QUANTIFICATION PROTOCOL FOR
GRAVEL AND LIGHTLY SURFACED ROAD REHABILITATION PROJECTS

Submitted to:

Alberta Environment

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for the project developer completing gravel and lightly surfaced road rehabilitation. The process involves recovering aggregate (without damaging the original road bed material – ie. crushing aggregate) from the existing road bed, mixing the materials to replenishing the design mix ratio and re-depositing the material forming a completely rehabilitated road surface. Some new material may also be required for the rehabilitation. This protocol is written assuming some familiarity with, or general understanding of, road maintenance and rehabilitation.

The opportunity for generating carbon offsets with this protocol arises from the direct and indirect reductions of greenhouse gas (GHG) emissions by reducing the use of fossil-fuel derived energy during the rehabilitation of gravel and lightly surfaced roads. Under traditional rehabilitation, an incremental volume of aggregate or aggregate and binder (or other additive - hereafter referred to collectively as binder), would be laid on top of the existing road bed, requiring significant fossil fuel use from the sourcing, processing and transportation of these materials. Projects applying this protocol achieve fuel savings from the recycling of the recovered, processed aggregate from the existing road bed, reducing the amount of aggregate and binder needing to be sourced, processed and transported to the project site.

1.1 Protocol Scope and Description

Typically, roads in need of rehabilitation are simply covered up with a new surface, consisting of 1.5 to 6 inches of new materials. The mining and transportation of aggregate or aggregate and binder for gravel or lightly surfaced roads produces greenhouse gas emissions, mainly through the combustion of fossil fuels to run excavation, processing and transportation equipment.

The project condition is the use of road rehabilitation equipment, which results in the recycling of the aggregate without significant stone fracturing or base contamination. Under this process, the existing road material is cut, separated and loosened from its base. This equipment should not fracture or damage the aggregate, minimizing the need for additional materials. This material is then retrieved, mixed with a small amount of new material if necessary, and re-laid forming a rehabilitated road surface. The reduction in the amount of new material used in the road rehabilitation process provides a reduction in the greenhouse gas emissions associated with the production and transportation of the aggregate or aggregate and binder used in road resurfacing. If sand, gravel or crushed stone are used as aggregate, the emissions factor as stated in the calculator is used. If other recycled or reclaimed materials are used, they are assumed to have no emissions associated with their production and are therefore not included in the calculations.

FIGURE 1.1 offers a process flow diagram for a typical project.

