September 11, 2017

April 12, 2018 – amended for privacy protection

Environmental Approvals Branch
Manitoba Sustainable Development
160-123 Main Street, Box 80
Winnipeg, MB R3C 1A5

Attention: Ms. Tracey Braun, M.Sc., Director

Dear Ms. Braun:

Subject: RE: EAL 1089 ERR, City of Winnipeg Biosolids Land Application Program, Pilot, Client File No. 963.20

WSP Canada Group Ltd., (WSP) has been retained by the City of Winnipeg to assist with the land application program for Environment Act Licence 1089 ERR based on the Notice of Alteration provided on June 8, 2017. The following letter outlines the approach used to develop the application rates for the City of Winnipeg biosolids and includes a site map, and application rate calculation worksheet.

In accordance with the Manitoba regulatory framework, the following Acts and Regulations apply and will be adhered to throughout the Pilot land application program.

- The Environment Act C.C.S.M. c. E125 (1987)
- Licensing Procedures Regulations 163/88
- Classes of Development Regulation 164/88
- Environment Act Fees Regulation 168/96
- Livestock Manure and Mortalities Management Regulation 42/98
- The Water Protection Act C.C.S.M. c. W65 (2005)
- Nutrient Management Regulation 62/2008

Cooperating Farm Producer

The agricultural field to receive biosolids is NE31-8-1EPM and the north half of SE31-8-1EPM (Figure 1, attached). The crop rotation established for this field by the producer is: oats or corn, then canola, then wheat followed by soybeans. In 2017, the crop was oats with a harvest yield of 157 bushels per acre (bu/ac) and the crop for 2018 will be canola with a target yield of 50 bu/ac.

Dominant Soil Series

Interpretation of the soil survey report for the areas indicates that the dominant soil series identified in the current agricultural fields includes: Red River, Osborne (RIV7-OBOd3) and Myrtle and Scanterbury (MYT5-SCY5) (Figure 1). Outlined in Table 1 are the classification of soil

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Myrtle and Scanterbury (MYT5-SCY5) (Figure 1). Outlined in Table 1 are the classification of soil and the Canada Land Inventory for dryland agricultural capability for each of the four identified soil series.

Table 1. Four Soil Series Identified within NE and SE31-08-01EPM

Order	Great Group	Subgroup	Soil Series, Family Description	Dryland Agricultural Capability
Chernozemic - Soils with chernozemic Ah horizon more than 10 cm thick and with B or C of high base saturation divalent cations, calcium usually common. Well to imperfectly drained soil.	Black horizon with dry colour Munsell values darker than 3.5	Orthic Black	**Myrtle** (MYT) well to moderately well drained Orthic Black soil developed on moderately to strongly calcareous fine textured lacustrine and alluvial deposits.	Class 1, No limitations
		Gleyed Black	**Scanterbury** (SCY) developed on moderately to strongly calcareous lacustrine clay, Imperfectly drained	2W
		Gleyed Rego Black	**Red River** (RIV) developed on moderately to strongly calcareous lacustrine clay, Imperfectly drained.	2W
Gleysolic Poorly drained soils which may have an organic and/or an A horizon. The subsoils show gleying and are dull coloured, but may have brighter colored prominent mottles. Soils associated with wetness.	Humic Gleysol	Rego Humic	**Osborne** (OBO) developed on moderately to strongly calcareous lacustrine clay, poorly drained. Drained phase	3W

CONSTRAINTS

The following constraints have been satisfied:

- The depth of clay or clay till is greater than 1.5m between the soil surface and water table based on the pedological development of the soil series.
- Application field is:
    - Greater than 1000m from a designated residential area;
    - Greater than 10m from any property line of a property with a residence;
    - Greater than 8m from a major wetland, bog, marsh or swamp;
    - Greater than 15m from first order waterway, 30m from a second order or higher waterway; and,
    - Greater than 50m from any groundwater well.
- Land is not subject to annual inundation.

NUTRIENT MANAGEMENT AND LAND APPLICATION PRESCRIPTIONS

Soil Samples

Two bench mark, composite soil samples were collected for each quarter section (NE31-8-1EPM: W001 and W002; SE31-8-1EPM: W003 and W004) and UTM coordinates were recorded for each location. The composite soil sample was comprised of 10 sub samples and collected from 0-15cm and 15-60cm depths. Sample analysis included:

Sample Analysis (0-15cm)		Sample Analysis (15-60cm)
Available Phosphate-P (Olsen)	Arsenic	Total Nitrogen
Available Potassium	Cadmium	Nitrate-N
Total Nitrogen	Chromium	Nitrate + Nitrite-N
Nitrate-N	Copper	Nitrate-N
Nitrate + Nitrite-N	Lead	
Nitrate-N	Mercury	
pH	Nickel	
	Zinc	

Laboratory results for the soil analysis will be outlined in Tables 2, 3, 4, and 5 and the attached Certificate of Analysis.

Biosolids Analysis

As a component of the overall biosolids management program, the City of Winnipeg has maintained a comprehensive biosolids quality monitoring program completing laboratory analysis for a wide spectrum of nutrients and metals. Biosolids analysis has been completed every two weeks by the City of Winnipeg Laboratory and ALS Laboratory. A summary of results for these analysis is included in Table 6 and are reported annually by the City of Winnipeg as required by EAL #1089E RR.

