 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 for the calculation.  | Related                         |
| B5 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                         |
| B6 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 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 and outputs (CH <sub>4</sub> ) would be tracked to calculate baseline emissions.  | Related                         |
| B10 Sludge N <sub>2</sub> O Emissions          | N <sub>2</sub> O emissions from baseline scenarios of landfilling, incineration or burning.   | Related                         |
| B11 Flash Dryer                                | Sludge is sometimes dried prior to incineration in a flash dryer which requires natural gas for operation. The type and amount of fuel used and the number of hours of operation will be tracked to evaluate the baseline condition.  | Related                         |
| B12 Sludge Incineration                        | Sludge may be disposed through incineration. To calculate the baseline emissions, the amount of CO <sub>2</sub> emitted after complete combustion of sludge in the incinerator would be calculated as well as the quantities and types of each of the energy inputs required for the operation and maintenance of the incinerator.                            | Related                         |
| B13 Beehive Burner                             | Sludge may be disposed through incineration in a beehive burner. Greenhouse gas emissions occur that are associated with the operation and maintenance of the beehive burner. Quantities of emissions would be estimated to evaluate total greenhouse gas emissions.  | Related                         |

|  |  |            |
|--|--|------------|
| B24 Fuel Extraction / Processing                 | Each of the fossil fuels used throughout baseline operations will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked. | Related    |
| B27 Fuel Delivery                                | Each of the fuels used throughout the baseline operations will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling stations as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery. | Related    |
| <b>Onsite SS's during Baseline Operation</b>     |  |            |
| B23 Fertilizer N <sub>2</sub> O Emissions        | Annual direct N <sub>2</sub> O -N emissions from synthetic fertilizer nitrogen applied to soils, kg N yr <sup>-1</sup>   | Related    |
| B14 Pesticide Application                        | Emissions associated with spreading pesticide. Type of equipment used and the area covered would be used to evaluate emissions from this activity.   | Controlled |
| B21 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 |
| B15 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 |
| B16 Above Ground Carbon Reservoir                | Carbon will accumulate in the above ground biomass from sequestration in plant tissue. Yield from the produced crop would be measured and carbon content would be estimated based on previous research to evaluate above ground carbon accumulation. The extent of this accumulation would need to be tracked to determine the extent of above ground carbon sequestration under baseline conditions.                            | Controlled |
| B17 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 sludge addition will be measured to a depth of 30 cm to determine the baseline condition.   | Controlled |
| B18 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 |
| <b>Downstream SS's during Baseline Operation</b> |  |            |
| B19 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    |
| B20 Crop Processing                              | Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the project condition.  | Related    |
| <b>Other</b>                                     |  |            |
| B25 Building Equipment                           | Equipment may need to be built either on site or off site. This includes all the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. 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    |

|                              |   |         |
|------------------------------|---|---------|
| B26 Equipment testing        | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using 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 |
| B28 Equipment Transportation | 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 |

## **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 in 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 2.4**.

**Table 2.4. Comparisons of SS's for Agricultural Sludge Applications.**

| SS                                    | Baseline<br>(C,R,A) | Project<br>(C,R,A) | Include or Exclude<br>from Quantification | Justification for Exclusion   |
|---------------------------------------|---------------------|--------------------|---|---|
| Upstream SS's                         |                     |                    |   |   |
| B1 Sludge Loading                     | Related             | N/A                | Exclude                                   | Excluded as the emissions from loading sludge are functionally equivalent in the project and baseline condition (i.e., sludge is loaded for landfilling or incineration and for land application).                            |
| P1 Sludge Loading                     | N/A                 | Related            | Exclude                                   |   |
| B2 Sludge Transportation              | Related             | N/A                | Include                                   | N/A   |
| P2 Sludge Transportation              | N/A                 | Related            | Include                                   | N/A   |
| B3 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. |
| P3 Pesticide Production               | N/A                 | Related            | Exclude                                   |   |
| B4 Pesticide Transportation           | Related             | N/A                | Exclude                                   | Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.   |
| P4 Pesticide Transportation           | N/A                 | Related            | Exclude                                   |   |
| B5 Seed 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. |
| P5 Seed Production                    | N/A                 | Related            | Exclude                                   |   |
| B6 Seed Transportation                | Related             | N/A                | Exclude                                   | Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.   |
| P6 Seed Transportation                | N/A                 | Related            | Exclude                                   |   |
| 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.  |
| B8 Fertilizer Transportation          | Related             | N/A                | Exclude                                   | Excluded as the emissions from transportation are negligible.   |
| B9 Landfill Operations                | Related             | N/A                | Include                                   | N/A   |
| B10 Sludge N <sub>2</sub> O Emissions | Related             | N/A                | Include                                   | N/A   |
| B11 Flash Dryer                       | Related             | N/A                | Include                                   | N/A   |