FIGURE 1.1: Process Flow Diagram for Project Condition

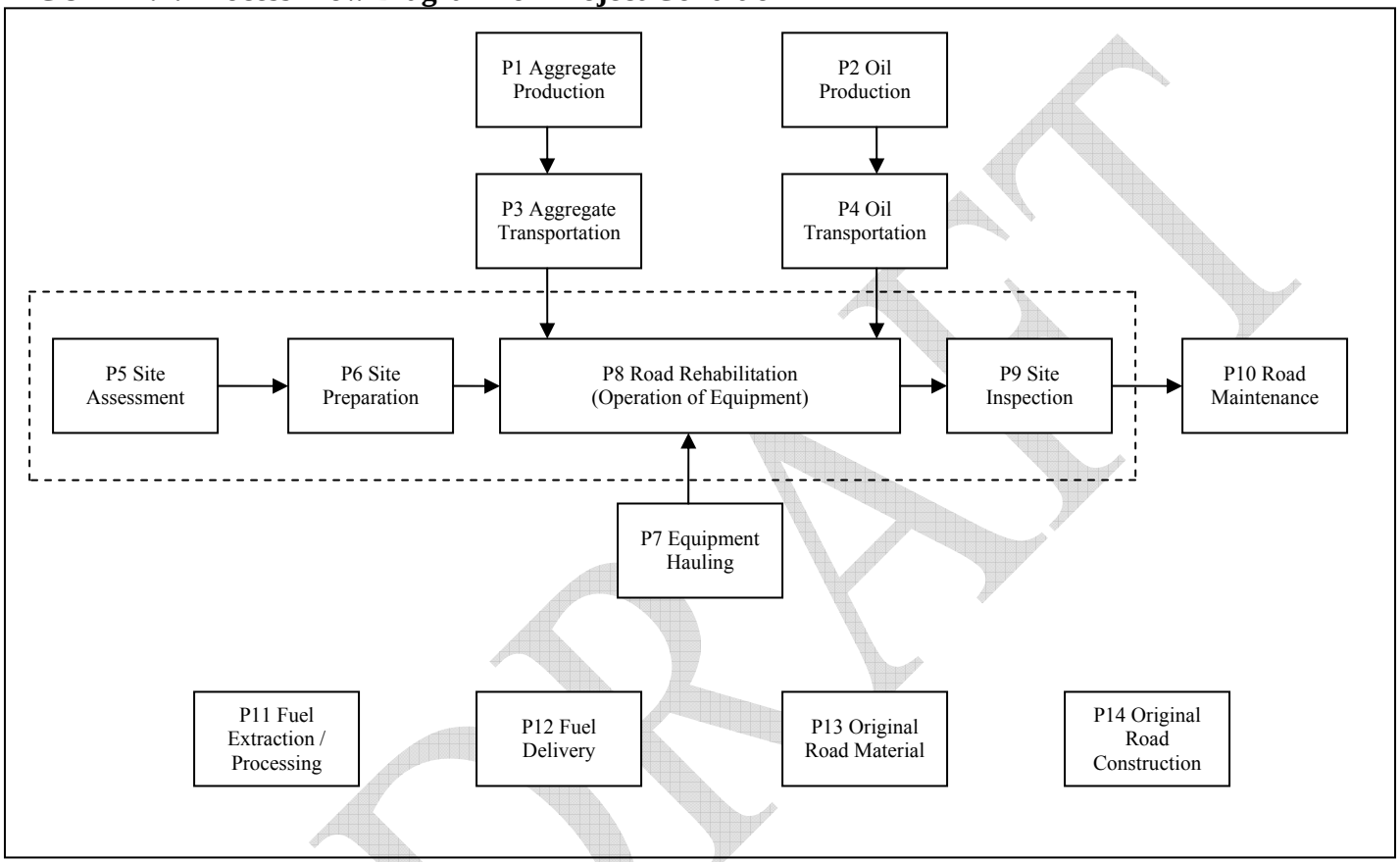
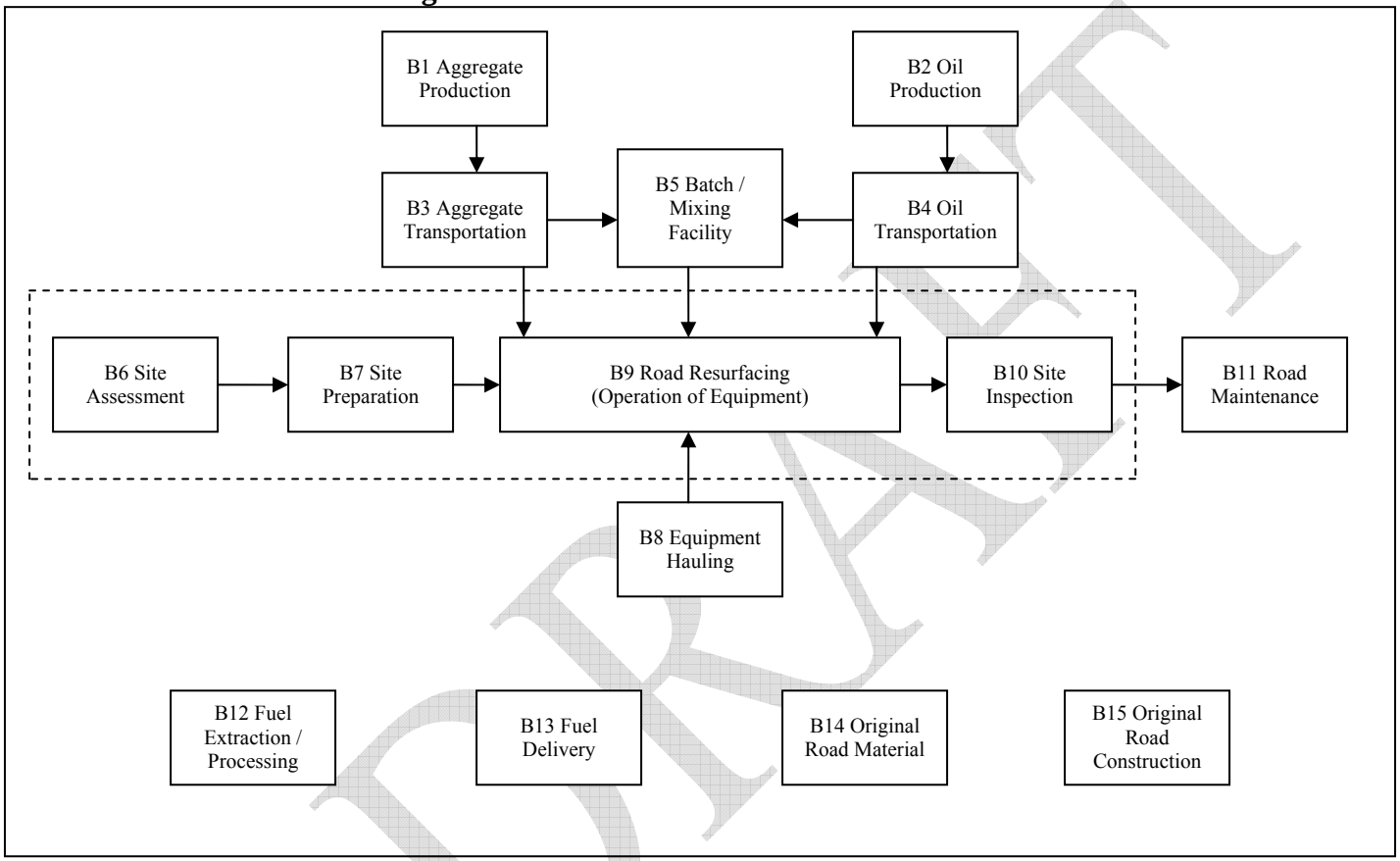


FIGURE 1.2: Process Flow Diagram for Baseline Condition



Protocol Approach:
The baseline condition for the road rehabilitation protocol is the resurfacing of the road using all new materials (aggregate or aggregate and binder). The production and transportation of the new material requires energy derived from the mining and combustion of fossil fuels. In the baseline condition, it is assumed that the aggregate used is either sand, gravel or crushed stone.

FIGURE 1.2 offers a process flow diagram for a typical baseline configuration.

