CONCRETE & ASPHALT RECYCLING FOR ROAD BASE MATERIAL PRODUCTION

City of Richmond Option 2 Project Plan

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Legal Address and GPS Coordinates of Project Site:

6711 Sidaway Road, Richmond, BC, V6W 1B7;
GPS Latitude 49° 9' 47.27" N Longitude 123° 4' 51.57" W

Project Plan:

Photos:

Acknowledgments:

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1 FOREWORD

Globally, the transportation sector (including road construction), is responsible for approximately 14% of greenhouse (GHG) emissions; in North America, road transport contributes to 85% of the sector's emissions (World Bank, 2010). In British Columbia (BC), the transportation sector produces an estimated 40% of the province's GHG emissions (Ministry of Transportation and Infrastructure/BC Road Builders and Heavy Construction Association, 2011). The Ministry of Transportation and Infrastructure has thus identified addressing climate change, and corresponding GHG emissions, as a top priority, noting their desire to work with partners to do so.

One option to help reduce GHG emissions, as they relate to road construction specifically, is by substituting virgin quarry materials with recycled materials, such as from construction and demolition (C&D) waste, for use as road base in road paving. Notably, embodied energy (i.e. the energy consumed by the processes associated with production, including mining and processing of materials, transport and delivery) is responsible for up to 80% of the associated GHG emissions; on-site impacts represent less than 5% of the associated GHG emissions of road networks (World Bank, 2010). Reducing this embodied energy, and the corresponding GHG emissions, will depend on a number of factors (e.g. material, transport distances between quarries or road recycling centres). However, making use of recycled road base aggregates offers a viable alternative to reducing GHG emissions associated to road base construction.

Establishing evidence of GHG emission reductions from both recycling activities and innovation for infrastructure projects provides an important imperative for other recycling and infrastructure projects in BC. Recycling and waste reduction is generally associated with environmental benefits; however BC lacks project profiles that provide guidance and good practice examples for emission reductions directly related to recycling activities. Also, projects involving innovative approaches to infrastructure projects are still few and far between. The hope is that this project activity will demonstrate the GHG emissions reduction benefits of using recycled material to displace virgin material, which in turn will inspire greater use of recycled materials in infrastructure projects.

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3 INTRODUCTION

3.1 Information on Road Base

Road base is a mixture of aggregate material used as the base for road paving, which is typically made from virgin quarry material. The quarry process and operation will involve the following aspects: deforestation of the land designated for the quarry site, site preparation, set up of machinery, operation of machinery, blasting, on-site transportation, on-site processing and transportation to a retail site and eventually site reclamation.

3.2 Project Activity Concrete and Asphalt Recycling for Use as Road Base

Concrete and asphalt materials can be used in a number of applications. One of the most straightforward ways to use them, which involves no additional processing or resources, is in the production of road base. The crushing process of the recycled material is functionally comparable to the crushing of quarry material. However, the process steps required for the quarry production are more extensive. Therefore the predominant emission reduction sources for both concrete and asphalt recycling project activities originate from the avoidance of emissions related to the production of road base material at a quarry site and the transportation from the quarry site to a customer yard. Typically, road base is mostly used in urban areas while the road base quarries are usually located in rural areas quite a distance away. Therefore the avoidance of transportation emissions from a quarry site to a customer's yard of this heavy material can be a material emissions reduction source.

Both concrete and asphalt are typically not considered as contributing significantly to GHG emissions at a landfill site. There is some research suggesting that there are emissions related to the slow degradation of both concrete and asphalt, but diverting them from landfill sites most likely does not contribute to the kind of on-site emission reductions that are associated with the diversion of organic waste material. However they do contribute to the commercial viability of landfill sites through tipping fees. Removing this tipping fee income will contribute to the desirable phase-out of landfill sites as a predominant pathway for any waste materials.

In addition to the end of life pathway, it is also of significant importance that both materials are extremely energy and emissions intensive in their production. Therefore recycling them would represent a desirable use in order to lower the life-cycle intensity of both products.

3.3 Background Consideration for GHG Emission Reductions

3.3.1 Environmental Impacts of Quarrying Aggregate Materials

Gravel pits and quarries provide primary sources of aggregate materials (e.g. rock, stone, gravel, sand) used in road construction and paving surfaces. The traditional quarrying process includes many environmental consequences, notably: deforestation, excavation and reclamation of a virgin site; energy consumption for machinery used in various processes, including for excavation, blasting, crushing, screening and material processing; on-site and off-site transportation; and water consumption to control dust and wash materials. Typically, a quarry's lifespan lasts between several years to several decades and follows three stages: (1) initial clearing and vegetation removal; (2) reclamation and use; and (3) abandonment (*Gravel Pit and Quarry Operations, Environmental Best Practices for Highway Maintenance Activities Manual - Oct/10*). The resulting paving materials, which are derived from these quarries, have significant embodied GHG due to associated land and energy consumption, thus generating GHG emissions from raw material extraction to final waste management and recycling (Santero *et al.,* 2013). The US Geological Service (2011) estimates that in the United States alone, approximately 460 million metric tons of crushed aggregate go into the construction, rehabilitation and maintenance to support the US pavement network every year. Consequently, significant emissions could be avoided via substituting recyclable aggregates.