Phosphorus

Since 2007, the City of Winnipeg wastewater treatment process has included chemical treatment with Ferric Chloride ($FeCl^{3+}$) at the North End Sewage Treatment Plant (NEWPCC) to precipitate Total Phosphorus out. The reaction between phosphorus and metal salts is as follows:

$$FeCl_3 + PO_4^{3-} \longrightarrow FePO_4 \text{ (precipitate)} + 3Cl^-$$

In 2002, the City of Winnipeg completed a number of studies on the process of chemical treatment. In Section 13 of the Nitrification Study (Earth Tech Inc., 2002), the chemical phosphorous removal alternatives are reviewed. In this study it is reported that on the basis of reaction stoichiometry, 162.3g of $FeCl_3$ will react with 95g of $P0_4$ to form 150.8g of $FePO_4$, resulting in a weight ratio of 5.2:1 of $FeCl_3$ to phosphorus. In general however, the chemicals required vary significantly depending upon the wastewater characteristics such as influent phosphorus concentrations, pH, alkalinity, quantity and nature of suspended solids, ionic constituents and the effluent phosphorus limit required. The NEWPCC feeds ferric chloride at the primary sludge feed influent to the digester (approximately 80L/hr set rate) and at the digested sludge feed effluent from the holding tanks (approximate feed rate 15L/hr, automatic flow adjusted ratio).

Laboratory analysis of the biosolids demonstrates (Table 6) Total Phosphorus is on average 17,905 mg/kg, dry and standard deviation of 4,125 mg/kg, dry (n=116). Further laboratory analysis between April 2017 and present establishes the average plant available Phosphate-P as 756 mg/kg, with a standard deviation of 266 mg/kg, dry (n=10) using the Modified Kelowna extraction (Table 6). The plant available Phosphate-P is approximately 4% of the Total Phosphorous (Table 2 and 3). This is far below the typical assumption that 50% of Total Phosphorous is made available in manure (Tri-Provincial Manure Application and User Guidelines), and non-chemically treated biosolids (USEPA, 1995).

Studies have demonstrated that biosolids treated with metal salts (Ferric Chloride or Alum) greatly reduce plant available Phosphate-P. Pastene (1981) as reported in O'Connor et al (2002) recommended the molar ratio of (Al + Fe) to phosphorus as an indicator of the P-supplying power of the biosolids. It was suggested that ratio values of <1 were characteristic of biosolids capable of supplying large quantities of soluble phosphorus, whereas ratio values of >1 indicate sources of poor phosphorus supply. O'Connor et al's (2002) work determined that significantly lower phosphorus availability was characterized by biosolids containing very high (>50g/kg) total Fe and Al concentrations and which have been processed by methods that result in dry materials (>60% solids). McCoy (1986) found that P uptake from sludges treated with $FeCl_3$, averaged 4% of the uptake from monocalcium phosphate (MCP). The uptake from the sludge treated with Fe_3 and Alum was 0% relative to MCP and plant uptake of phosphorus from $FeCl_3$ treated sludge relative to triple superphosphate (TSP) was only 10%.

Based on the knowledge that the City of Winnipeg Biosolids are treated with Ferric Chloride salt to achieve a reduction in the total phosphorus concentration in the wastewater stream, the assumption is that the resulting biosolids (post Ferric Chloride treatment) provide a low percentage of plant available phosphorus to plants. As important to this assumption is that the receiving soils are calcium based with an average soil pH of 7.5 where it is understood that the $FePO_4$ precipitate will remain insoluble form and continue to limit plant availability of phosphorus.

Therefore, it is concluded that the land application program should be based on nitrogen value rather than phosphorus to ensure that full agronomic nutrient value is achieved in a land application program.

Nitrogen Mineralization

The biosolids application rate to the agricultural land will be based on the content and availability of the nitrogen present in the biosolids. Fitzgerald and Racz (1999) evaluated the effect of biosolids on crops, soil and environmental quality and in this work the nitrogen mineralization of nitrogen in the City of Winnipeg Biosolids is reported to be between 11% and 17%. A conservative approach to nitrogen mineralization rate for this program will be estimated at 20%, less than the typical 25% mineralization applied in manure application programs, but more than the observed mineralization rate reported by Fitzgerald and Racz (1999).

Nutrient Management Plan

The 2018 crop is planned to be canola, with a target yield of 55 bu/ac, thus requiring an estimated 168 kg/ha (150 lb/ac) of nitrogen and 62 kg/ha (55 lb/ac) of P_2O_5. Field crop nutrient uptake and removal for canola is reported to be between 33 to 44 lbs/ac for a 35 bu/ac yield, this is approximately 1 lb P_2O_5 per bushel of Canola or 55 lb/ac for the target yield.

Fall 2017 soil nutrients demonstrate a field that is nearly depleted in plant available nitrogen and phosphorus, therefore permitting an application rate that is sufficient to permit suitable redevelopment of the plants' nutrient base. The field prescription for application rate is outlined in Table 2 and 3; the basic assumptions that the application rate is based on are as follows:

- Fall 2017 soil residual nitrogen and phosphorus concentrations are low and are not included as a resource for plant uptake and removal in 2018 cropping year.
- Biosolids solids content is consistent at an average 27%.
- $FeCl_3$ biosolids Phosphate-P is approximately 4% of Total Phosphorous content and significantly less than the assumed 50% Plant Available Phosphate.
- Organic nitrogen mineralization in Year 1 is estimated at 20%, Year 2 @ 12% and Year 3 @ 6%.
- Biosolids will be surface applied and incorporated within 48 hours. The assumed volatilization loss is estimated to be 15% for Ammonium-nitrogen.