|   |            |            |          |  |
|---|------------|------------|----------|--|
| B12 Sludge Incineration                   | Related    | N/A        | Include  | N/A  |
| B13 Beehive Burner                        | Related    | N/A        | Include  | N/A  |
| B24 Fuel Extraction / Processing          | 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, emissions from fuel extraction and processing are likely functionally equivalent in the project condition as the baseline scenario.  |
| P24 Fuel Extraction / Processing          | N/A        | Related    | Exclude  |  |
| B27 Fuel Delivery                         | 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.  |
| P27 Fuel Delivery                         | N/A        | Related    | Exclude  |  |
| <b>Onsite SS's</b>                        |            |            |          |  |
| B23 Fertilizer N <sub>2</sub> O Emissions | Related    | N/A        | Exclude  | Excluded as fertilizer emissions are covered under proposed protocol which will be able to be used in conjunction with this one.   |
| P23 Sludge N <sub>2</sub> O Emissions     | N/A        | Controlled | Exclude  | The emissions from sludge application have not been thoroughly researched therefore no concrete data is available at the time of protocol development.   |
| B14 Pesticide Application                 | N/A        | Controlled | Exclude  | Excluded as the emissions from application are negligible and likely functionally equivalent to the baseline scenario.   |
| P14 Pesticide Application                 | Controlled | N/A        | Exclude  |  |
| B21 Fertilizer Application                | Controlled | N/A        | Exclude  | Excluded as emissions from fertilizer application over the 5 year credit allocation period are likely functionally equivalent or higher than sludge application and incorporation (i.e., fertilizer would be applied 5 times during the credit allocation period and although sludge application and incorporation may require more initial energy inputs, it is only required once during the same period). |
| P21 Sludge Application                    | N/A        | Controlled | Exclude  |  |
| P22 Sludge Incorporation                  | N/A        | Controlled | Exclude  |  |
| B15 Crop Seeding                          | Controlled | N/A        | Exclude  | Excluded as the emissions from crop seeding are likely functionally equivalent to the baseline scenario.   |
| P15 Crop Seeding                          | N/A        | Controlled | Exclude  |  |
| B16 Above Ground Carbon Reservoir         | Controlled | N/A        | Excluded | Excluded as the amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. Annual crops which are harvested each year therefore there is no long-term storage of carbon in biomass (IPCC 2006 Guidelines for Agricultural Land).  |
| P16 Above Ground Carbon Reservoir         | N/A        | Controlled | Excluded |  |
| B17 Soil Organic Carbon Reservoir         | Controlled | N/A        | Include  | N/A  |
| P17 Soil Organic Carbon Reservoir         | N/A        | Controlled | Include  |  |

|                              |            |            |         |  |
|------------------------------|------------|------------|---------|--|
| B18 Crop Harvest             | Controlled | N/A        | Exclude | Excluded as the emissions from crop harvesting are likely functionally equivalent to the baseline scenario.                            |
| P18 Crop Harvest             | N/A        | Controlled | Exclude |  |
| <b>Downstream SS's</b>       |            |            |         |  |
| B19 Crop Transportation      | Controlled | N/A        | Exclude | Excluded as the emissions from crop transportation are negligible and likely functionally equivalent to the baseline scenario.         |
| P19 Crop Transportation      | N/A        | Controlled | Exclude |  |
| B20 Crop Processing          | Controlled | N/A        | Exclude | Excluded as the emissions from crop processing are likely functionally equivalent to the baseline scenario.                            |
| P20 Crop Processing          | N/A        | Controlled | Exclude |  |
| <b>Other</b>                 |            |            |         |  |
| B25 Building Equipment       | Related    | N/A        | Exclude | Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required. |
| P25 Building Equipment       | N/A        | Related    | Exclude |  |
| B26 Equipment Testing        | Related    | N/A        | Exclude | Emissions from testing of equipment are not material given the minimal testing of equipment typically required.                        |
| P26 Equipment Testing        | N/A        | Related    | Exclude |  |
| B28 Equipment Transportation | Related    | N/A        | Exclude | Emissions from transportation of equipment are not material given the minimal transportation of equipment that would be required.      |
| P28 Equipment Transportation | N/A        | Related    | 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 2.5**. 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.

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

$$\begin{aligned} \text{Emissions}_{\text{Baseline}} = & \text{Emissions}_{\text{Landfill Operations}} + \text{Emissions}_{\text{Flash Dryer}} + \text{Emissions}_{\text{Incineration}} + \\ & \text{Emissions}_{\text{Sludge N20}} + \text{Emissions}_{\text{Beehive Burner}} + \text{Emissions}_{\text{Sludge Transportation}} + [(-\text{Emissions}_{\text{carbon}} \\ & \text{sequestration}) \times \text{Assurance Factor}] \end{aligned}$$

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

Where:

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

$\text{Emissions}_{\text{Landfill Operations}}$  = Emissions under B9 Landfill Operations

$\text{Emissions}_{\text{Flash Dryer}}$  = Emissions under B11 Flash Dryer

$\text{Emissions}_{\text{Incineration}}$  = Emissions under B12 Incineration

$\text{Emissions}_{\text{Sludge N20}}$  = Emissions under B10 Sludge N<sub>2</sub>O Emissions

$\text{Emissions}_{\text{Beehive Burner}}$  = Emissions under B13 Beehive Burner

$\text{Emissions}_{\text{Sludge Transportation}}$  = Emissions under SS B2 Sludge Transportation

$\text{Emissions}_{\text{carbon sequestration}}$  = Sequestration under SS B17 (Soil Organic 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 P17 (Soil Organic Carbon Reservoir)

$\text{Emissions}_{\text{Sludge Transportation}}$  = Emissions under SS P2 Sludge Transportation