Additionally, there are many secondary environmental/health impacts associated with the quarrying process. These include: the release of particulate matter and sediment to air and waterways during excavation and processing, which can be harmful to fish and wildlife, air quality and drinking water; possible salt contamination of soil and groundwater; growth of invasive plants and noxious weeks in gravel pits, disrupting post-quarry restoration efforts; and ongoing dust and erosion from exposed earth (*Environmental Best Practices for Highway Maintenance Activities Manual - Oct/10*). Due to possible impacts, there are multiple performance standards and legal requirements that quarries and gravel pits must adhere to in BC, which include the *Environmental Management Act, Contaminated Site Regulation, Wildlife Act,* provincial environmental objectives pertaining to air quality criteria for PM10, the *Weed Control Act, Integrated Pest Management Act,* and the federal *Fisheries Act.* Quarries and gravel pits are suggested to work closely with local regulatory agencies, such as during the disposal of invasive plants, and to report any infestations to the Ministry of Transport's Gravel Managers.

3.3.2 Recycling Benefits and Drawbacks

Due to the growing environmental impacts of quarrying, expanding waste volumes and stricter regulations, there is a need to examine recycling strategies, while also seeking to optimize operations within the industry (Bohne *et al.,* 2008). Recycling aggregates, as substitutes for road base, have many environmental and economic benefits. These include:[1]

- reduced costs, as recycled aggregates are often more affordable and have fewer associated transport and labour costs;
- reduced resource consumption, thus conserving quarry aggregates for use by future generations;
- land preservation for other uses (e.g. forestry) or ecological protection;
- material reuse and diversion of bulky waste materials from landfills, thus extending a landfill's EOL;
- reduced quarrying, which has significant impacts on amenity costs and biodiversity loss; and

[1] All examples are from: Sustainable Aggregates, ND; OHMPA, 2010

- reduced GHG emissions, as recycled aggregates have lower proportions of embodied energy, and generate fewer transport emissions when recycled materials are reused in close proximity to their reprocessing sites (for example when stored at recycling depots in or near urban centres).

According to ARRB Group[2] (2009), recycled aggregates produce approximately four kg CO_2e per tonne, up to 46% fewer emissions than an equivalent quarry product.

Several studies also document the ability of concrete[3] to capture carbon – a chemical process known as carbonation – during its primary and secondary (recycled) life; a phenomenon not considered by most conventional lifecycle assessment (LCA) models when examining concrete (Collins, 2009; Santero *et al.,* 2013; Thomas *et al.,* 2009). The capture of airborne carbon dioxide, through carbonation, has been found to be even greater during secondary life, offering an additional environmental benefit for selecting recycled concrete aggregate (RCA) (Collins, 2009). Collins also found that up to 41% of CO_2 emitted during manufacture could be absorbed; and thus current GHG emission estimates from concrete may be overestimated by between 13- 48%, pending the cement binder type used and the application of the RCA in its second life.

Despite these benefits, some drawbacks exist. For example, while stockpiling of existing recycled aggregate is largely a cost-effective approach, some studies have found that departments of transport (DOTs) and other relevant stakeholders may find this impractical (Santero *et al.,* 2013). RCAs are often used quickly after processing, for example in the construction sector, highlighting that there are several uses for recycled materials, and the most appropriate use is often context dependent.

3.3.3 Recycling Process

Recycling of aggregates includes the demolition and accumulation of old C&D wastes, road materials, concrete, asphalt and other aggregate materials that have reached their EOL. These are then transported to a holding station or depot for crushing and sorting (e.g. removal of reinforced steel and screening materials) (OHMPA, 2010). These materials can then be used for applications including: road base, engineering fill, scrap steel and combustibles (Sustainable Aggregates, ND; OHMPA, 2010). The recycling process is often done in or near urban centres, thus reducing excessive transportation; however this is dependent on local conditions and the availability of recycling centres.

3.3.4 Equivalency and Applications

There is some debate as to the full structural equivalency of recycled aggregates, and this depends largely on the use, and which aggregate material is examined. According to one study, recycled concrete is often damaged during demolition and crushing, and thus is of lower quality than quarried natural rock (Collins, 2009). As a result, recycled concrete is likely to be used in

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[2] As cited in Sustainable Aggregates

[3] As opposed to other aggregate materials, these studies specify the ability of concrete, re: carbonation.

more temporary applications, with an estimated second life of roughly 30 years (Collins, 2009). However, Collins's study specifically addresses RCA, not asphalt or other aggregate recycling.

OHMPA[4] (2010) states that recycled aggregate is structurally equivalent in many applications, and that crushed asphalt can be used as an aggregate in a granular base or sub-base to a maximum of 30%. OHMPA also states that recycled aggregates are comparable to natural aggregates, with the physical properties equivalent to crushed limestone. OHMPA highlights additional benefits, namely less dust, better subsurface drainage due to greater permeability, and since recycled aggregates are fully crushed, they are more compactable than virgin granular materials.

As for applications of crushed concrete and asphalt aggregates, examples include use as a granular base or sub-base for pavements, for trench backfill material, fill under concrete slap-on-grade, as well as construction access roads, bike paths, trails and rural driveways, pavement shoulders, and engineering fill (OHMPA, 2010). Applications vary between approximately 30%-100% use of recycled aggregates, depending on the required durability of their use. An additional use, hot in-place recycling, is an on-site rehabilitation method that can recycle 100% of the existing pavement to a certain depth (Ministry of Transportation and Infrastructure/ BC Road Builders and Heavy Construction Association, 2011). Hot in-place recycling addresses specific distressed surface and involves heating, removing and mixing the existing surface asphalt with a recycling agent. (More information included in report cited above).