This establishes a nitrogen based application of approximately 20 dry tonnes per hectare to provide 168 kg/ha (150 lbs/acre) of plant available nitrogen and approximately 15 kg/ha (14 lb/ac) of P_2O_5 (33% of required). Therefore the application of 5,000 wet tonnes biosolids will require approximately 66 hectares or 164 acres of land (Table 2 and 3).

Trace Element Loading

Table 4 and 5 outline the cumulative trace element concentrations based on the anticipated land application loading rate of 20 dry tonnes per hectare. None of the metals required to be monitored exceed the applied cumulative weight allowed in both NE31 and SE31-08-01EPM.

Schedule

It is anticipated that the Pilot land application program will be initiated September 13, 2017 and continue for approximately five weeks or until 5,000 wet tonnes of biosolids have been land applied. The program will not extend beyond the November 10, 2017 restriction date.

Monitoring and Reporting

On or before December 1, 2017 the details of the Pilot land application program will be reported to MSD including: location, spread area, tonnes applied, application rates and dates, total land applied volumes and any deviations that may occur.

For three years following the biosolids land application, annual post-harvest soil testing of each field at bench mark sample locations will be completed for Nitrate-N (0-60cm) and Phosphorus using the Olsen-P test (0-15cm). Supplemental information from the cooperating farm producer including the nutrient management program and cropping system employed will also be provided to MSD. The annual monitoring information will be provided to MSD before the 15th day of March of each year.

Closing

On behalf of the City of Winnipeg, WSP is pleased to provide the outlined nutrient management plan and application prescription rate for biosolids to NE and SE31-08-01EPM. We respectfully request approval from MSD for this Pilot land application program to proceed by September 13, 2017. Should MSD have any further questions or require further clarification, please contact the undersigned directly at: 204-259-1488 or Darren.keam@wsp.com

Sincerely,

Darren Keam, M.Sc., P.Ag.
Manager, Environmental Management

DK/xx
Encl.
cc:
Siobhan Burland Ross, Environmental Approval Branch, Manitoba Sustainable Development
Robert Boswick, Environmental Approval Branch, Manitoba Sustainable Development
David Hay, Water Science and Watershed Management Branch, Manitoba Sustainable Development
Brian Wiebe, Water Science and Watershed Management Branch, Manitoba Sustainable Development
Duane Griffin – Water and Waste Department, City of Winnipeg
Amanda Wolfe - Water and Waste Department, City of Winnipeg

RGE 1

SW-6-9-1E1

SE-6-9-1E1

SW-5-9-1E1

NW-31-8-1E1

NE-31-8-1E1

4

NW-32-8-1E1

(RIV$_7$ - OBO$_3$)

(MYT$_5$ - SCY$_5$)

W002

W003

W004

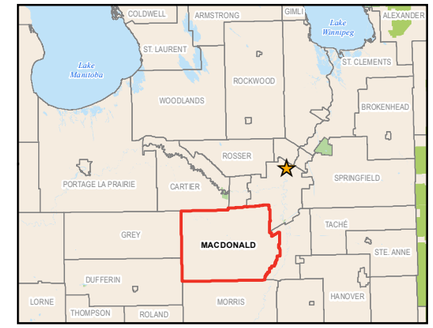
SW-31-8-1E1

SE-31-8-1E1

SW-32-8-1E1

bing

RGE 1



CITY OF WINNIPEG
BIOSOLIDS LAND APPLICATION
17M-00008

Legend

- North End Sewage Treatment Plant (NEWPCC)
- Soil Sample Location

Farm Producer Name

- Land Application Area

Agricultural Capability

- Class 1
- Class 2
- Class 3
- Class 4
- Quarter Section Grid
- Waterbody
- Provincial Trunk Highway
- Provincial Road
- Railway Line

Coordinate System: NAD 83, UTM Zone 14 N
Data Source: MLI, WSP, NRCan, Bing
Date Created: August 01, 2017
Revision Date: September 11, 2017

N

0 50 100 200 Metres

0 0.03 0.06 0.12 0.18 Miles

FIGURE 1
E 1/2 31-08-01 EPM
Biosolids Land Application Field (2017)
Agricultural Capability

wsp

U:\Projects\PROJECTS_2017\17M-00008-00_CityWinnipegBiosolids\Phase_II\MXD\FIG1_SITE4_BiosolidsLandApplicationField_AgCap_20170911.mxd

Table 2. Field Prescription Application Rate, NE31-08-01EPM

September 11, 2017

Field ID:	NE31-08-01EPM	
Land Area Available (ha):		64
2018 Crop	Canola	
2018 Target Yield:	55 bu/ac	
	lb/ac	kg/ha
Target Nitrogen total :	150	168
Fertilizer Phosphate (P2O5) total:	40	45
1 x P2O5 Crop Removal @ target Yield:	55	62
2 x P2O5 Crop Removal @ target Yield:	110	123
3 x P2O5 Crop Removal @ target Yield:	165	185
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data			
	W0001	**W0001**	
Sample Depth	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1
Total Nitrogen	0.318	0.202	
Available Nitrate-N	02.6	2	17
Available Phosphate-P	12.6		25
Available Potassium	418		836
Available Sulfate-S			-
	W0002	**W0002**	
Sample Depth	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1
Total Nitrogen	0.238	0.254	
Available Nitrate-N	02.0	2	16
Available Phosphate-P	07.0		14
Available Potassium	309		618
Available Sulfate-S			-