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

**Table 2.5. Quantification Procedures – Agricultural Sludge Utilization**

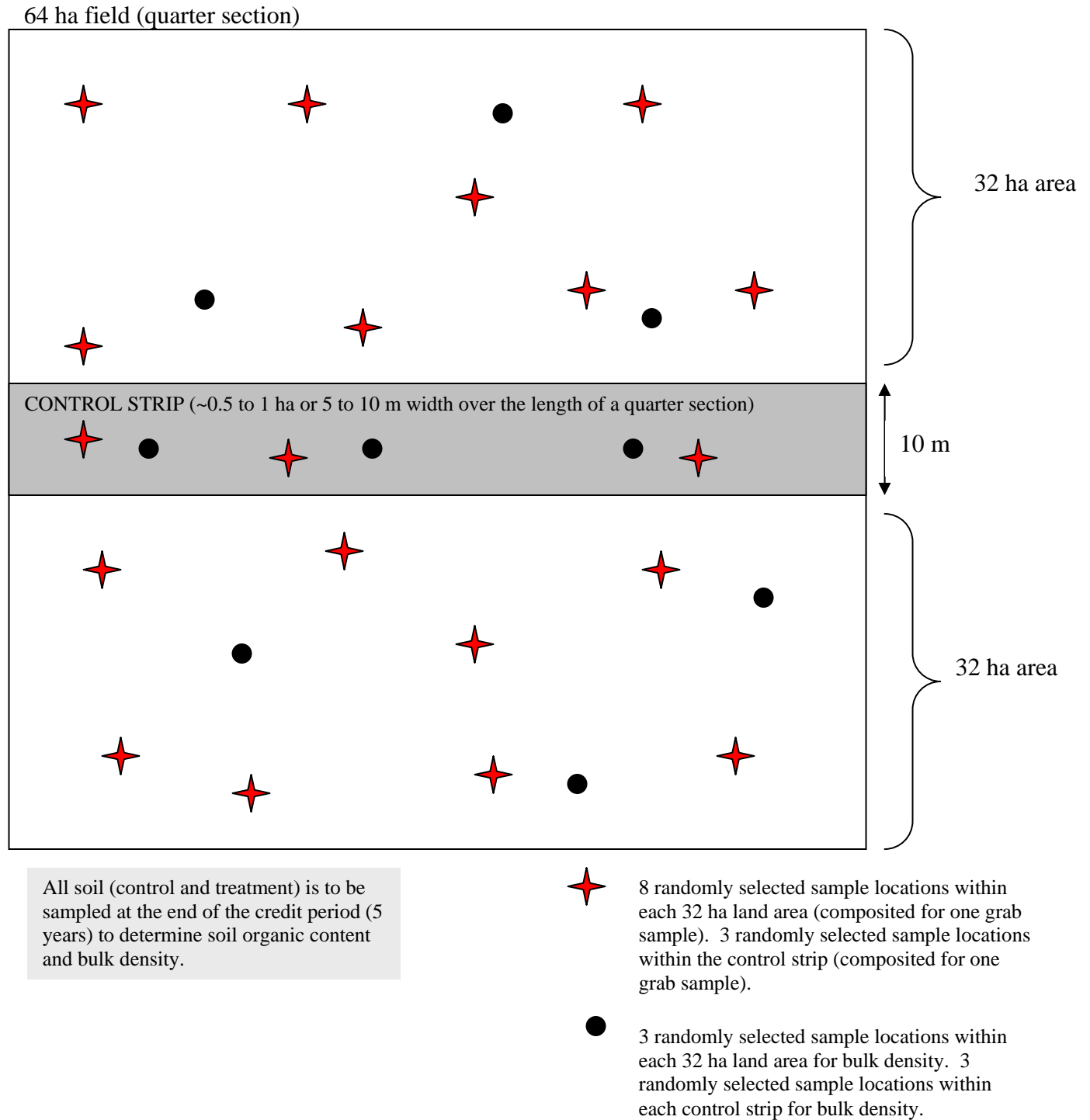
| Baseline SS's   |   |                              |                             |   |                |                            |   |
|---|---|------------------------------|-----------------------------|---|----------------|----------------------------|---|
| Project/<br>Baseline  | Parameter/<br>Variable                        | Unit                         | Measured<br>or<br>Estimated | Method  | Sample<br>Size | Frequency                  | Justify Measurement<br>or Estimation or<br>Frequency  |
| $Gi = Mi * k * Lo * \exp^{-k*Ti}$ Where: $Lo = MCF * DOC * DOC_F * F(16/12) * (1000 \text{ kg CH}_4/\text{t CH}_4)$ (IPCC/OECD/IEA, 1997)   |   |                              |                             |   |                |                            |   |
| <b>B9 Landfill Operations</b>   | Gi = generation rate                          | kg CH <sub>4</sub> /yr       | Estimated                   | Scholl Canyon model (IPCC / Environment Canada guidelines)    | N/A            | Annual                     | Quantity being calculated   |
|   | Mi = mass of wet sludge                       | Mg                           | Measured                    | Direct measurement of amount of sludge going to landfill      | N/A            | Continuous                 | May be measured when loaded or delivered to site  |
|   | k = CH <sub>4</sub> generation rate           | CH <sub>4</sub> /yr          | Estimated                   | NCASI, 2003 default = 0.03/yr                                 | N/A            | N/A                        | Default value for k based on NCASI (2003) report  |
|   | Ti = age of landfill                          | Years                        | Measured                    | Age of sludge diverted from landfill                          | N/A            | Continuous                 | CH <sub>4</sub> generated over credit period  |
|   | Lo = generation                               | kg CH <sub>4</sub> /t sludge | Estimated                   | IPCC/Environment Canada                                       | N/A            | Continuous                 | Represents amount of CH <sub>4</sub>  |
|   | MCF = CH <sub>4</sub> correction              | 0.8                          | Estimated                   | IPCC/Environment Canada                                       | N/A            | Continuous                 | Correction factor accounts for difference between managed/unmanaged sites                                     |
|   | DOC=degradable organic fraction               | wood waste=0.3               | Estimated                   | Environment Canada Greenhouse Gas Inventory, 2004             | N/A            | Continuous                 | Represents the amount of degradable organic carbon  |
|   | DOC <sub>F</sub>                              | 0.5                          | Estimated                   | Environment Canada Greenhouse Gas Inventory, 2004             | N/A            | Continuous                 | Fraction of DOC dissimilated  |
|   | F=fraction of CH <sub>4</sub> in landfill gas | F=0.4 to 0.6                 | Estimated                   | Environment Canada Greenhouse Gas Inventory, 2004             | N/A            | Continuous                 | Value of 0.5 was chosen   |
| Sludge combustion $CO_2 \text{ equiv} = \text{BDT sludge} * \% \text{ carbon} * \text{MW } CO_2/\text{MW Carbon}$ (assuming complete combustion)<br>$N_2O = t_{\text{sludge}} * (t \text{ N} / t_{\text{sludge}}) * (44 \text{ t} \cdot \text{mol } N_2O / 28 \text{ t} \cdot \text{mol } N_2)$ |   |                              |                             |   |                |                            |   |
| <b>B12 Incineration</b>   | BDT sludge                                    | Mg dry sludge                | Measured                    | Direct measurement of sludge produced                         | N/A            | Continuous                 | Mill records of produced sludge   |
|   | % carbon                                      | Mg C/Mg dry sludge           | Measured                    | Analysis by total combustion and infrared detection           | N/A            | Continuous or with process | Determine carbon content of sludge incinerated  |
|   | CO <sub>2</sub> equivalent                    | 44/12                        | Measured                    | Stoichiometric factor to convert Mg carbon to CO <sub>2</sub> | N/A            | Continuous                 | Factor to convert carbon to CO <sub>2</sub>   |
| <b>B10 N<sub>2</sub>O Emissions</b>   | N <sub>2</sub> O emissions                    | t N <sub>2</sub> O           | Measured                    | Environment Canada Greenhouse Gas Inventory, 2004             | N/A            | continuous                 | Amount of N in sludge converted to N <sub>2</sub> O by stoichiometric factor to convert N to N <sub>2</sub> O |