Guignot *et al.* (2015) conducted a study, comparing C&D wastes of two recycling schemes for gravel wastes. The first served as the baseline; the second relied on an innovative technology for gravel processing, based on electrical fragmentation. The latter was found to offer a clear separation between the aggregate contained in the gravel and the cement, resulting in greater purity of the recycled materials, and possibly new recycling outlets. Another study conducted by Santero *et al.* (2013) compared approaches to improve cost effectiveness and environmental efficiency, namely: reducing embodied emissions by increasing fly ash content; avoiding over-design through optimization of materials; increasing albedo via white aggregates; increasing carbonation by temporarily stockpiling recycled concrete aggregates; and reducing vehicle fuel consumption. These latter two studies, while providing future direction on the recycling of secondary aggregates, and alternative approaches to reduce GHG emissions in the road construction sector, are outside the scope of this project. Nonetheless, they demonstrate growing interest to reduce GHG emissions, offering approaches that engineers can consider regarding road construction and maintenance.

3.3.5 Uncertainties

Despite the benefits of incorporating recycled aggregates as a road base, uncertainties remain. There are notable discrepancies regarding GHG emissions associated with the road network, which depend on the different types of pavement design standards used, the road type (e.g.

[4] OHMPA is the *Ontario Hot Mix Producers Association*. Accordingly, this is not an independent scientific study.

urban, rural roads or motorways), the existence of road furniture, etc. (World Bank, 2010; Thomas *et al.,* 2009). Large variations and lack of clarity also exist regarding the role of by-products, the EOL treatment of aggregates (including recycled materials) and the distance to the recycling facility or the quarry. Variation also depends on the precise location of sourced materials, the choice (and efficiency) of the technology used, the transport used to haul materials (including the speed of transport, the size of transport[5] and transport fuel) and the construction schedule (e.g. working during the rainy seasons is more energy intensive, working on days with greater traffic volumes) (World Bank, 2010; Thomas *et al.,* 2009). Many of these aspects are important in the initial quarry process and in consequent recycling. Other influential factors include: optimization of earthworks, drainage systems, and the pavement's lifetime. When comparing GHG emission scenarios, this also depends on whether virgin forests or farmlands were quarried, as well as whether excavations occurred in hard or soft soils[6] (World Bank, 2010). Consequently, it becomes difficult to do an exact comparison of the GHG emissions, *vis-à-vis* using virgin aggregate materials or recycled materials.

3.3.6 Existing Tools, Standards and Voluntary Reporting

Despite difficulties to quantify exact GHG emissions, many tools attempt to do so, largely focusing on: material comparisons, transportation and construction processes (World Bank, 2010). The local conditions in which these different tools are compared and examined are also important. One example is the UK-based Waste and Resource Action Programme (WRAP) to enable engineers to quantify and optimize CO_2 emissions associated with aggregates (Thomas *et al.,* 2009). Another approach, the eco-efficiency analysis, examines the value-added and environmental impacts of production processes, namely used at a corporate scale (Bohne *et al.,* 2008).

The European Research Area Network (ERANET) published a study, comparing nine European CO_2 calculation tools, which apply to road infrastructure projects, assessing among other issues, their pros and cons, methodologies, and usefulness of their databases (ERANET, 2012). ERANET made the following conclusions, noting that existing tools are: largely not transparent; require considerable data; mainly focus on construction, with little consideration of maintenance, while noting that American models are largely more 'user-friendly' than their European counterparts. The outcome of this study led to the creation of a CEREAL tool.

In Canada, a software programme, ÉCOLOGICIEL, was designed to aid decision makers. By quantifying energy and GHG emissions for various structures, including local parameters, the materials used and relative distances[7] (Dorchies, 2008). ECOAGE (Environmental Comparison of Aggregate/asphalt GHG Emissions), it is another tool that has been developed to estimate environmental benefits, including GHG reductions, as they pertain to alternate highway maintenance activities (Holt *et al.,* 2010).

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[5] In the Masshouse study, 30 t vehicles were considered a minimum (Thomas *et al.,* 2009).
[6] Hard soils produce 2-3x more GHG emissions than softer soils (World Bank, 2010).
[7] At the time of the report's publishing, the tool was in a preliminary development stage.

While many international tools are available, most of them are older and none are designed to support small scale projects in BC. While the latest one is not yet available, it will most likely be designed to aid scientific evaluation work rather than actual GHG reduction quantification. No specific GHG quantification protocol addressing road base production is available with the Verified Carbon Standard (VCS), Clean Development Mechanism (CDM) or any of the jurisdiction specific offset programs in BC, Alberta, Ontario, Québec or California.

3.4 Methodical Considerations

Due to a lack of existing GHG quantification protocols and the straightforward character of the Option 2 project requirements, the following considerations have been made in determining the GHG emission reductions:

1. Wherever possible, actual data was used in quantification calculations rather than estimates or statistical industry considerations. Therefore none of the existing calculators were suitable.
2. The baseline scenario was quantified using the actual quarry site of the City of Richmond's main road base material vendor.
3. The GHG emission sources, sinks and reservoirs were limited to controlled, material and relevant ones, namely the production of road base material and the transportation of the road base material to and from the City of Richmond.

For reasons of simplification, emissions from transportation are only included so far as they occur beyond the recycling site. Therefore excluded from the considerations for the project scenario are the emissions related to transportation from the demolition site to the recycling site in the City, because the waste material would also be transported the same distance enroute to the landfill site in the baseline scenario. Excluded further are the distribution emissions from the recycling site to the road construction site, because the virgin material would also be transported within the city from the retail site to the road construction site in the baseline scenario. Additionally excluded from the considerations for the project scenario are the emissions related to the demolition of the infrastructure resulting in the waste material, because these activities are taking place in both base and project scenarios and are independent of the project activities.