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	**Parameter Description**	**Unit**	**Biosolid Analysis Pilot Project**
Estimated Biosolid Volume	In-field	m^3	5,000
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	5,000
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	1,345
Moisture	As Received	**%**	73.3
Total Solids	As Received	**%**	26.9
Total Volatile Solids	Dry Basis	%	
Organic Matter	Dry Basis	%	-
Inorganic Content	Dry Basis	%	-
Total Organic Carbon	Dry Basis	%	28.94
N:P Ratio	Dry Basis	x:1	2.07
pH	Saturated Paste		6.15
Total N	Dried Basis	%	3.7
	Dried Basis	mg kg^{-1}	37,144
	Dried Basis	kg $Tonne^{-1}$	37.1
Ammonium - N (NH4-N)	wet	mg kg-1	4,963.0
	Dried Basis	mg kg^{-1}	1,325.3
	Dried Basis	kg $Tonne^{-1}$	1.3
Available Nitrate-N	Dried Basis	mg kg^{-1}	3.22
Available Nitrate-N		kg $Tonne^{-1}$	0.003
Total Phosphorous	Dried Basis	mg kg^{-1}	17,905
Phosphate-P (Modified Kelowna solution)	Dried Basis	mg kg-1	721
Total P:Phosphate-P ratio	Dried Basis	x:1	25
Percent Phosphate of Total		%	4

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN-ammonium N)	Dried Basis	mg kg^{-1}	35,818
Organic N	Dried Basis	kg $Tonne^{-1}$	36
Method of Application:			Incorporated
Anticipated Weather			Cool/dry
Anticipated Volatilization (%)	within 1 day		15
Available Organic N (@ 20%)	Dried Basis	kg $Tonne^{-1}$	7.2
Ammonium nitrogen available	Dried Basis	kg $Tonne^{-2}$	1.13
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg $Tonne^{-1}$	8.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg $Tonne^{-1}$	4.3
PAN Year 3 (@6% mineralization)	Dried Basis	kg $Tonne^{-1}$	2.1
$P_2O_{5\ equivalent}$	Dried Basis	kg $Tonne^{-1}$	0.7

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	20	**66** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	15	164 Ac
P_2O_5 Application check		%	33	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	85	**16** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	709	**39** Ac
		lb ac^{-1}	631	
Additional Nitrogen required		kg ha^{-1}	- 541	
		lb ac-1	- 482	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**171**	**8** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	1,418	**19** Ac
Additional Nitrogen required		kg ha^{-1}	- 1,250	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**256**	**5** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	2,127	**13** Ac
Additional Nitrogen required		kg ha^{-1}	- 1,959	

Selected Application rate based on:		**Nitrogen**	**PAN Year 1**
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**20**
		tons ac^{-1}	**9**
	Wet Basis	tonnes ha^{-1}	79
		tons ac^{-1}	36
Estimated Biosolids Volume Applied	Wet	Tonnnes	5,070
Estimated Biosolids Volume Remaining	Wet	Tonnes	- 70

Notes

Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)

Organic N - TKN - Ammonium N

Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)

Mineralization of Year 2 = 12%, Year 3 = 6%

Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization

Plant Available Phosphorus based on P2O5 (Modified Kelowna Analysis) as the biosolids are FeCl treated and fixes the majority of the total P.

Soil Phosphorous Olsen method.

* See Estimates of Ammonium-N Retained After Biosolids application

Table 3. Field Prescription Application Rate, SE31-08-01EPM

September 11, 2017

Field ID:	SE31-08-01EPM	
Land Area Available (ha):		25
2018 Crop	Canola	
2018 Target Yield:	55 bu/ac	
	lb/ac	kg/ha
Target Nitrogen total :	150	168
Fertilizer Phosphate (P2O5) total:	40	45
1 x P2O5 Crop Removal @ target Yield:	40	45
2 x P2O5 Crop Removal @ target Yield:	80	90
3 x P2O5 Crop Removal @ target Yield:	120	134
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data			
	W0003	**W0003**	
Sample Depth	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1
Total Nitrogen	0.29	0.186	
Available Nitrate-N	02.0	2	16
Available Phosphate-P	09.0		18
Available Potassium	390		780
Available Sulfate-S			-
	W0004	**W0004**	
Sample Depth	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1
Total Nitrogen	0.333	0.202	
Available Nitrate-N	02.0	2	16
Available Phosphate-P	17.3		35
Available Potassium	430		860
Available Sulfate-S			-

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	5,000
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	5,000
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	1,345
Moisture	As Received	**%**	73.3
Total Solids	As Received	**%**	26.9
Total Volatile Solids	Dry Basis	%	
Organic Matter	Dry Basis	%	-
Inorganic Content	Dry Basis	%	-
Total Organic Carbon	Dry Basis	%	28.94
N:P Ratio	Dry Basis	x:1	2.07
pH	Saturated Paste		6.15
Total N	Dried Basis	%	3.7
	Dried Basis	mg kg^{-1}	37,144
	Dried Basis	kg $Tonne^{-1}$	37.1
Ammonium - N (NH4-N)	wet	mg kg-1	4,963.0
	Dried Basis	mg kg^{-1}	1,325.3
	Dried Basis	kg $Tonne^{-1}$	1.3
Available Nitrate-N	Dried Basis	mg kg^{-1}	3.22
Available Nitrate-N		kg $Tonne^{-1}$	0.003
Total Phosphorous	Dried Basis	mg kg^{-1}	17,905
Phosphate-P (Modified Kelowna solution)	Dried Basis	mg kg-1	721
Total P:Phosphate-P ratio	Dried Basis	x:1	25
Percent Phosphate of Total		%	4