**Table 2.5. (Continued) Quantification Procedures – Agricultural Sludge Utilization**

| Project and Baseline SS's  |   |  |                             |  |                |            |  |
|--|---|--|-----------------------------|--|----------------|------------|--|
| Project/<br>Baseline   | Parameter/<br>Variable                        | Unit   | Measured<br>or<br>Estimated | Method   | Sample<br>Size | Frequency  | Justify Measurement<br>or Estimation or<br>Frequency   |
| Flash Dryer Natural Gas Usage $t\ CO_{2\text{equiv}} = Mg\ \text{wet sludge} * 5.62\ GJ/Mg\ \text{wet} * m^3 / 0.03723\ GJ * 1.902\ kg\ CO_{2\text{equiv}} * Mg\ CO_{2\text{equiv}} / 1000\ kg\ CO_{2\text{equiv}}$  |   |  |                             |  |                |            |  |
| <b>B11 Flash<br/>Dryer</b>   | Wet sludge                                    | Mg wet   | Measured                    | Direct measurement of amount of sludge to dryer                    | N/A            | Continuous | Determined from ratio of pulp to produced sludge   |
|  | Natural gas usage                             | Gj/Mg Wet  | Measured                    | Metered gas usage to flash dryer                                   | N/A            | Annual     | Natural gas usage for flash dryer  |
|  | Conversion of Gj to m <sup>3</sup> equivalent | m <sup>3</sup>                                   | Estimated                   | Natural resources Canada, issues table (1998-1999)                 | N/A            | Continuous | Factor to convert Gj natural gas to m <sup>3</sup>   |
|  | GHG emission factor                           | 1.902 kg e /m <sup>3</sup>                       | Estimated                   | Environment Canada Greenhouse Gas Inventory, 2004                  | N/A            | Continuous | Factor to convert m <sup>3</sup> natural gas used in flash dryer to CO <sub>2</sub> equivalent |
| CO <sub>2</sub> emissions $t\ CO_{2\text{equiv}} = t\ \text{sludge} * (\% \text{ solid}/100) * (21.1\ GJ\ HHV / t\ \text{dry sludge}) * (TJ\ HHV/1000\ GJ) * (104 * 10^3\ kg\ CO_2/TJ\ HHV) * (t\ CO_2 / 1000\ kg)$<br>Methane emissions $CH_4 = TJ\ HHV * (30\ kg\ CH_4/TJ\ HHV)$<br>Nitrous oxide emissions $N_2O = TJ\ HHV * (4\ kg\ N_2O / TJ\ HHV)$ |   |  |                             |  |                |            |  |
| <b>B13 Beehive<br/>Burner</b>  | BDT sludge                                    | Mg dry sludge                                    | Measured                    | Direct measurement of sludge produced                              |                | Continuous | Mill records of produced sludge  |
|  | Heat content                                  | 21.1 Gj (HHV/Mg) dry solids                      | estimated                   | Tier 1 emission factors, NCASI, 2005                               | N/A            | continuous | based on heat content of 21.1 Gj (HHV/Mg)  |
|  | CO <sub>2</sub> emissions                     | 104 * 10 <sup>3</sup> kg CO <sub>2</sub> /TJ HHV | estimated                   | Tier 1 emission factors, NCASI, 2005                               | N/A            | continuous | CO <sub>2</sub> emission factor from biomass combustion  |
|  | CH <sub>4</sub> emissions                     | 30 kg CH <sub>4</sub> /TJ HHV                    | estimated                   | Tier 1 emission factors, NCASI, 2005                               | N/A            | continuous | CH <sub>4</sub> emission factor from biomass combustion  |
|  | N <sub>2</sub> O emissions                    | 4 kg N <sub>2</sub> O/TJ HHV                     | estimated                   | Tier 1 emission factors, NCASI, 2005                               | N/A            | continuous | N <sub>2</sub> O emission factor from biomass combustion                                       |
| <b>P2/B2 Sludge<br/>Transportation</b>   | combustion emission factor for fuel           | T CO <sub>2</sub> e /L                           | estimated                   | Use data from Canada's GHG Inventory for Heavy Duty Diesel Vehicle | N/A            | annually   | Use truck haul records of haul distance, running hours, or actual fuel records                 |