4 Project Information

4.1 Project Title

Concrete and Asphalt Recycling for Road Base Material Production

4.2 Project Description

4.2.1 *Project Site*

At a city-owned facility called Sidaway Yard, concrete and asphalt waste is delivered to the facility by trucks and stored there. The site is located within the City of Richmond boundaries. At regular intervals, a third party operator is hired to process the waste material on-site to produce road base material. The road base material is used for the City's road construction and maintenance work.

4.2.2 Project Activity

The project activity involves storing and processing of concrete and asphalt waste material, diverting it away from landfill sites. The waste material is processed into road base material at regular intervals at the project site. The transportation to and from the site is done using regular trucks powered by regular market diesel. The machinery on-site is powered by a diesel generator. In the future, additional emission reductions might be achieved by utilizing a higher bio-diesel blend than required under *Renewable & Low Carbon Fuel Requirements Regulation* for transportation and using electrical power to operate the road base production machinery.

All project activities and the project site itself are outside of the City of Richmond's corporate emissions boundary and none of the project activities are required by law or regulation federally, provincially or regionally.

The recycling process was developed over several production cycles between July 23, 2014 and September 7, 2016. The process initially involved a three machinery process set-up that was optimized to a two machinery set-up that was finally simplified to a single processing design. The single machinery set-up is the preferred processing solution that was first used on September 7, 2016. In all set-ups, an excavator was and is used for loading the machines and a wheel loader is used to move the road base to the storage area.

Going forward, the single machinery set-up with the excavator loading and the wheel loader handling the road base product is going to be used as the standard production solution. Currently, the machinery is rented. The City is contemplating the purchase or lease of the processing machinery going forward. No other changes are anticipated to the current process.

4.3 Project Measurements

All shipments into the yard are recorded and the road base production is monitored. Data collection will be designed following the good practice guidance criteria set out in the "Becoming Carbon Neutral: Guidebook for B.C. Local Governments. This guidance stipulates that the data monitoring and calculations be "*flexible, administratively streamlined and credible*".[8]

4.3.1 GHG Quantification

The GHG emission reduction quantification is based on the following formula:

Total GHG Emission Reductions = (controlled, material and relevant Baseline GHG Emissions of Production and Transport of road base material) – (controlled, material and relevant Project Scenario GHG Emissions of Production and Transport of road base material)

4.3.1.1 Baseline Scenario

The selected Baseline Scenario is the condition and practice before the project start, specifically the use of road base material from virgin material quarry supplied originating at Mainland's Cox Station Quarry. The baseline boundaries will include the quarry operation and the associated energy and the transportation to the project site. The transportation distance from the quarry to the closest marine loading site in Richmond is 94 km by river. However due to the specific way the barge and tug boat operations are conducted on the Fraser River, the actual distance travelled is much longer. By tracking a specific tug boat that services the quarry on a ship tracking site for several weeks, an average distance travelled of 506 km was established.

The tug boat leaves the overnight mooring, picks up two barges from the barge staging area, and makes a trip with two barges up to the Mission Bridge. Before reaching the bridge, one barge is moored and the tug boat continues with only one barge to the quarry side. After mooring the barge, the tug boat goes back to pick up the second barge to be moored at the quarry. The tug boat returns to the staging area to be serviced or to do another job. When the barges are both filled, the tug boat returns to transport one barge back to a location behind the bridge and returns to the quarry to pick up the second one. Once they are both combined, the tug boat continues from the bridge with two barges to the loading dock in Richmond. There the barges are moored for unloading. During the unloading the tug boot returns to the staging area or performance another job only to return later to return the empty barges to the staging area or reused for another job. The round trip from the staging area to the staging area is the tracked distance.