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN-ammonium N)	Dried Basis	mg kg^{-1}	35,818
Organic N	Dried Basis	kg $Tonne^{-1}$	36
Method of Application:			Incorporated
Anticipated Weather			Cool/dry
Anticipated Volatilization (%)	within 1 day		15
Available Organic N (@ 20%)	Dried Basis	kg $Tonne^{-1}$	7.2
Ammonium nitrogen available	Dried Basis	kg $Tonne^{-2}$	1.13
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg $Tonne^{-1}$	8.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg $Tonne^{-1}$	4.3
PAN Year 3 (@6% mineralization)	Dried Basis	kg $Tonne^{-1}$	2.1
$P_2O_{5\ equivalent}$	Dried Basis	kg $Tonne^{-1}$	0.7

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	20	**66** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	15	164 Ac
P2O5 Application check		%	33	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	62.18	**22** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	516	**53** Ac
		lb ac^{-1}	459	
Additional Nitrogen required		kg ha^{-1}	- 348	
		lb ac-1	- 309	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**124.36**	**11** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	1,031	**27** Ac
Additional Nitrogen required		kg ha^{-1}	- 863	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**186.54**	**7** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	1,547	**18** Ac
Additional Nitrogen required		kg ha^{-1}	- 1,379	

Selected Application rate based on:		**Nitrogen**	**PAN Year 1**
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**20**
		tons ac^{-1}	**9**
	Wet Basis	tonnes ha^{-1}	79
		tons ac^{-1}	36
Estimated Biosolids Volume Applied	Wet	Tonnnes	1,980
Estimated Biosolids Volume Remaining	Wet	Tonnes	3,020

Notes

Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)

Organic N - TKN - Ammonium N

Available Organic N - Organic N x 0.25year 1

Mineralization of Year 2 = 12%, Year 3 = 6%

Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization

Plant Available Phosphorus based on P2O5 (Modified Kelowna Analysis) as the biosolids are FeCl treated and fixes the majority of the total P.

Soil Phosphorous Olsen method.

* See Estimates of Ammonium-N Retained After Biosolids application

Table 4. City of Winnipeg Biosolid Trace Elements (Metal) Field Specific Soil Metal Concentrations and Cumulative Metal Concentrations

Trace Element	City of Wpg Average Concentration		NE31-8-1E (0-15cm) W001		NE31-8-1E (0-15cm) W002		Mean Soil Metal Concentration	Loading Rate 20 Tonnes / Ha (dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]
	mg kg^{-1}	kg $tonne^{-1}$	mg kg^{-1}	kg ha^{-1}	mg kg^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Arsenic (As)	4.39	0.00	8.99	0.009	9.06	0.009	0.01	0.000	0.01	21.6
Cadmium (Cd)	2.25	0.00	0.20	0.000	0.20	0.000	0.00	0.000	0.00	2.5
Chromium (Cr)	115.80	0.12	44.5	0.045	48.6	0.049	0.05	0.000	0.05	115.2
Copper (Cu)	596.81	0.60	32.2	0.032	30.6	0.031	0.03	0.000	0.03	113.4
Lead (Pb)	72.73	0.07	15.1	0.015	13.6	0.014	0.01	0.000	0.01	126
Mercury (Hg)	1.01	0.00	00.0	0.000	00.0	0.000	0.00	0.000	0.00	11.9
Nickel (Ni)	55.21	0.06	44.0	0.044	44.8	0.045	0.04	0.000	0.04	90
Zinc (Zn)	1394.99	1.39	092	0.092	93.0	0.093	0.09	0.000	0.09	360

Notes:

Max loading rate calculated

[1] = Soil concentrations less than detection

[2] = Cumulative Weight Allowed by Guideline includes the metals in soils.

Table 5. City of Winnipeg Biosolid Trace Elements (Metal) Field Specific Soil Metal Concentrations and Cumulative Metal Concentrations

Trace Element	City of Wpg Average Concentration		SE31-8-1E (0-15cm) W003		SE31-8-1E (0-15cm) W004		Mean Soil Metal Concentration	Loading Rate 20 Tonnes / Ha (dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]
	mg kg^{-1}	kg $tonne^{-1}$	mg kg^{-1}	kg ha^{-1}	mg kg^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Arsenic (As)	4.39	0.00	9.23	0.009	9.34	0.009	0.01	0.000	0.01	21.6
Cadmium (Cd)	2.25	0.00	0.25	0.000	0.30	0.000	0.00	0.000	0.00	2.5
Chromium (Cr)	115.80	0.12	51.2	0.051	43.5	0.044	0.05	0.000	0.05	115.2
Copper (Cu)	596.81	0.60	32.9	0.033	31.8	0.032	0.03	0.000	0.03	113.4
Lead (Pb)	72.73	0.07	14.5	0.015	15.7	0.016	0.02	0.000	0.02	126
Mercury (Hg)	1.01	0.00	00.0	0.000	00.0	0.000	0.00	0.000	0.00	11.9
Nickel (Ni)	55.21	0.06	15.6	0.016	39.0	0.039	0.03	0.000	0.03	90
Zinc (Zn)	1394.99	1.39	101	0.101	90.0	0.090	0.10	0.000	0.10	360

Notes:

Max loading rate calculated

[1] = Soil concentrations less than detection

[2] = Cumulative Weight Allowed by Guideline includes the metals in soils.