Protocol Applicability
To meet the requirements under this protocol, the project developer must supply sufficient evidence to demonstrate that:

1. The project involves the recovery, recycling and re-depositing of the materials from existing gravel and lightly surfaced roads, including some supplementation with new materials, as part of the rehabilitation of the road;
2. The rehabilitated road meets or exceeds the specifications for traditional resurfacing as dictated by the relevant standard (i.e. guideline or building code); and
3. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

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

1. The calculation of aggregate transportation distances may employ regional average distances from a mining site, if sufficient evidence can be provided; and

2. Site specific emission factors and other project specific factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy.

The project proponent must be able to justify their approach in detail to apply any of these flexibility mechanisms.

1.2 Glossary of New Terms

The following definitions are critical to the appropriate interpretation of this quantification protocol.

Aggregate:	For the purposes of this protocol document, aggregate is any mass of hard, inert materials used for its load-bearing capacity. Aggregate can include natural rock or mineral fragments (e.g. gravel, crushed stone), as well as artificial, reclaimed or recycled materials.
Batch / Mixing Facility:	For the purposes of this protocol document, a batch / mixing facility is a facility where the aggregate and binder are mixed together to produce the mix for a cold mix road before being transported to the site.
Binder:	A substance with adhesive properties added to form dry ingredients into a solid mass (examples: Asphalt, Calcium Chloride, Lignum, etc.).
Lightly Surfaced Road:	Unpaved roads with controlled alignment, defined width, cross-section profile, and drainage.
Rehabilitation:	For the purposes of this protocol document, rehabilitation is the process by which a road is broken up and its material is re-used for its rehabilitation, using equipment and methodologies equivalent to those developed by Road Badger. This process may also include the use of some new materials.

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

SS's were identified for the project by reviewing the relevant process flow diagrams, consulting with stakeholders (i.e. project proponents) and reviewing the good practice guidance. This iterative process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided in **FIGURE 1.1**, 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