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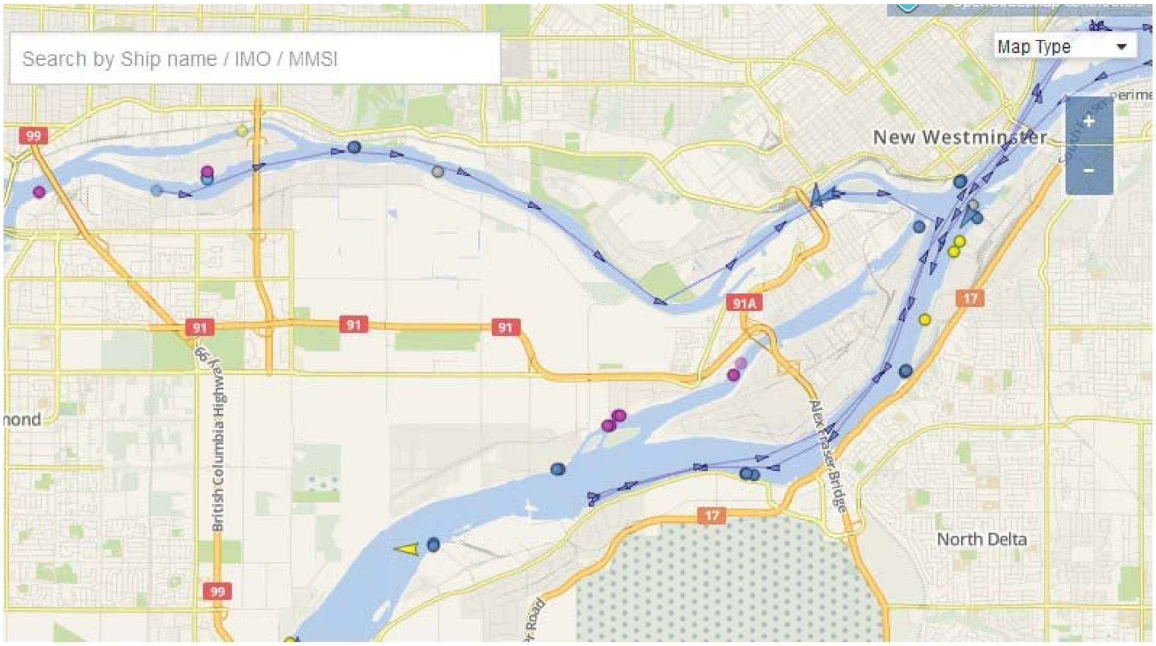
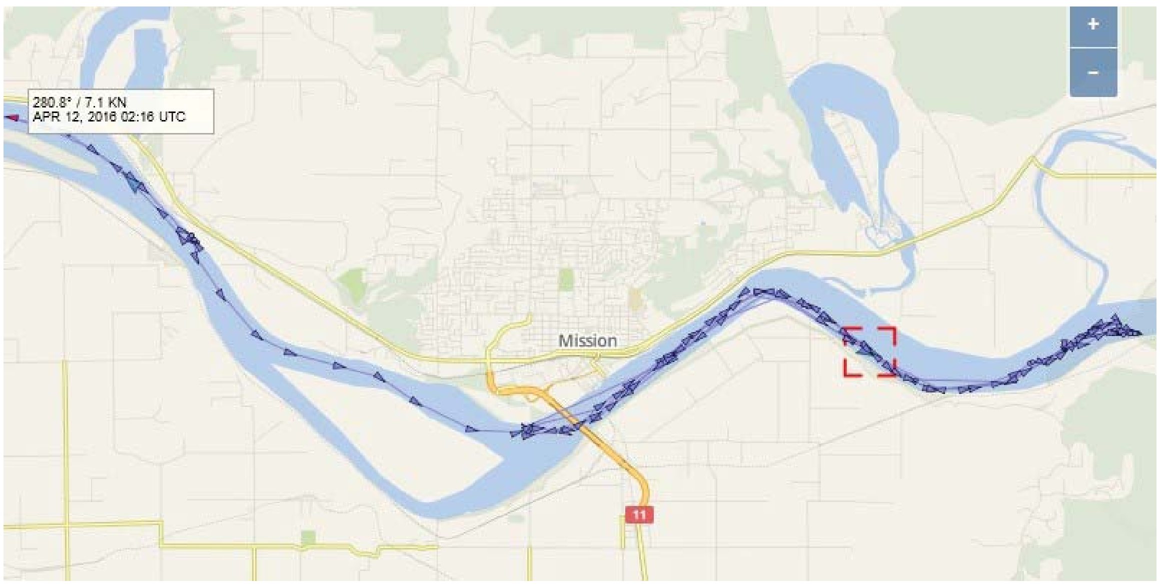
8 *Becoming Carbon Neutral: Guidebook for B.C. Local Governments* (July 2011).

Ship Tracking Screenshots:





The distance from the loading site to the project site by road is 5.1 km. For reasons of conservativeness, it is assumed that the transport took the direct route from the marine loading site known as No 6 Rd. Depot in Richmond (14271 River Road, Richmond, BC) to the Sidaway Yard, instead of via Mainland Sand and Gravel's bulk retail storage site known as No 5 Rd. Depot in southern Richmond (located at 12500 No 5 Rd, Richmond); the distance to project site is 5.7 km. In total, the transportation will also include one return trip; therefore the total distance is 10.2 km.

Mainland's Cox Station Quarry operations involve site preparation, blasting, on-site transportation, crushing, sorting and storage of several infrastructure construction materials.

The on-site operations are highly mechanized using fuel, electricity and natural gas to operate machinery and vehicles. To quantify the emissions associated with these operations, data was generously provided by Mainland Sand and Gravel using a five year average from 2010 to 2015. Also, a site visit was conducted to validate the baseline activities on-site. The energy use data was considered in proportion of the share of road based material in the overall annual product mix monitored over several years.

The transportation of the waste material to other sites in the Baseline Scenario has also been considered in the emission reduction quantification. Prior to the project start, waste material was transported to various sites across the Lower Mainland. For conservativeness reasons, the two closest sites (Richvan Holdings Ltd, and Mitchell Island) were chosen and the medium distance from the Works Yard was selected at 6.5 km.

However a 12% portion of this activity has been excluded because the collection and transportation of waste from city maintenance activities are considered part of the municipal traditional service boundaries. The 12% is a conservative estimate made by the City based on their volume reviews and experience. Less than 20% of the recycled material is asphalt and 60% of that asphalt comes from maintenance work. Maintenance work and the related transportation form part of the municipal traditional service boundaries. New construction-related waste transportation is not part of the municipal traditional service boundaries.

4.3.1.2 Project Scenario

The project scenario is the project activity of storage and processing of concrete and asphalt waste on the project site. The project boundaries will include the Sidaway Yard site on-site transportation and on-site processing. The on-site transportation included the use of a loader and an excavator. The project scenario's main activity is the processing of concrete and asphalt material. The main energy used is generated from diesel fuel. The fuel use for the machinery and vehicles is recorded using a fuel use data collection template which is also used to record the production volumes and dates. A small amount of electric energy is used to operate the staff office. The on-site office is used for the operation of the entire yard and all activities on it. It is not exclusively established for on-site recycling activities. Therefore the emissions related to the operation of the on-site office have been determined not to be material.