Table 6. Analytical Summary of City of Winnipeg Biosolids Analysis (2012 to Present)

Statistical Analysis Summary	Total Solids	Moisture	Total Organic Carbon (dry basis)	Total Kjendal Nitrogen	Total Nitrogen (Slu-ext)	pH	Conductivity	Aluminum	Arsnic	Cadmium	Colbolt	Chromium
	(%)			*(mg/kg N)*			*(µS/cm)*	*Total (mg/kg dry)*				
Min	21.5	68.9	23.2	23600.0	30900.0	5.8	5260.0	27.4	3.0	1.3	4.0	63.6
Max	34.1	79.8	34.8	39900.0	44200.0	7.3	20600.0	11600.0	6.3	9.8	24.9	345.0
Average	26.9	73.3	27.4	32627.6	37347.1	6.1	9459.9	6923.4	4.4	2.2	6.6	115.8
95th percentile	31.3	77.9	32.5	38100.0	42360.0	6.7	15330.0	9561.5	5.6	4.1	8.5	203.9
Standard Deviation	2.9	3.0	3.3	3491.1	3606.9	0.3	3341.4	1690.0	0.7	1.2	2.3	42.9
Count (n=)	114	100	90	101	17	59	55	108	108	108	104	108

Notes:
Data provided by City of Winnipeg

Table 6. Analytical Summary c

Statistical Analysis Summary	Copper	Iron	Mercury	Potassium	Molybdenum	Nickel	Phosphorus	Lead	Selenium	Zinc
	Total (mg/kg dry)									
Min	370.0	24700.0	0.6	705.0	7.7	16.7	13400.0	29.5	1.9	632.0
Max	954.0	68000.0	1.8	2810.0	30.6	121.0	26800.0	325.0	106.0	5080.0
Average	596.8	38517.6	1.0	1760.1	15.0	55.2	17905.0	72.7	5.3	1395.0
95th percentile	813.5	59725.0	1.4	2368.0	20.3	82.8	24695.0	120.3	5.5	2852.0
Standard Deviation	126.1	10481.9	0.2	338.1	3.8	16.2	4125.7	46.4	12.8	762.9
Count (n=)	108	108	95	105	107	106	108	106	108	110

Notes:
Data provided by City of Winni

Table 6. Analytical Summary c

Statistical Analysis Summary	Ammonium-N	Phosphate-P (mg/Kg)	Sulfate-S (mg/Kg)	Potassium (mg/Kg)	Nitrite-N (mg/Kg)	Nitrate-N (mg/Kg)	Nitrate + Nitrite-N (mg/Kg)	Loss On Ignition (%)	Inorganic Carbon as CaCO3	Total Carbon by combustion	Total Inorganic Carbon in Soil	Total Organic Carbon Calculation
	(mg/Kg) (wet)	*(mg/kg dry)*						*(%)*	*(%)*			
Min	3120.0	450.0	554.0	530.0	1.0	4.6	3.0	40.5	5.7	25.5	0.7	24.3
Max	6700.0	1380.0	2540.0	690.0	1.8	4.6	3.3	52.7	10.2	31.9	1.2	31.2
Average	4963.0	720.5	1994.4	625.3	1.4	4.6	3.2	47.0	7.8	28.9	0.9	28.0
95th percentile	5804.0	1188.0	2516.0	683.2	1.7	4.6	3.3	52.5	10.1	31.8	1.2	30.9
Standard Deviation	1076.7	255.3	544.9	53.8	0.2	0.0	0.1	3.8	1.3	1.8	0.2	1.9
Count (n=)	10	10	10	10	6	1	5	10	15	15	15	15

Notes:
Data provided by City of Winni

WSP Canada Group Limited
ATTN: BRIAN MOONS
1600 Buffalo Place
Winnipeg MB R3T 6B8

Date Received: 22-AUG-17
Report Date: 01-SEP-17 07:37 (MT)
Version: FINAL

Client Phone: 204-477-6650

Certificate of Analysis

Lab Work Order #: L1978983

Project P.O. #: NOT SUBMITTED
Job Reference: 17M-00008-01
C of C Numbers:
Legal Site Desc:

Hua Wo
Chemistry Laboratory Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	MU	Qualifier*	D.L.	Units	Bias	Extracted	Analyzed	Batch
L1978983-1 W001 0-15									
Sampled By: BM on 22-AUG-17 @ 09:00									
Matrix: SOIL									
Miscellaneous Parameters									
Available Phosphate-P	12.6	-		1.0	mg/kg	-	25-AUG-17	25-AUG-17	R3812043
Available Potassium	418	+/-52	DLHC	40	mg/kg	-11.8%	25-AUG-17	25-AUG-17	R3812127
Mercury (Hg)	0.0380	+/-0.010		0.0050	mg/kg	0	25-AUG-17	29-AUG-17	R3814622
Total Nitrogen by LECO	0.318	+/-0.056		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
pH (1:2 soil:water)	6.52	+/-0.18		0.10	pH	0	31-AUG-17	31-AUG-17	R3816229
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	2.6	+/-1.5		2.0	mg/kg	0	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	2.6	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Metals									
Arsenic (As)	8.99	+/-1.1		0.10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Cadmium (Cd)	0.196	+/-0.035		0.020	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Chromium (Cr)	44.5	+/-8.0		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Copper (Cu)	32.2	+/-4.8		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Lead (Pb)	15.1	+/-2.9		0.20	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Nickel (Ni)	44.0	+/-5.5		0.50	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Zinc (Zn)	92	+/-12		10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
L1978983-2 W001 15-60									
Sampled By: BM on 22-AUG-17 @ 09:00									
Matrix: SOIL									
Miscellaneous Parameters									
Total Nitrogen by LECO	0.202	+/-0.037		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
L1978983-3 W002 0-15									
Sampled By: BM on 22-AUG-17 @ 10:00									
Matrix: SOIL									
Miscellaneous Parameters									
Available Phosphate-P	7.0	-		1.0	mg/kg	-	25-AUG-17	25-AUG-17	R3812043
Available Potassium	309	+/-40		20	mg/kg	-11.8%	25-AUG-17	25-AUG-17	R3812127
Mercury (Hg)	0.0290	+/-0.0084		0.0050	mg/kg	0	25-AUG-17	29-AUG-17	R3814622
Total Nitrogen by LECO	0.238	+/-0.043		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
pH (1:2 soil:water)	7.50	+/-0.18		0.10	pH	0	31-AUG-17	31-AUG-17	R3816229
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Metals									
Arsenic (As)	9.06	+/-1.2		0.10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Cadmium (Cd)	0.204	+/-0.036		0.020	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Chromium (Cr)	48.6	+/-8.8		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Copper (Cu)	30.6	+/-4.6		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Lead (Pb)	13.6	+/-2.6		0.20	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Nickel (Ni)	44.8	+/-5.6		0.50	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Zinc (Zn)	93	+/-12		10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
L1978983-4 W002 15-60									
Sampled By: BM on 22-AUG-17 @ 10:00									
Matrix: SOIL									