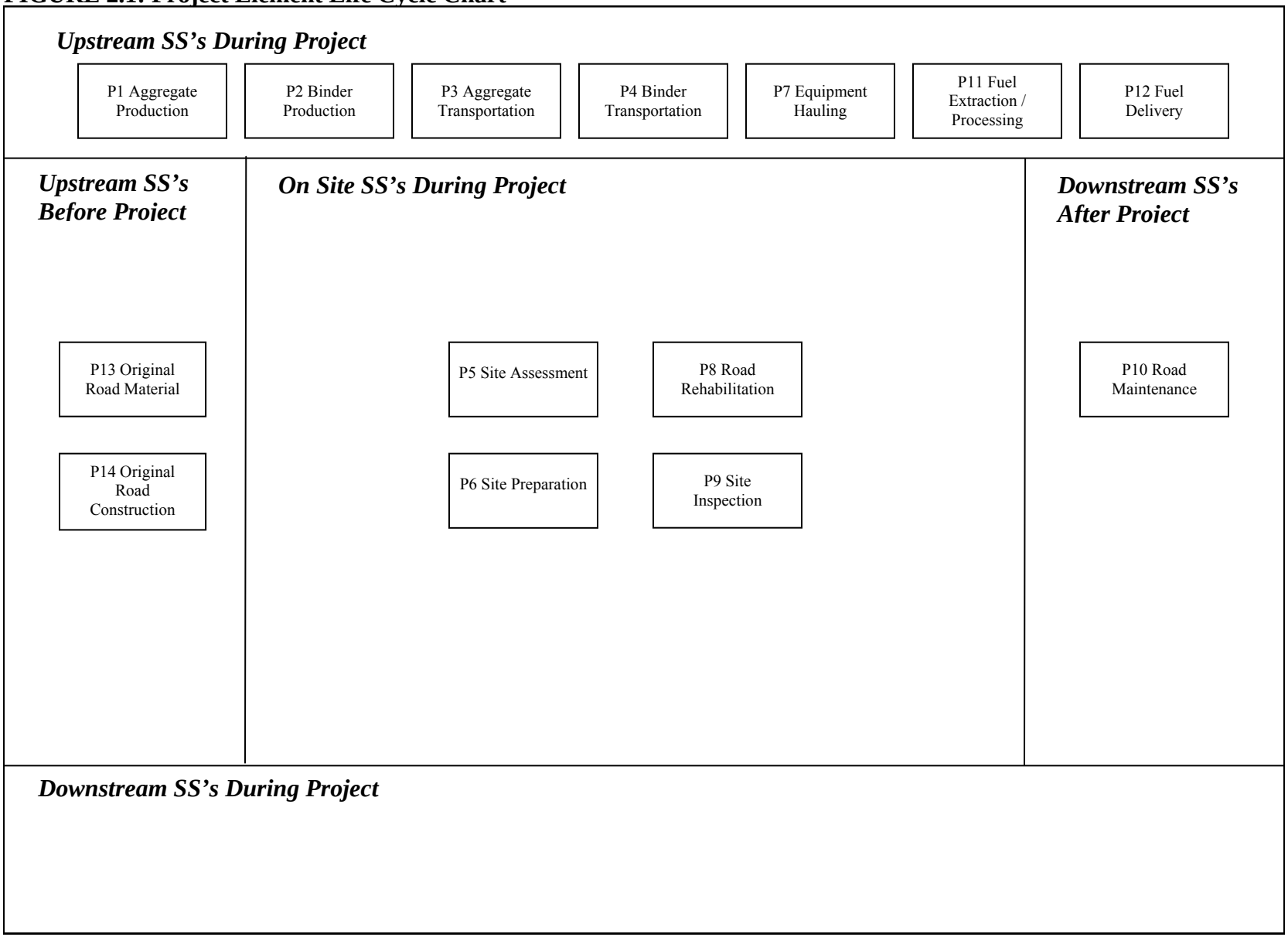


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Aggregate Production	Sand, gravel and crushed stone are produced by extracting and crushing rock, followed by size separation. Quantities for each of the energy inputs related to the generation of this type of aggregate would be contemplated to evaluate functional equivalence with the baseline condition. The production of other types of aggregate, such as recycled or reclaimed materials, shells, etc., is assumed to be emission-free.	Related
P2 Binder Production	Binders used in road rehabilitation may be produced by several unique methods. Quantities for each of the energy inputs related to the production of each binder would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P3 Aggregate Transportation	Aggregate may be transported either to the site, or to the mixing facility. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P4 Binder Transportation	Binder may be transported from the production site to either the site or to the mixing facility. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P7 Equipment Hauling	Equipment will be transported to the site. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P11 Fuel Extraction and Processing	Each of the fuels used for transportation will need to be sourced and processed. Upstream fuel extraction and processing emissions associated with aggregate and binder production are excluded as the emission factors used cannot be disaggregated to individual fuel volumes. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P12 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by 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 station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related

Onsite SS's during Project Operation		
P5 Site Assessment	The site may need to be assessed prior to rehabilitation. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
P6 Site Preparation	The site may need to be prepared prior to road rehabilitation. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
P8 Road Rehabilitation	Rehabilitation of the road will require the use of vehicles and equipment resulting in greenhouse gas emissions. These emissions will need to be tracked and quantified.	Controlled
P9 Site Inspection	The site may need to be inspected following rehabilitation. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
Downstream SS's during Project Operation		
None		
Other		
P10 Road Maintenance	The road may need to be maintained. Road maintenance may require the use of aggregate, vehicles and equipment resulting in greenhouse gas emissions. These emissions will need to be tracked and quantified. The type and frequency of maintenance required would be contemplated in order to ensure functional equivalence with the baseline condition.	Related
P13 Original Road Material	Aggregate or aggregate and binder would have been used in the construction of the original road that is now being rehabilitated. Emissions would have resulted during the production and transportation of these materials. These emissions may need to be tracked and quantified.	Related
P14 Original Road Construction	Fossil fuels would have been combusted during the construction of the original road that is now being rehabilitated. The combustion of these fossil fuels would have resulted in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Related

2.2 Identification of Baseline

The baseline condition for projects applying this protocol involves the use of new aggregate or aggregate and binder, the production and transportation of which results in emissions of greenhouse gases due to the combustion of fossil fuels. The baseline condition for the road rehabilitation protocol is defined as a process that involves resurfacing the road using all new materials (aggregate or aggregate and binder).

The approach to quantifying the baseline will be calculation based as there are suitable data available for the applicable baseline condition that can provide reasonable certainty. The baseline scenario for this protocol is dynamic as the distance to the site would be expected to change materially from project to project and the amount of aggregate and binder added also vary.

If a project specific specification as per the mass of gravel / km of road or the depth of gravel-binder mix exists, this will be used as the baseline. Otherwise, a default baseline condition, based on common practice, will be used. For gravel roads, such a default value could be 400 Tonnes / km. For a gravel-binder mix road, such a default could be a 2.5 inch depth of mix. Such numbers are for guidance purposes only. Where available, project specific values should be used. The mix percent of binder and aggregate will reflect the vendor specifications.

In the baseline condition, it is assumed that the aggregate used is either sand, gravel or crushed stone, and therefore an emissions factor of 9.98 kg / T for its production is used.

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, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagram provided in **FIGURE 1.2**, the baseline 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