4.3.1.3 Baseline Scenario Quantification

Baseline Emissions "Production of virgin Material" / t based on total annual production average from five years (2010 - 2015) all data provided from Mainland Sand and Gravel

Input Data	Emission factors **	Annual Emission	Emission kg CO_2e per t
Average Annual Electricity in kwh	Factor in kg CO_2e per kwh for BC Hydro	kg CO_2e	
4,983,360	**0.01**	**49,833.6**	
Average Annual Diesel Fuel Use in l	Factor in kg CO_2e per l	kg CO_2e	

1,950,870	**2.888**	**5,634,113**	
Annual use of Explosives in t*	Factor in kg CO_2e per t	kg CO_2e	
862.11 t	**2,418**	**2,084,582**	
Total Emissions in kg CO_2e		**7,768,528.6**	
Average Annual Production in t		**2,171,000**	
Emissions in kg CO_2e per t			**3.578318102**

* Extrapolated data from Mainland Sand and Gravel partial year 2015 (25%)

**Emission factors based on *2014/2015 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions* and *Environment Canada NPRI Toolbox Pits and Quarries Guidance 8.3 Emissions from Blasting*.

Baseline Emissions "Transportation of virgin Material" / t based on data provided from Mainland Sand and Gravel

Input Data	Emission factors **	Emissions per trip	Emission per t
Tug boat and Barge Operation distance in km. Based on ship tracking and including empty delivery			
506			
Tug boat and Barge Average Diesel use per km and t in l. Median of credible sources available			
.0092			
Total Marine Diesel Fuel Use for distance per t	Factor in kg CO_2e per l		
4.6552	**2.888**		**13.4442176**
Diesel Fuel Use for unloading in l per t based on actuals from production Sep 2016	Factor in kg CO_2e per l		
0.25	**2.888**		**0.7222**
Trucking distance Dock to Yard in km (Google Map)			
5.1			
15 t Capacity Dump Truck Average Diesel use l per km (GHGenius)			
0.77859			

Total Diesel Fuel Use for distance in l (including return)	Factor in kg CO2e per l		
2 x 3.970809 = 7.941618	2.604	20.67997327	
Average load (95% of 15t capacity*) Dump Truck in t			
14.25			1.451226194
Total in kg per t			**15.61764379**

* For equity reasons, the same efficiency references are use as was for the Trenchless Technology Project Profile sponsored by Metro Vancouver: 1. Bauer C., Dubetz C., Freeman D., Grainger M., Millen T., 1998, An Environmental Review of Hot In-Place Recycling in British Columbia, Major Projects Final Report, Royal Roads University August 1998

** Emission factors based on *2014/2015 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions*

Baseline Emissions "Transportation of Waste Material" / t

Input Data	Emission factors **	Emission per t
Medium Trucking distance Yard to Dump Sites in km (Google Maps)		
6.5		
15 t load Capacity Dump Truck Average Diesel use l per km (GHGenius)		
0.77859		
Total Diesel Fuel Use for distance in l (including return)		
2x 5.060835 = 10.12167		
Average load (95% of 15t capacity*) Dump Truck in t		
14.25		
Dump Truck Diesel use in l per t for input distance	Factor in kg CO2e per l	Kg CO_2e per t
0.710292631	2.604	1.849602011
Total Additional		
-12%		1.627649769

* For equity reason, the same efficiency references are use as was for the Trenchless Technology Project Profile sponsored by Metro Vancouver: 1. Bauer C., Dubetz C., Freeman D., Grainger M., Millen T., 1998, An Environmental Review of Hot In-Place Recycling in British Columbia, Major Projects Final Report, Royal Roads University August 1998

** Emission factors based on *2014/2015* BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions

4.3.1.4 Project Scenario Quantification

Project Emissions "Production" / t Method

Equipment	Data Source	Emission factors *
Machinery 1 Fuel Use in l		Kg CO_2e per l
Use actual use Volumes	Refueling data and or Fuel Billing	2.888
Machinery 2 Fuel Use in l		Kg CO_2e per l
Use actual use Volumes	Refueling data and or Fuel Billing	2.888
Machinery 3 Fuel Use in l		Kg CO_2e per l
Use actual use Volumes	Refueling data and or Fuel Billing	2.888
Excavator Fuel use in l		Kg CO_2e per l
Use actual use Volumes	Refueling data and or Fuel Billing	2.888
Wheel Loader		Kg CO_2e per l
Use actual use Volumes	Refueling data and or Fuel Billing	2.888

*Emission factors based on 2014/15 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions

4.3.1.5 Emission Reduction Quantification

Production data recorded on site

Production Dates	Fuel Use Machinery in l	Fuel Use Excavator in l	Fuel Use Loader in l	Total Fuel Use in l	Emission factor in kg CO2e	Total in kg of CO_2e	Baseline in of kgCO_2e per t	Production Amount in t	Total Baseline Emissions in kg of CO_2e	Reductions in t of CO_2e
2014				Calculated*				Actual		
				6,996	**2.888**	**20,204.448**	**20.8236 1165**	**4,741**	**98,724.74283**	**78.520**
2015				Calculated*				Actual		
				10,812	**2.888**	**31,225.056**	**20.8236 1165**	**9,779**	**203,634.0983**	**172.710**
2016				Calculated*				Actual		
Spring				**26,535.23**	**2.888**	**76,633.74424**	**20.8236 1165**	**24,000**	**499,766.6796**	**423.133**
Sep 2016	Actual	Actual	Actual					Actual		
7- 30	**2597**	**2083.4**	**928.7**	**5609.1**	**2.888**	**16,199**	**20.8236 1165**	**8,325.43**	**173,365.5211**	**157.167**
Total:										**831**

* Based on Fuel Cost & Estimated Operating Hours

4.3.2 Third Party Review and Validation

The project activity site – Sidaway Yard – as well as the baseline activity site – Mainland Sand and Gravel Quarry – were both visited by an independent service provider, GHG Accounting Services.