**Table 2.5. (Concluded) Quantification Procedures – Agricultural Sludge Utilization**

| Project SS's  |                        |                   |   |  |  |  |  |
|---|------------------------|-------------------|---|--|--|--|--|
| Project/<br>Baseline  | Parameter/<br>Variable | Unit              | Measured/<br>Estimated                                    | Method   | Sample Size  | Frequency  | Justify<br>Measurement or<br>Estimation or<br>Frequency                            |
| Sequestration below ground carbon reservoir = SOC% x bulk density (g/cm <sup>3</sup> ) x sample depth (cm)                                    |                        |                   |   |  |  |  |  |
| <b>P17 Soil Organic Carbon Reservoir</b><br><br>(Emission reductions from soil carbon addition and accumulations, Mg CO <sub>2</sub> e/ha/yr) | Soil bulk density      | g/cm <sup>3</sup> | Measured using core sample of known volume and dry weight | Collect samples to a depth of 30 cm, using bulk density sampler and dry to constant weight               | Sample minimum of 3, GPS referenced sample locations in each 32 ha area to confirm bulk density at end of credit period                | At the end of each 5 year credit allocation period | Representative sample to account for variability in receiving soil characteristics |
|   | Soil organic carbon    | %                 | Measured  | Using soil from bulk density sample measure SOC by total carbon by LECO furnace (Leco Corporation, 1993) | Minimum 8 randomly selected, GPS referenced sample locations within each 32 ha treatment area composited for one grab sample           | At the end of each 5 year credit allocation period | 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  |
| <b>B17 Soil Organic Carbon Reservoir</b><br><br>(Emission reductions from soil carbon addition and accumulations, Mg CO <sub>2</sub> e/ha/yr) | Soil bulk density      | g/cm <sup>3</sup> | Measured using core sample of known volume and dry weight | Collect samples to a depth of 30 cm, using bulk density sampler and dry to constant weight               | Minimum of 3 randomly selected, GPS referenced, individual sample locations within each control strip to confirm baseline bulk density | At the end of each 5 year credit allocation period | Representative sample to account for variability in receiving soil characteristics |
|   | Soil organic carbon    | %                 | Measured  | Using soil from bulk density sample measure SOC by total carbon by LECO furnace (Leco Corporation, 1993) | Minimum of 3 randomly selected, GPS referenced sample locations within each control strip and composited for one grab sample           | At the end of each 5 year credit allocation period | For calculation of soil organic carbon content area to be treated with sludge      |
|   | Area treated           | ha                | Measured  | Field survey or map  | N/A  | Initial survey of treated area                     | For determination of total credit  |



**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.

## 2.5.2 Contingent Data

A contingent way for calculating or estimating the carbon offsets from land application of mechanical pulp mill sludge is summarized in TABLE 2.6. The carbon offsets generated by not landfilling or incinerating sludge would be calculated as outlined in TABLE 2.5.

The quantification methods outlined in TABLE 2.6 can be applied to areas where no control strip has been established for comparison measurements. Appropriate time and date stamped operational records are required to verify the amount of sludge hauled and applied to each designated section of land.

A range of soil carbon and bulk density data for soil regions in northern Alberta can be found in Appendix A, further research will be required to extrapolate this quantification method to other regions of the province and country. When using this quantification approach the protocol user is required to consult the appropriate soil survey maps and other relevant information sources (references listed in Appendix A) to determine the most appropriate soil organic carbon content and bulk density values to use in the calculations. Only the below ground soil organic carbon reservoir can be quantified with this approach.

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Landfill Operations}} + \text{Emissions}_{\text{Sludge N}_2\text{O}} + \text{Emissions}_{\text{Flash Dryer}} + \text{Emissions}_{\text{Incineration}} + \text{Emissions}_{\text{Beehive Burner}} + \text{Emissions}_{\text{Sludge Transportation}} + [(-\text{Emissions}_{\text{Carbon sequestration}}) \times \text{Assurance Factor}]$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Sludge Transportation}} + [(-\text{Emissions}_{\text{Carbon sequestration}}) \times \text{Assurance Factor}]$$

Where:

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

$\text{Emissions}_{\text{Landfill Operations}}$  = Emissions under B9 Landfill Operations

$\text{Emissions}_{\text{Sludge N}_2\text{O}}$  = Emissions under B10 Sludge N<sub>2</sub>O Emissions

$\text{Emissions}_{\text{Flash Dryer}}$  = Emissions under B11 Flash Dryer

$\text{Emissions}_{\text{Incineration}}$  = Emissions under B12 Incineration

$\text{Emissions}_{\text{Beehive Burner}}$  = Emissions under B13 Beehive Burner

$\text{Emissions}_{\text{Sludge Transportation}}$  = Emissions under SS B2 Sludge Transportation

$\text{Emissions}_{\text{Carbon sequestration}}$  = Sequestration under SS B17 (Soil Organic Carbon Reservoir in upper 30 cm of soil)

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

Emissions<sub>Project</sub> = sum of emissions under the project condition

Emissions<sub>Sludge Transportation</sub> = Emissions under SS P2 Sludge Transportation

Emissions<sub>carbon sequestration</sub> = Sequestration under SS P17 (Soil Organic Carbon Reservoir in upper 30 cm of soil)

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

See Appendix C for an example calculation.