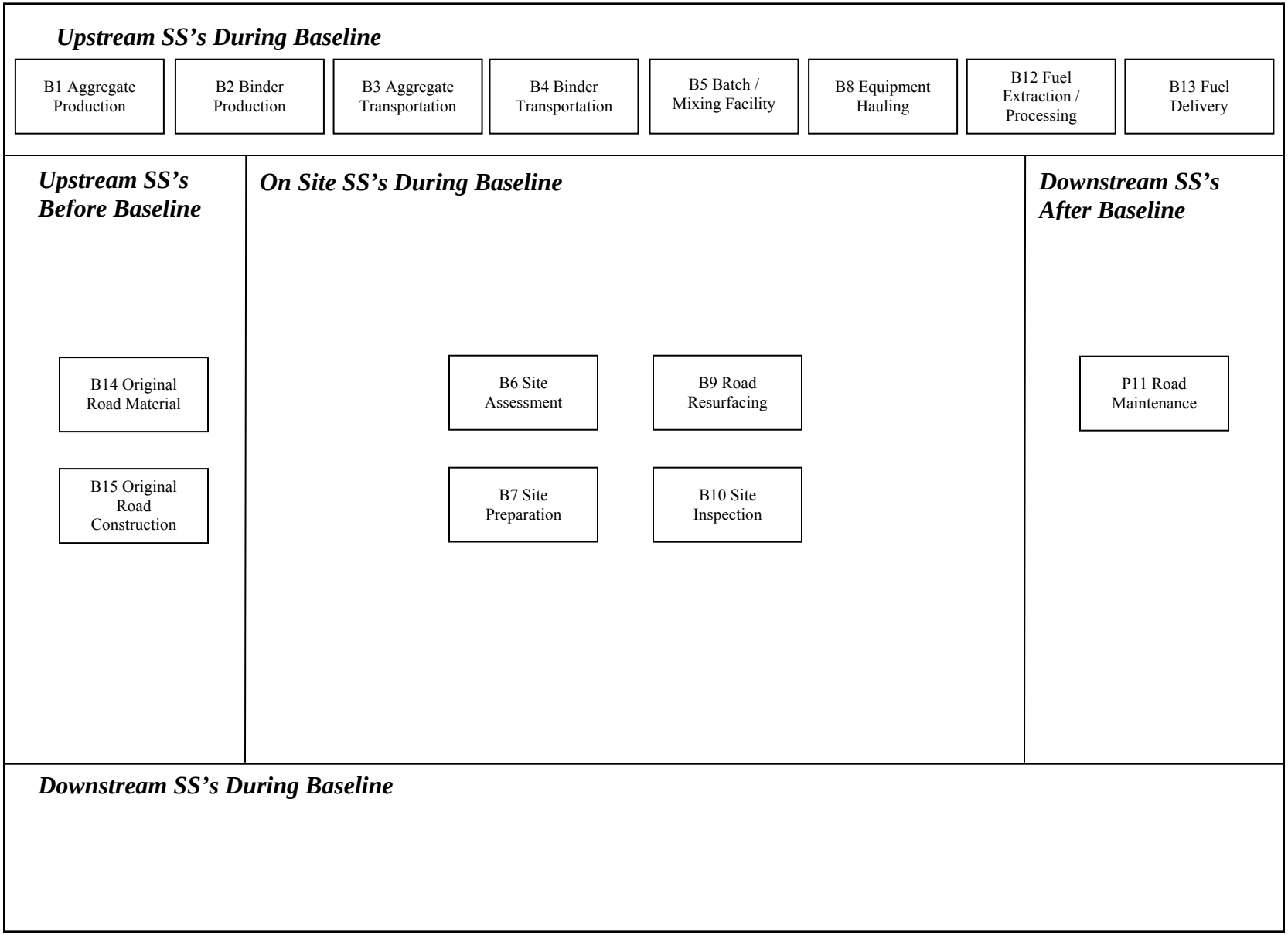


TABLE 2.2: Baseline SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Aggregate Production	Aggregate is produced by excavating and crushing rock, followed by size separation. Quantities for each of the energy inputs related to the generation of the aggregate would be quantified to evaluate greenhouse gas emissions. In the baseline condition, only sand, gravel and crushed stone are considered as aggregate.	Related
B2 Binder Production	Binders used in road resurfacing may be produced by several unique methods. Quantities for each of the energy inputs related to the production of each binder would be contemplated to evaluate functional equivalence with the baseline condition.	Related
B3 Aggregate Transportation	Aggregate may be transported either to the site, or to the mixing facility, from either a quarry or a stockpiling site. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B4 Binder Transportation	Binder may be transported from the production site to either the site or to the mixing facility. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B5 Batch / Mixing Facility	Binder and aggregate may be mixed at a dedicated mixing facility. The related energy inputs for running such a facility will need to be captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions.	Related
B8 Equipment Hauling	Equipment will be transported to the site. The related energy inputs for fuelling the transportation equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B12 Fuel Extraction and Processing	Each of the fuels used for transportation will need to sourced and processed. Upstream fuel extraction and processing emissions associated with aggregate and binder production are excluded as the emission factors used cannot be disaggregated to individual fuel volumes. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related

B13 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by 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 station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Baseline Operation		
B6 Site Assessment	The site may need to be assessed prior to resurfacing. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
B7 Site Preparation	The site may need to be prepared prior to road resurfacing. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
B9 Road Resurfacing	Resurfacing of the road will require the use of vehicles and equipment resulting in greenhouse gas emissions. These emissions will need to be tracked and quantified.	Controlled
B10 Site Inspection	The site may need to be inspected following resurfacing. This may include the transportation of people and equipment resulting in greenhouse gas emissions. These emissions may need to be tracked and quantified.	Controlled
Downstream SS's during Baseline Operation		
None		
Other		
B11 Road Maintenance	The road may need to be maintained. Road maintenance may require the use of aggregate, vehicles and equipment resulting in greenhouse gas emissions. These emissions will need to be tracked and quantified. The type and frequency of maintenance required would be contemplated in order to ensure functional equivalence with the baseline condition.	Related
B14 Original Road Material	Aggregate and / or binder would have been used in the construction of the original road that is now being rehabilitated. Emissions would have resulted during the production and transportation of these materials. These emissions may need to be tracked and quantified.	Related
B15 Original Road Construction	Fossil fuels would have been combusted during the construction of the original road that is now being rehabilitated. The combustion of these fossil fuels would have resulted in greenhouse gas emissions. These emissions may need to be tracked and quantified.	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 Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion, or the conditions upon which SS's may be excluded, is provided below. All other SS's listed previously are included. This information is summarized in **TABLE 2.3**, below.