Contact details:

Svend Andersen, MSc, MBA, CEO GHG Accounting Services Ltd.
1275 West 6th Ave., Vancouver BC, V6H 1A6
Phone: 604-351-1851, Email: Svend.Andersen@GHGaccounting.ca

4.3.3 Beyond Business-As-Usual Criteria

1. The project start date is after November 2007 and after January 1, 2012.

2. The project is not required to meet any federal, provincial or regional legislative requirements.

3. Additionality:
   - Financial: The project might serve some financial benefits due to the use of City staff and resources. However the ongoing use of the yard as a recycling site represents some challenges to the other activities taking place at the same site. Therefore a significant financial implication is the necessary expansion of the recycling site, possibly to the land directly adjacent to the current recycling site. The precise financial implications of the acquisition or a long term lease of the land are not currently known, however they are expected to be significant. Therefore the establishment of the project activity faces a financial barrier.
   - Barrier: The storage and processing of the waste material required a learning process with City staff. This included the establishment of reliable and consistent processes for the production of material suitable for road construction and maintenance as well as the changes to the site management to accommodate the delivery and storage of the waste material.
   - Common Practice: While it is common practice in the industrial asphalt production to add portions of recycled material in the aggregate mix, it is uncommon in BC for cities to set up their own road base production site.
   - Functional equivalence: Functional equivalence is evident due to equivalent end product use.

4.3.4 Co-Benefits

The co-benefits of the project activities are in two areas. One being the diversion of material from land fill sites, resulting in small amounts of reductions of GHG emission at the landfill sites (see research review), and to stop contributing to the commercial viability of landfill sites through tipping fees. The second area is the benefit of avoiding virgin material production. The co-benefits are related to the avoidance of land use change with new quarry and expanding quarry sites, as well as the reduction in water use and air contaminant pollution at existing quarry sites.

5 Accountability and Reporting

5.1 Scope and Project Eligibility Statement

The City of Richmond asserts that this project plan and report for the crediting period meets all eligibility requirements of the BC Green Communities Committee's (GCC) "Becoming Carbon Neutral Guidebook". Based on the Project Eligibility Requirements, emission reductions have to be outside the local government corporate traditional services boundary (as defined in the Carbon Neutral Workbook). Emissions associated with the purchase and transport of road construction material and the storage and production of road base material are outside the corporate boundary, according to the Carbon Neutral Workbook boundary definition. In addition, there is currently no provincial or federal regulatory requirement for municipalities to process and recycle concrete and asphalt waste material.

5.2 Counted Once

Emission reductions can only be accounted for once. The emission reductions claimed in this report have not been previously committed or sold as emission reductions.

5.3 Ownership

The project proponent, City of Richmond, has clear ownership of all emission reductions due to fact that all project activities are occurring on a City-owned site, executed and managed by City staff.

5.4 Verification

Third party verification provided by Jon Davis Chartered Accountant of Davies & Co.

5.5 Reports

To provide public transparency on this emission reductions/sequestration project, this report will be made publicly available.

6 Signature Pages

Option 2 Project Plan - City of Richmond

Project Proponent Information	
Name of Local Government Project Proponent(s)	City of Richmond
Project Designate appointed to sign off on Project Plan	Name: Andrew Nazareth Title: General Manager, Finance and Corporate Services Phone: 604-276-4095 Email anazareth@richmond.ca
Project Contact	Name: Mr. Levi Higgs, B.Sc., EMIT Title: Corporate Energy Manager, Phone: (604) 244-1239 Email: lhiggs@richmond.ca
Project Information	
Project title	Concrete and Asphalt Recycling at Sidaway Yard
Project description and objectives	The City of Richmond began to undertake the recycling of concrete and some asphalt material, with the intention of reducing landfill waste, reducing truck traffic on City roads, and displacing some of the virgin road base material the City uses on construction sites. Using mobile sorting and crushing equipment the City has completed numerous road base material batches since 2014. Through this project it was determined that on average the GHG emissions associated with virgin production and transportation equalled 20.8 t of CO2e emitted per ton of material produced compared to 3.1 t of CO2e emitted per ton of material produced from recycled material. There are numerous environmental, economic, and social benefits that this project has achieved, and reducing GHG emissions is simply one part of the overall benefits. As a part of the City of Richmond's action plan to achieve this goal, the City will be using this Carbon Reduction Project as an "Option 2 Emission Reduction Project".
Project measurement	See attached Project Measurement form for a description of the formulas, methodologies and assumptions used for this project, and the total anticipated Greenhouse Gas (GHG) reductions
Third party validation of formulas and methodologies	Provide third party validation of the proposed project formulas and methodologies Name: Jon Davies Title: Chartered Professional Accountant, Davies and Co. Phone: Email: jondavies@shaw.ca
Beyond Business as Usual	1) Proposed project start date 2014 2) Is the project required to meet a legislative or regulatory requirement? ☐ Yes ☒ No 3) Indicate how the Project meets one of the following tests (see Appendix 1): ☒ *Common Practice Test: A project can only be considered additional if it employs technologies or practices that are not already in common use.* This project uses practices that are outside of traditionally provided services for solid waste management, as municipalities are not required to recycle concrete or asphalt material. This is not a core service that a BC Municipality would typically provide.
Project co-benefits (Optional)	Main areas of co-benefit include the diversion of material from land fill sites, and avoiding further mining of virgin material and disturbance of natural habitat, as well as the reduction in water use and air contaminant pollution at existing quarry sites.
Project Transparency: Accountability and Reporting	
Scope	This project is outside the City of Richmond's corporate emissions boundary, as it exists outside of the traditional services provided for solid waste management.
Counted Once	The emission reductions for this project have been counted only once, and have not been previously committed, sold, or included in any alternate offset scheme.