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	MU	Qualifier*	D.L.	Units	Bias	Extracted	Analyzed	Batch
L1978983-4 W002 15-60									
Sampled By: BM on 22-AUG-17 @ 10:00									
Matrix: SOIL									
Miscellaneous Parameters									
Total Nitrogen by LECO	0.254	+/-0.046		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
L1978983-5 W003 0-15									
Sampled By: BM on 22-AUG-17 @ 10:20									
Matrix: SOIL									
Miscellaneous Parameters									
Available Phosphate-P	9.0	-		1.0	mg/kg	-	25-AUG-17	25-AUG-17	R3812043
Available Potassium	390	+/-49		20	mg/kg	-11.8%	25-AUG-17	25-AUG-17	R3812127
Mercury (Hg)	0.0310	+/-0.0088		0.0050	mg/kg	0	25-AUG-17	29-AUG-17	R3814622
Total Nitrogen by LECO	0.290	+/-0.052		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
pH (1:2 soil:water)	6.98	+/-0.18		0.10	pH	0	31-AUG-17	31-AUG-17	R3816229
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Metals									
Arsenic (As)	9.23	+/-1.2		0.10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Cadmium (Cd)	0.252	+/-0.045		0.020	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Chromium (Cr)	51.2	+/-9.3		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Copper (Cu)	32.9	+/-4.9		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Lead (Pb)	14.5	+/-2.8		0.20	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Nickel (Ni)	45.6	+/-5.7		0.50	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Zinc (Zn)	101	+/-13		10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
L1978983-6 W003 15-60									
Sampled By: BM on 22-AUG-17 @ 10:20									
Matrix: SOIL									
Miscellaneous Parameters									
Total Nitrogen by LECO	0.186	+/-0.035		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
L1978983-7 W004 0-15									
Sampled By: BM on 22-AUG-17 @ 10:45									
Matrix: SOIL									
Miscellaneous Parameters									
Available Phosphate-P	17.3	-		1.0	mg/kg	-	25-AUG-17	25-AUG-17	R3812043
Available Potassium	430	+/-54	DLHC	40	mg/kg	-11.8%	25-AUG-17	25-AUG-17	R3812127
Mercury (Hg)	0.0383	+/-0.010		0.0050	mg/kg	0	25-AUG-17	29-AUG-17	R3814622
Total Nitrogen by LECO	0.333	+/-0.059		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
pH (1:2 soil:water)	6.63	+/-0.18		0.10	pH	0	31-AUG-17	31-AUG-17	R3816229
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Metals									

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	MU	Qualifier*	D.L.	Units	Bias	Extracted	Analyzed	Batch
L1978983-7 W004 0-15									
Sampled By: BM on 22-AUG-17 @ 10:45									
Matrix: SOIL									
Metals									
Arsenic (As)	9.34	+/-1.2		0.10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Cadmium (Cd)	0.295	+/-0.053		0.020	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Chromium (Cr)	43.5	+/-7.9		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Copper (Cu)	31.8	+/-4.8		1.0	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Lead (Pb)	15.7	+/-3.1		0.20	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Nickel (Ni)	39.0	+/-4.9		0.50	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
Zinc (Zn)	90	+/-11		10	mg/kg	0	25-AUG-17	28-AUG-17	R3813733
L1978983-8 W004 15-60									
Sampled By: BM on 22-AUG-17 @ 10:45									
Matrix: SOIL									
Miscellaneous Parameters									
Total Nitrogen by LECO	0.202	+/-0.038		0.020	%	0	29-AUG-17	29-AUG-17	R3814347
Nitrate, Nitrite and Nitrate+Nitrite-N									
Nitrite-N	<0.40	-		0.40	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate+Nitrite-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380
Nitrate-N	<2.0	-		2.0	mg/kg	-	31-AUG-17	31-AUG-17	R3816380

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLHC	Detection Limit Raised: Dilution required due to high concentration of test analyte(s).