**Table 2.6. Contingent Data Collection and Quantification Procedures – Agricultural Sludge Utilization.**

| Project/<br>Baseline   | Parameter/<br>Variable     | Unit                     | Measured/<br>Estimated | Method  | Sample<br>Size | Frequency  | Justify Measurement or<br>Estimation or Frequency   |
|--|----------------------------|--------------------------|------------------------|---|----------------|--|---|
| $X * \text{Sludge}_{\text{carbon}} + Y * \text{Soil}_{\text{carbon}} = \text{final mix}_{\text{carbon}}$ ‡ |                            |                          |                        |   |                |  |   |
| <b>P17 Soil<br/>Organic<br/>Carbon<br/>Reservoir</b>   | Sludge application<br>rate | Mg/ha                    | Measured               | Operational records   | N/A            | Continuous   | Rate of application determines<br>carbon loading  |
|  | Sludge wet bulk<br>density | Wet<br>Mg/m <sup>3</sup> | Measured               | Operational records   | N/A            | Continuous or<br>to reflect<br>process change            | Wet bulk density and moisture<br>content of applied sludge to<br>determine application rate |
|  | Sludge moisture<br>content | % solids                 | Measured               | Operational records   | N/A            |  |   |
|  | Sludge carbon<br>content   | %<br>Carbon              | Measured               | Operational records   | N/A            |  | Carbon content of dry sludge to<br>calculate applied carbon equivalent                      |
|  | Soil bulk density          | g/cm <sup>3</sup>        | Estimated              | Estimation from<br>published soil survey<br>data (Appendix A) | N/A            | Check for<br>updates or site<br>specific<br>measurements | Soil bulk density information related<br>to established soil series                         |
|  | Soil carbon content        | %<br>carbon              | Estimated              | Estimation from<br>published soil survey<br>data (Appendix A) | N/A            | Check for<br>updates or site<br>specific<br>measurements | Carbon content information related<br>to soil survey data                                   |
|  | Soil/Sludge mix<br>depth   | cm                       | measured               | Calculate using<br>concentration x mass<br>relations          | N/A            | Continuous   | Calculate based on 30 cm depth for<br>comparison to baseline condition<br>(30 cm depth)     |
| $t \text{ Carbon} = \text{bulk density} * \text{depth} * (\% \text{Carbon}/100) * \text{area}$             |                            |                          |                        |   |                |  |   |
| <b>B17 Soil<br/>Organic<br/>Carbon<br/>Reservoir</b>   | Soil Bulk Density          | g/cm <sup>3</sup>        | Estimated              | Estimation from<br>published soil survey<br>data (Appendix A) | N/A            | Check for<br>updates or site<br>specific<br>measurements | Soil bulk density information related<br>to established soil series                         |
|  | Soil carbon content        | %<br>carbon              | Estimated              | Estimation from<br>published soil survey<br>data (Appendix A) | N/A            | Check for<br>updates or site<br>specific<br>measurements | Carbon content information related<br>to soil survey data                                   |
|  | Soil Depth                 | cm                       |                        | Calculate using<br>concentration x mass<br>relations          | N/A            | continuous   | Calculate based on 30 cm depth for<br>comparison  |

‡ Using simple mass relations, an approximation of carbon in the final soil mix can be obtained as follows:

Let X = proportion of sludge in the final mix:  $X = (\text{Sludge (Mg/ha)}) / (\text{Sludge (Mg/ha)} + \text{Soil (Mg/ha)})$

Let Y = proportion of soil in the final mix:  $Y = (\text{Soil (Mg/ha)}) / (\text{Sludge (Mg/ha)} + \text{Soil (Mg/ha)})$

Where: Sludge (Mg/ha) = application rate (Mg<sub>dry sludge</sub>/ha)

Soil (Mg/ha) = soil depth (cm) \* bulk density (g/cm<sup>3</sup>) \* Area (10 000 m<sup>2</sup>/ha)

Soil depth = incorporation depth (cm) – sludge depth (cm)

Therefore: Carbon content of final mix = X \* Sludge<sub>carbon</sub> + Y \* Soil<sub>carbon</sub> = final mix<sub>carbon</sub>

Then: Mg C/ha = (Mg Carbon/Mg mix) \* Mg mix/ha

## 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

Generators that distribute mechanical pulp sludge for the purposes of land application are to document and retain the following information for a minimum of 10 years:

- a) Name, address, and phone number of the land owner, company, or individual using the sludge.
- b) Legal land description of all areas of sludge application.
- c) Quantity of sludge issued to each user.
- d) Sample location, timing and name of qualified individuals conducting the sampling program.
- e) Written logs of all field measurements and observations.
- f) Electronic files of all raw and calculated data.
- g) Blanks, duplicates, and internal standard tracking for all analytical data.
- h) 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.
  - Collection, analyses of samples and reporting should be conducted by qualified personnel in accordance with the following documents:
    - i. *Soil Sampling and Methods of Analysis*, Carter, M. (ed.), Lewis Publishers, 1993, Boca Raton, Florida.

ii. *Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land*, Alberta Environmental Protection, 1999.

- 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

### Fuel Use – Sludge Transportation

$$\text{Emissions}_{\text{Sludge Transportation}} = (\text{L fuel} * 2730 \text{ g CO}_2/\text{L}) + ((\text{L fuel} * 0.15 \text{ g CH}_4/\text{L}) * 21) + ((\text{L fuel} * 0.08 \text{ g N}_2\text{O}/\text{L}) * 310) = \text{g CO}_2 \text{ equivalent}$$

Fuel Economy factors

$$\text{g CO}_2/\text{L fuel used} = 2730$$

$$\text{g CH}_4/\text{L fuel used} = 0.15$$

$$\text{g N}_2\text{O}/\text{L fuel used} = 0.08$$

or

$$\text{Emissions}_{\text{Sludge Transportation}} = (\text{km} * 33.6 \text{ L}/100\text{km} * 2730 \text{ g CO}_2/\text{L}) + ((\text{km} * 33.6 \text{ L}/100\text{km} * 0.15 \text{ g CH}_4/\text{L}) * 21) + ((\text{km} * 33.6 \text{ L}/100\text{km} * 0.08 \text{ g N}_2\text{O}/\text{L}) * 310) = \text{g CO}_2 \text{ equivalent}$$

$$\text{Diesel heavy truck} = 33.6\text{L}/100 \text{ km}$$

Greenhouse Gas Potential

$$\text{CO}_{2e} = \text{N}_2\text{O} * 310$$

$$\text{CO}_{2e} = \text{CH}_4 * 21$$

Source:

*Canada's Greenhouse Gas Inventory, 2004, Environment Canada*

### Landfill Emissions

CH<sub>4</sub> emissions from landfilling pulp sludge (IPCC/OECD/IEA, 1997) calculated using the Scholl Canyon Model (IPCC/OECD/IEA, 1997) which is used to estimate methane generation from landfills using 1st order decay equation,

$$G_i = M_i * k * L_o * \exp^{-k * t_i}$$

Where:       $G_i$  = generation rate (kt CH<sub>4</sub>/yr)  
               $M_i$  = mass of sludge (Mt)  
               $k$  = CH<sub>4</sub> generation constant (/yr)  
               $L_o$  = CH<sub>4</sub> generation potential (kg CH<sub>4</sub>/t sludge)  
               $T_i$  = age of material in landfill (years)

$$L_o = \text{MCF} * \text{DOC} * \text{DOC}_F * F(16/12) * (1000 \text{ kg CH}_4/\text{t CH}_4)$$