Ownership	The City of Richmond has clear ownership of all emission reductions due to fact that all project activities are occurring at a City-owned site, executed and managed by City staff. The City of Richmond has clear ownership of the emission reduction credits and has exclusive rights to the credits listed in this form.
Verification	Third party verification is required for all Option 2 Projects.
Reports	GHG reductions from Option 2 projects will be subject to public reporting requirements. After January 1, 2012, the public reporting requirements under the Climate Action Revenue Incentive Program (CARIP) will be revised to include information on total annual corporate emissions , the reductions being claimed from GHG projects undertaken under the Carbon Neutral Framework (Option 1 and 2) , and purchased offsets (Option 3) in order demonstrate carbon neutrality for any given year, as per the Project Eligibility Requirements outlined in Appendix 1 of the *Becoming Carbon Neutral* guidebook.

Preliminary Review Template: Authorization and Sign Off

Project Designate

The information provided in this Preliminary Review Template is to the best of my knowledge correct and complete.

Designate Signature

Andrew Nazareth

Title: General Manager, Finance and Corporate Services

Date March 30, 2017

Option 2 Third Party Verification Form – City of Richmond

Project Proponent Information	
Name of Local Government Project Proponent(s)	City of Richmond
Name of Third Party Verification Organization	Davies and Company
Project Contact	Name Jon Davies, CPA Title Chartered Professional Accountant – 302-6880 Wallace Drive, Brentwood Bay, BC Phone 250 888 8097 Email: jondavies@shaw.ca
Project Information	
Project title	Concrete and Asphalt Recycling at Sidaway Yard Copy of Project Plan & Third Party Verification Report attached
Timing and Amount of reductions being claimed	Please indicate the amount of GHG reductions, expressed in tonnes, being claimed from the project and the timeframe during which the emission reductions being claimed occurred. Number of tonnes: **831 tonnes of CO2e** Timeframe from 2014 to 2016
Certification that the required work occurred	I declare that the project work required to achieve the GHG reductions from this project, as estimated by the validated Option 2 project formulas/methodologies, actually occurred during the year in which they are being claimed, as per the *Becoming Carbon Neutral* guidebook
Self Verification Template: Authorization and Sign off	

Third Party Verifier

I have conducted a review of the GHG reductions reported by the City, and the supporting emission reductions report completed by GHG Accounting. See detailed third-party verification report.

As a result of my observations and review of the information provided in the project plan template, the project to baseline comparison, and the resulting emission reductions case, nothing came to my attention to suggest that the reported reduction is not supportable and reasonable for the purposes intended. I have not performed an audit and this report does not constitute an opinion on the overall emission reduction calculations.

Davies & Co.
Chartered Professional Accountant
Victoria BC

March 23, 2017

7 SUMMARY OF REFERENCES

General note: Only references used in this report are listed here. As part of the project work, a wider number of sources were reviewed.

BC Road Builders and Heavy Construction Association, and the Ministry of Transportation and Infrastructure (2011). *Road Building and Highway Maintenance Best Practice Guidelines*.

Bohne R.A., Brattebø H., and Bergsdal, H. (2008). *Dynamic Eco-Efficiency Projections for Construction and Demolition Waste: Recycling Strategies at the City Level*. Journal of Industrial Ecology 12(1): 52-68.

Collins F. (2010). *Inclusion of carbonation during the life cycle of built and recycled concrete: influence on their carbon footprint*. International Journal of Life Cycle Assessment 15:549–556.

Dorchies, P. (2008). *The environmental road of the future: Analysis of energy consumption and greenhouse gas emissions*. Paper presented at the Annual Conference of the Transportation Association of Canada, in Toronto, Ontario.

ERANET. (2012). *Tool assessment for CEREAL: Evaluation of existing CO2 tools for roads*.

Holt C., O'Toole, L. and Sullivan P. (2010) *Quantifying Greenhouse Gas Emission Reductions When Utilizing Road Recycling Maintenance Processes*. Presented at the Annual Conference of the Transportation Association of Canada, in Halifax, Nova Scotia.

Guignot S., Touzé S., Von der Weid F., Ménard Y., and Villeneuve J. (2015) *Recycling Construction and Demolition Wastes as Building Materials: A Life Cycle Assessment*. Journal of Industrial Ecology 19(6): 1030–1043.

Environmental Best Practices for Highway Maintenance Activities Manual - Oct/10 Gravel Pit and Quarry Operations.

Ontario Hot Mix Producers Association (OHMPA) (2010). *The ABCs of Recycled Aggregate*.

Santero, N.J., Loijos A., and Ochsendorf, J. (2013). *Greenhouse Gas Emissions Reduction Opportunities for Concrete Pavements*. Journal of Industrial Ecology. DOI: 10.1111/jiec.12053.

Sustainable Aggregates, South Australia. No Date. *Recycled aggregates bring carbon reduction benefits*.

Thomas A., Lombardi D.R., Hunt D., and Gaterell, M. (2009). *Estimating carbon dioxide emissions for aggregate use*. Engineering Sustainability 162: 135-144.

World Bank (2010). *Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation: A Toolkit for Developing Countries*.