TABLE 2.3: Comparison of SS's

1. Identified SS	2. Baseline (C, R, A)	3. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
Upstream SS's				
P1 Aggregate Production	N/A	Related	Include	N/A
B1 Aggregate Production	Related	N/A	Include	
P2 Binder Production	N/A	Related	Include	N/A
B2 Binder Production	Related	N/A	Include	
P3 Aggregate Transportation	N/A	Related	Include	N/A
B3 Aggregate Transportation	Related	N/A	Include	
P4 Binder Transportation	N/A	Related	Include	N/A
B4 Binder Transportation	Related	N/A	Include	
B5 Batch / Mixing Facility	N/A	Related	Exclude	Excluded as emissions from this SS occur only under the baseline condition, and it is therefore conservative to exclude these emissions.
P7 Equipment Hauling	N/A	Related	Exclude	Excluded as the emissions from equipment hauling are expected to be equivalent in the project and baseline conditions.
B8 Equipment Hauling	Related	N/A	Exclude	
P11 Fuel Extraction / Processing	N/A	Related	Include	N/A
B12 Fuel Extraction / Processing	Related	N/A	Include	
P12 Fuel Delivery	N/A	Related	Exclude	Excluded as the emissions from fuel delivery are expected to be equivalent in the project and baseline conditions.
B13 Fuel Delivery	Related	N/A	Exclude	
Onsite SS's				
P5 Site Assessment	Controlled	N/A	Exclude	Excluded as the emissions site assessment are expected to be equivalent in the project and baseline conditions.
B6 Site Assessment	N/A	Controlled	Exclude	
P6 Site Preparation	Controlled	N/A	Exclude	Excluded as the emissions from site preparation are expected to be equivalent in the project and baseline conditions.
B7 Site Preparation	N/A	Controlled	Exclude	
P8 Road Rehabilitation	Controlled	N/A	Exclude	Excluded as the emissions from road rehabilitation are expected to be equivalent in the project and baseline conditions as both processes rely on a limited number of passes over the road surface with heavy equipment. The only difference between baseline and project condition is typically a single pass for the scarifying and granulating stage only; the shaping, smoothing, and packing stages are equivalent in both processes.
B9 Road Resurfacing	N/A	Controlled	Exclude	

P9 Site Inspection	Controlled	N/A	Exclude	Excluded as the emissions from site inspection are expected to be equivalent in the project and baseline conditions.
B10 Site Inspection	N/A	Controlled	Exclude	
Downstream SS's				
None				
Other				
P10 Road Maintenance	Controlled	N/A	Exclude	Excluded as the emissions from road maintenance are expected to be equivalent in the project and baseline conditions.
B11 Road Maintenance	N/A	Controlled	Exclude	
P13 Original Road Material	N/A	Related	Exclude	Excluded as the emissions from original road material are expected to be equivalent in the project and baseline conditions.
B14 Original Road Material	Related	N/A	Exclude	
P14 Original Road Construction	N/A	Related	Exclude	Excluded as the emissions from original road construction are expected to be equivalent in the project and baseline conditions.
B15 Original Road Construction	Related	N/A	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 2.3.** These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Aggregate Production}} + \text{Emissions}_{\text{Oil Production}} + \text{Emissions}_{\text{Transportation Aggregate}} + \text{Emissions}_{\text{Transportation Oil}} + \text{Emissions}_{\text{Fuel Extract / Process}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Aggregate Production}} + \text{Emissions}_{\text{Oil Production}} + \text{Emissions}_{\text{Transportation Aggregate}} + \text{Emissions}_{\text{Transportation Oil}} + \text{Emissions}_{\text{Fuel Extract / Process}}$$

Where:

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

- $\text{Emissions}_{\text{Aggregate Production}}$ = emissions under SS B1 Aggregate Production
- $\text{Emissions}_{\text{Binder Production}}$ = emissions under SS B2 Binder Production
- $\text{Emissions}_{\text{Transportation Aggregate}}$ = emissions under SS B3 Aggregate Transportation
- $\text{Emissions}_{\text{Transportation Binder}}$ = emissions under SS B4 Binder Transportation
- $\text{Emissions}_{\text{Fuel Extract / Process}}$ = emissions under SS B12 Fuel Extraction / Processing

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

- $\text{Emissions}_{\text{Aggregate Production}}$ = emissions under SS P1 Aggregate Production
- $\text{Emissions}_{\text{Binder Production}}$ = emissions under SS P2 Binder Production
- $\text{Emissions}_{\text{Transportation Aggregate}}$ = emissions under SS P3 Aggregate Transportation
- $\text{Emissions}_{\text{Transportation Binder}}$ = emissions under SS P4 Binder Transportation
- $\text{Emissions}_{\text{Fuel Extract / Process}}$ = emissions under SS P11 Fuel Extraction /Processing