Where:       $\text{MCF}$  = CH<sub>4</sub> correction factor (0.8)  
               $\text{DOC}$  = degradable organic carbon (3)

$DOC_F$  = fraction of DOC dissimilated (0.5)  
 $F$  = fraction of  $CH_4$  in landfill gas (0.5)  
 16/12 = stoichiometric factor to convert  $CH_4$  to carbon

$$Lo = 0.8 * 3 * 0.5 * 0.5 (16/12)^{1.33} * 1000 = 80 \text{ kg } CH_4 / \text{ t sludge}$$

$MCF$  =  $CH_4$  correction factor (fraction = 0.8 (IPCC/OECD/IEA, 1997))  
 $DOC$  = degradable organic carbon (t C/t sludge = 0.3\*100 (fraction of waste that is wood) = 3)  
 $DOC_F$  = fraction of degradable organic carbon dissimilated = 0.5 (IPCC/OECD/IEA, 1997)  
 $F$  = fraction of  $CH_4$  in landfill gas = 0.5

The fraction of degradable organic carbon represents the amount of organic carbon that is accessible to biochemical decomposition, therefore assuming 100% wood composition the  $DOC$  value =3

### **Incineration**

Assuming complete combustion, carbon is converted to  $CO_2$  and nitrogen is converted to  $N_2O$

$$CO_2 \text{ equiv} = \text{BDT sludge} * \% \text{ carbon} * \text{MW } CO_2 / \text{MW Carbon}$$

*Canada's Greenhouse Gas Inventory, 2004, Environment Canada*

### **$N_2O$ Emissions**

Assuming all nitrogen contained in the sludge gets converted to  $N_2O$

$$N_2O = t_{\text{sludge}} * (t \text{ N} / t_{\text{sludge}}) * (44 t \cdot \text{mol } N_2O / 28 t \cdot \text{mol } N_2) * 310 CO_2 \text{ equiv}$$

*Canada's Greenhouse Gas Inventory, 2004, Environment Canada (IPCC/OECD/IEA 1997)*

### **Flash Dryer – Natural Gas Usage**

$$CO_2 \text{ equivalent} = t_{\text{wet sludge}} * (\text{GJ nat.gas} / t_{\text{wet sludge}}) * (m^3 / 0.03723 \text{ GJ}) * (1.902 \text{ kg } CO_2e / m^3 \text{ nat.gas}) * (t \text{ } CO_2e / 1000 \text{ kg } CO_2e)$$

Energy content of Natural Gas = 0.03723 GJ/ $m^3$  (National Inventory Report (1990-2004 - Greenhouse Gas Sources and Sinks in Canada))

Emission Factor = 1.902 kg  $CO_2e/m^3$  of natural gas (National Inventory Report (1990-2004 - Greenhouse Gas Sources and Sinks in Canada))

Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Product Facilities] (Prepared for ICFPA by NCASI 2005)).

### **Beehive Burner Emissions**

CH<sub>4</sub> Emission factor for wood, wood residuals and other biomass wastes = 30 kg/TJ HHV (NCASI 2005)

N<sub>2</sub>O Emission factor for wood, wood residuals and other biomass wastes = 4 kg/TJ HHV (NCASI 2005)

Calculations based on heat content of 21.1 GJ (HHV)/tonne of dry solids

Emission Factor =  $104 * 10^3$  kg CO<sub>2</sub>/ TJ HHV (NCASI 2005)

#### **C0<sub>2</sub> emissions**

$t \text{ CO}_{2e} = t \text{ dry sludge} * (\% \text{ solid}/100) * (21.1 \text{ GJ HHV}/t \text{ dry sludge}) * (1 \text{ TJ HHV}/1000\text{GJ HHV}) * (104 * 10^3 \text{ kg CO}_2/\text{TJ HHV}) * (1 \text{ t CO}_2 /1000 \text{ kg CO}_2)$   
(IPCC/OECD/IEA, 1997)

#### **Methane emissions**

$\text{CH}_4 = (\text{tonnes}_{\text{sludge}} * (21.1 \text{ GJ HHV}/ \text{tonne}_{\text{sludge}}) * (1 \text{ TJ HHV}/1000 \text{ GJ HHV}) * (30 \text{ kg CH}_4/\text{TJ HHV})$

Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Product Facilities] (Prepared for ICFPA by NCASI 2005)).

#### **Nitrous Oxide emissions**

$\text{N}_2\text{O} = (\text{tonnes}_{\text{sludge}} * (21.1 \text{ GJ HHV}/ \text{tonne}_{\text{sludge}}) * (1 \text{ TJ HHV}/1000 \text{ GJ HHV}) * (4 \text{ kg N}_2\text{O}/\text{TJ HHV})$

Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Product Facilities] (Prepared for ICFPA by NCASI 2005)).

### **Table A1. Soil Organic Carbon and Bulk Density Values**

| Soil Group                     | Horizon* | Organic Carbon (%)** | Bulk Density (Mg/m3)** |
|--------------------------------|----------|----------------------|------------------------|
| Dark Gray and Dark Gray Wooded | Ap       | 3.5 to 12.0          | 0.60 to 1.0            |
|                                | B        | 0.5 to 2.0           | 0.90 to 1.4            |
| Gray Wooded                    | Ap       | 1.5 to 6.0           | 0.60 to 1.0            |
|                                | B        | 0.2 to 1.2           | 0.90 to 1.4            |

\* Ap – defined as upper 15 cm of soil and representative of zone of incorporation  
 B – Defined as 15 to 30 cm of soil representing mineral zone below Ap (could include portions of Ae, AB and B horizons)

\*\* Values based on data generated from field research trials resulting from sampling associated with operational sludge spreading programs in the vicinity of Whitecourt, Slave Lake and published soil survey data.