TABLE 2.4: Quantification Procedures

1. Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P1 Aggregate Production	$Emissions_{Aggregate\ Production} = Mass_{Aggregate} * EF_{CO2E\ Aggregate\ Production}$					
	Emissions due to the production and mining of aggregate / $Emissions_{Aggregate\ Production}$	kg of CO_2	N/A	N/A	N/A	Quantity being calculated.
	Mass of Aggregate used in road rehabilitation / $Mass_{Aggregate}$	kg	Measured	Direct measurement of mass delivered.	Per Project	Direct measurement is standard practice and highest level possible.
	Emissions factor for aggregate production / $EF_{CO2E\ Aggregate\ Production}$	kg CO_{2E}	Estimated	Values provided in Appendix B.	Annual	Reference value
P2 Binder Production	$Emissions_{Binder\ Production} = Vol.\ Binder * EF\ Binder_{CO2}$; $Vol.\ Binder * EF\ Binder_{CH4}$; $Vol.\ Binder * EF\ Binder_{N20}$					
	Emissions due to the production of binder used in lightly surfaced roads / $Emissions_{Binder\ Production}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Volume of Each Type of Binder used in lightly surfaced roads / $Vol\ Binder_i$	L, m^3 or other	Measured	Direct measurement of mass delivered to the job site.	Per Project	Direct measurement is standard practice and highest level possible.
	CO_2 Emissions Factor for Each Type of Fuel / $EF\ Fuel_{i\ CO2}$	Kg CO_2 per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
	CH_4 Emissions Factor for Each Type of Fuel / $EF\ Fuel_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
P3 Aggregate Transportation	Emissions $_{Aggregate\ Transportation}$ = $\sum$ ((# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel $_{CO2}$) ; $\sum$ ((# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel CH_4) ; $\sum$ ((# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel N_2O)					
	Emissions $_{Aggregate\ Transportation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads $_{Job\ Number\ i}$	-	Measured	Number of loads recorded.	Every load recorded upon arrival at the site.	Measuring the percent of total load weight would be an incremental industry practice.
	Distance Driven for each Job / Distance $_{Job\ Number\ i}$	km	Measured	Distance each load travels.	Per project	The distance of most probable route is measured once for each source of aggregate for each project.
	Fuel Efficiency of the vehicle used for each job / Fuel Eff $_{Job\ Number\ i}$	L per 100 km	Estimated	Volume of fuel use is divided by distance travelled.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P4 Binder Transportation	Emissions $_{Binder\ Transportation}$ = $\sum$ (# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel $_{CO2}$) ; $\sum$ ((# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel CH_4) ; $\sum$ ((# Loads $_{Job\ Number\ i}$ * Distance $_{Job\ Number\ i}$ * Fuel Eff $_{Job\ Number\ i}$ * EF Fuel N_2O)					
	Emissions $_{Binder\ Transportation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads $_{Job\ Number\ i}$	-	Measured	Number of loads recorded.	Every load recorded upon arrival at the site.	Measuring the percent of total load weight would be an incremental industry practice.

	Distance Driven for each Job / Distance $_{\text{Job Number i}}$	km	Measured	Distance each load travels.	Per project	The distance of most probable route is measured once for each source of binder for each project.
	Fuel Efficiency of the vehicle used for each job/Fuel Eff $_{\text{Job Number i}}$	L per 100 km	Estimated	Volume of fuel use is divided by distance travelled.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{\text{i CO2}}$	kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{\text{i CH4}}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{\text{i N2O}}$	kg N2O per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P11 Fuel Extraction and Processing	Emissions $_{\text{Fuel Extraction / Processing}} = \sum$ (Vol. Fuel $_i$ * EF Fuel $_{\text{i CO2}}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{\text{i CH4}}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{\text{i N2O}}$)					
	Emissions $_{\text{Fuel Extraction / Processing}}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's.
	Volume of Fossil Fuel Combusted for P1 and P2 / Vol $_{\text{Fuel}}$	L	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Including CO_2 Emissions Factor for Fuel Production and Processing / EF Fuel $_{\text{CO2}}$	kg CO_2 per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
	CH_4 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{\text{CH4}}$	kg CH_4 per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

	N_20 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{N2O}$	kg N2O per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

Baseline SS's						
B1 Aggregate Production	Emissions $_{Aggregate\ Production}$ = Length $_{Road}$ * Mass $_{Aggregate\ /\ km}$* EF CO_{2E}					
	Emissions due to the production and mining of aggregate / Emissions $_{Aggregate\ Production}$	kg of CO_2 / tonne of aggregate	N/A	N/A	N/A	Quantity being calculated.
	Length of the road being rehabilitated / Length $_{Road}$	meters	Measured	Direct Measurement	Per project	Direct measurement is standard practice and highest level possible.
	Mass of Aggregate being laid on each km of road / Mass $_{Aggregate\ /\ km}$	Tonnes	Estimated	Project Specification or Default Value	Per project	Project specification or default based on most accurate data available.
B2 Binder Production	Emissions $_{Binder\ Production}$ = $\sum$ (Vol. Binder $_i$ * EF Binder $_{i\ CO2}$); $\sum$ (Vol. Binder $_i$ * EF Binder $_{i\ CH4}$) ; $\sum$ (Vol. Binder $_i$ * EF Binder $_{i\ N20}$)					
	Emissions due to the production of binder used in lightly surfaced roads / Emissions $_{Binder\ Production}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Volume of Each Type of Binder used in lightly surfaced roads / Vol Binder $_i$	L, m^3 or other	Estimated	Based on an estimated ratio of binder to aggregate (% by wt. of binder in the final mix).	Per project	Based on most accurate data available.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	Kg CO_2 per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