Dumanski, J., Macyk, T.M, Veaury, C.F, and J.D. Lindsay. 1972. Soil survey and land evaluation of the Hinton-Edson area, Alberta. Alberta Institute of Pedology Report No. S-72-31. 1972.

Wynnyk, A., Lindsay, J.D., and W. Odynsky. 1969. Soil survey of the Whitecourt and Barrhead area. Alberta Soil Survey Report No. 27, 1969.

Kyearsgaard, A. 1972. Soil survey of the Tawatinaw map sheet (83-I). Alberta Institute of Pedology Report No. S-72-29. 1972.

Pedocan Land Evaluation Ltd. 1993. Soil series information for reclamation planning in Alberta. Alberta Conservation and Reclamation Council Report No. RRTAC 93-7. ISBN 0-7732-6041-2.

Alberta Agriculture and Rural Development. 2008. Agricultural Region of Alberta Soil Inventory Database (AGRASID 3.0)  
[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/sag3252?opendocument](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3252?opendocument)

## **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.

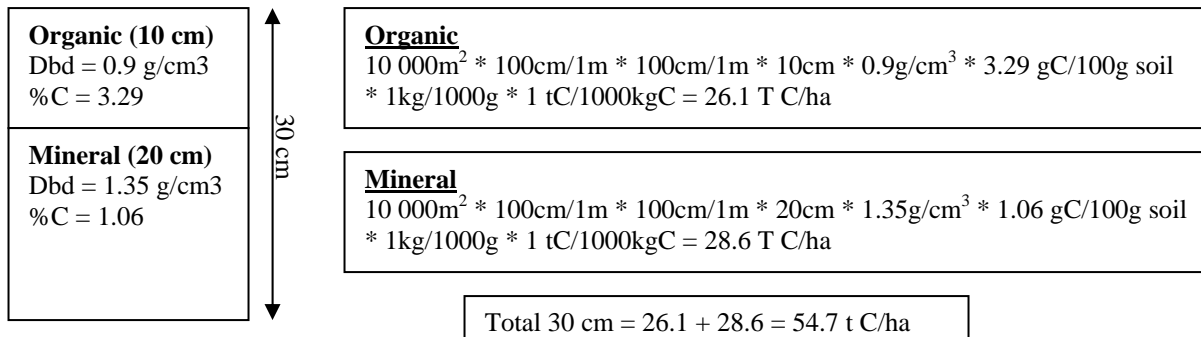
Based on the analysis of available data from 15 years of research of sludge utilization on agricultural land, a reasonable assurance factor would exceed 90%. For the purposes of this protocol and until more operational data is available, a 90% assurance factor was deemed reasonable.

### **Development of Assurance Factors for Contingent Quantification Approach**

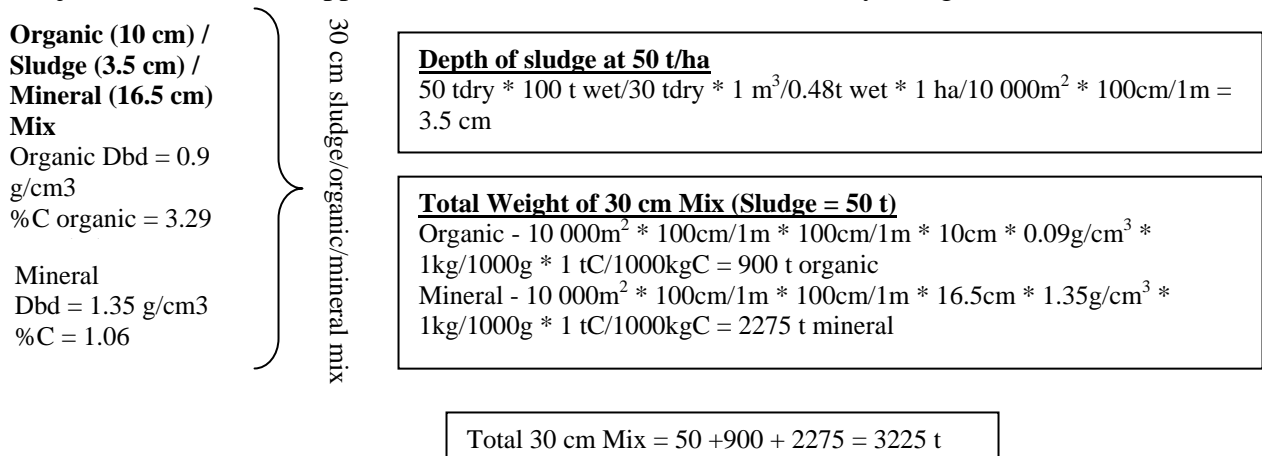
An assurance factor of 80% was deemed reasonable for the quantification approach used in the contingent data section (2.5.2). A factor of 20% variability should account for the range in bulk density and soil organic carbon in the receiving soil for the purposes of quantification.

## **Appendix C. Example Calculation for Contingent Data Quantification Method**

Baseline (t carbon/ha in upper 30 cm of soil)



Project (t carbon/ha in upper 30 cm of soil after addition of 50 t dry sludge/ha)



**t C/ha/30 cm mix =**

$$\frac{(\text{t sludge} * \% \text{ C}/100)}{\text{t mix}} + \frac{(\text{t organic} * \% \text{ C}/100)}{\text{t mix}} + \frac{(\text{t mineral} * \% \text{ C}/100)}{\text{t mix}} * \text{t Mix}$$

$$= (50*(45/100)/3225) + (900*(3.29/100)/3225) + (2275*(1.06/100)/3225) * 3225$$

$$= 76\text{ t C}/\text{ha} / 30\text{ cm mix}$$

**Emission Reduction = 54.7 t C/ha – 76 t C/ha = -21.3 t C/ha (or 78.1 t CO<sub>2</sub>e/ha)**