B3 Aggregate Transportation	$Emissions_{Aggregate\ Transportation} = \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel_{CO2}) ; \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel\ CH_4) ; \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel\ N_2O)$					
	$Emissions_{Aggregate\ Transportation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / $\#\ Loads_{Job\ Number\ i}$	-	Estimated	Divide theoretical mass of aggregate used by load size.	Per project	Estimated based on project or a standard load size.
	Distance Driven for each Job / $Distance_{Job\ Number\ i}$	km	Estimated	Distance each load travels in the project condition.	Per project	The distance of most probable route is measured once for each source of aggregate for each project.
	Fuel Efficiency of the vehicle used for each job/ $Fuel\ Eff_{Job\ Number\ i}$	L per 100 km	Estimated	Fuel efficiency from project condition.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO_2 Emissions Factor for Each Type of Fuel / $EF\ Fuel_{i\ CO2}$	kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / $EF\ Fuel_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / $EF\ Fuel_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B4 Binder Transportation	$Emissions_{Binder\ Transportation} = \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel_{CO2}) ; \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel\ CH_4) ; \sum((\#\ Loads_{Job\ Number\ i} * Distance_{Job\ Number\ i} * Fuel\ Eff_{Job\ Number\ i} * EF\ Fuel\ N_2O)$					
	$Emissions_{Binder\ Transportation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job Number / $\#\ Loads_{Job\ Number\ i}$	-	Estimated	Divide theoretical mass of aggregate used by load size.	Per project	Measuring the percent of total load weight would be an incremental industry practice.

	Distance Driven for each Job / Distance $_{Project\ i}$	km	Estimated	Distance each load travels in the project condition.	Per project	The distance of most probable route is measured once for each source of binder for each project.
	Fuel Efficiency of the vehicle used for each job / Fuel Eff $_{Project\ i}$	L per 100 km	Estimated	Fuel Efficiency from project condition.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B12 Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction\ /\ Processing}$ = $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)					
	Emissions $_{Fuel\ Extraction\ /\ Processing}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's.
	Volume of Fossil Fuel Combusted for P1 and P2 / Vol $_{Fuel}$	m^3	Estimated	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Including CO_2 Emissions Factor for Fuel Production and Processing / EF Fuel $_{CO2}$	kg CO_2 per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.
	CH_4 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{CH4}$	kg CH_4 per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

	N_20 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{N2O}$	kg N2O per m^3	Estimated	Values provided in Appendix A.	Annual	Reference values from the Canadian Association of Petroleum Producers report.

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practices should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.2 Quality Assurance/Quality Control (QA/QC)

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

a. Protecting monitoring equipment (sealed meters and data loggers);
b. Protecting records of monitored data (hard copy and electronic storage);
c. Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d. Comparing current estimates with previous estimates as a ‘reality check’;
e. Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f. Establish minimum experience and requirements for operators in charge of project and monitoring; and
g. Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.5: Contingent Data Collection Procedures

1.0 Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P1 Aggregate Production	Mass of Aggregate used in road rehabilitation / $Mass_{Aggregate}$	kg	Estimated	Use mass of aggregate billed for the project.	Per project	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P2 Binder Production	Volume of Each Type of Binder used in cold mix roads / $Vol\ Binder_i$	L	Measured	Use average volume of binder billed for the project.	Per project	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
Baseline SS's						
None.						

APPENDIX A:

Emission Factors for Fuel Production and Processing

Emission Factors for Fuel Production and Processing

All values interpreted from volume 1 of the technical report: A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP).

Table A1: Emission Factors for Gasoline and Diesel Production

	Approximate Proportionate Amount in Year of Emission Factor Generation		Emission Factors			
			CO_2	CH_4	N_2O	Units
Light / Medium Crude Oil Production	55,588	10^3 m^3 / yr	86.3	4.41	0.0038	t / 10^3 m^3
Heavy Crude Oil Cold Production	30,924	10^3 m^3 / yr	75	25.1	0.0033	t / 10^3 m^3
Heavy Crude Oil Thermal Production	10,589	10^3 m^3 / yr	594.2	3.75	0.009	t / 10^3 m^3
Weighted Average			0.1381	0.0109	4.208E-6	kg / L

APPENDIX B:

Emission Factors for Aggregate Production

Table B1: QPA Emission Factor

	Emission Factor	
Aggregate Production	**9.98**	Kg CO_{2E} / Tonne of Aggregate output

This figure includes the production of aggregates and value-added products such as asphalt and ready-mixed concrete, but does not include the use of energy in delivering products to the market.

Source: "A Sustainable Development Report from the Aggregate and Quarry Products Industry", March 2006. Page 21.

Table B2: Calculation based on Canadian Data

Year	**1997**	**2002**
Raw Materials Price Index (Non-Metallic Minerals)	100	114.3
Production Cost	$11.33 / T	$12.95 / T
Emissions Intensity		0.8 T CO_{2E} / $1000 production
Production Cost		77.22 Tonnes of Aggregate / $1000
Emissions per Tonne Produced		**10.36 kg CO_{2E} / T aggregate**

Sources: Statistics Canada; Natural Resources Canada, Canadian Minerals Yearbook, 1998; CANISM

Table B3: Canadian Technical Asphalt Association Data

	Emission Factor	
Crushed Aggregate (0-20 mm)	**10**	Kg CO_{2E} / Tonne of Aggregate output

Source: The Environmental Road of the Future: Analysis of Energy Consumption and Greenhouse Gas Emissions, Canadian Technical Asphalt Association, 2005, page 25.

Based on these 3 tables, an emissions factor of 9.98 kg CO_{2E} / Tonne of Aggregate Produced will be used as it is the most conservative number.