Test Method References:

ALS Test Code	Matrix	Test Description	Preparation Method Reference	Method Reference**
HG-200.2-CVAF-WP	Soil	Mercury in Soil by CVAFS		EPA 200.2/1631E (mod)
Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CVAFS.				
K-AVAIL-SK	Soil	Available Potassium		Comm. Soil Sci. Plant, 25 (5&6)
Plant available potassium is extracted from the soil using Modified Kelowna solution. Potassium in the soil extract is determined by flame emission at 770 nm.				
MET-200.2-MS-WP	Soil	Metals		EPA 200.2/6020A
Samples for analysis are homogenized, dried at 60 degrees Celsius, sieved through a 2 mm (10 mesh) sieve, and a representative subsample of the dry material is weighed. The sample is then digested by block digester (EPA 200.2). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A). Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may become "environmentally available." By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.				
N-TOT-LECO-SK	Soil	Total Nitrogen by combustion method		CSSS (2008) 22.4
The sample is ignited in a combustion analyzer where nitrogen in the reduced nitrous oxide gas is determined using a thermal conductivity detector.				
N2/N3-AVAIL-SK	Soil	Nitrate, Nitrite and Nitrate+Nitrite-N		APHA 4500 NO3F
Available Nitrate and Nitrite are extracted from the soil using a dilute calcium chloride solution. Nitrate plus Nitrite is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is measured at colorimetrically at 520nm. Nitrite is determined on the same extract by following the same instrumental procedure without a cadmium column. Reference: Recommended Methods of Soil Analysis for Canadian Prairie Agricultural Soils. Alberta Agriculture (1988) p. 19 and 28				
PH-1:2-SK	Soil	pH (1:2 Soil:Water Extraction)		AB Ag (1988) p.7
1 part dry soil and 2 parts de-ionized water (by volume) is mixed. The slurry is allowed to stand with occasional stirring for 30 - 60 minutes. After equilibration, pH of the slurry is measured using a pH meter.				
PO4-AVAIL-OLSEN-SK	Soil	Available Phosphate-P by Olsen		CSSS (2008) 8.2
Plant available phosphorus is extracted from the sample with sodium bicarbonate. PO4-P in the filtered extract is determined colorimetrically at 880 nm.				

** The indicated Method Reference is the closest nationally or internationally recognized reference for the applicable ALS test method. ALS methods may incorporate modifications from the specified reference to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA

Chain of Custody Numbers:

Reference Information

GLOSSARY OF REPORT TERMS

Surr - Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.
MU: Measurement Uncertainty. The reported uncertainty is an expanded uncertainty calculated using a coverage factor of 2 which gives a level of confidence of approximately 95%.
Bias: The reported method bias is the average long term deviation from the target value for a long term reference or control sample, measured in percent. Zero values indicate no detectable method bias.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: WSP Canada Group Limited
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: BRIAN MOONS

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-200.2-CVAF-WP	**Soil**							
Batch R3814622								
WG2604093-4 CRM		**PACS-3**						
Mercury (Hg)			107.1		%		70-130	29-AUG-17
WG2604093-5 DUP		**L1978983-7**						
Mercury (Hg)		0.0383	0.0370		mg/kg	3.5	40	29-AUG-17
WG2604093-2 LCS								
Mercury (Hg)			106.8		%		80-120	29-AUG-17
WG2604093-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	29-AUG-17
K-AVAIL-SK	**Soil**							
Batch R3812127								
WG2600851-1 DUP		**L1979030-3**						
Available Potassium		398	401		mg/kg	0.8	30	25-AUG-17
WG2600851-3 IRM		**FARM2005**						
Available Potassium			94.6		%		70-130	25-AUG-17
WG2600851-2 MB								
Available Potassium			<20		mg/kg		20	25-AUG-17
MET-200.2-MS-WP	**Soil**							
Batch R3813733								
WG2601712-4 CRM		**PACS-3**						
Arsenic (As)			99.2		%		70-130	28-AUG-17
Cadmium (Cd)			92.6		%		70-130	28-AUG-17
Chromium (Cr)			101.5		%		70-130	28-AUG-17
Copper (Cu)			102.8		%		70-130	28-AUG-17
Lead (Pb)			92.2		%		70-130	28-AUG-17
Nickel (Ni)			100.1		%		70-130	28-AUG-17
Zinc (Zn)			99.4		%		70-130	28-AUG-17
WG2601712-5 CRM		**CANMET TILL-1**						
Arsenic (As)			102.0		%		70-130	28-AUG-17
Cadmium (Cd)			101.9		%		70-130	28-AUG-17
Chromium (Cr)			99.0		%		70-130	28-AUG-17
Copper (Cu)			103.1		%		70-130	28-AUG-17
Lead (Pb)			104.4		%		70-130	28-AUG-17
Nickel (Ni)			101.0		%		70-130	28-AUG-17
Zinc (Zn)			98.9		%		70-130	28-AUG-17
WG2601712-7 DUP		**WG2601712-6**						
Arsenic (As)		9.34	9.45		mg/kg	1.1	30	28-AUG-17

Quality Control Report

Client: WSP Canada Group Limited
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: BRIAN MOONS

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-MS-WP	**Soil**							
Batch R3813733								
WG2601712-7 DUP		**WG2601712-6**						
Cadmium (Cd)		0.268	0.251		mg/kg	6.8	30	28-AUG-17
Chromium (Cr)		43.5	43.0		mg/kg	1.2	30	28-AUG-17
Copper (Cu)		31.8	30.7		mg/kg	3.6	30	28-AUG-17
Lead (Pb)		15.7	15.5		mg/kg	1.5	40	28-AUG-17
Nickel (Ni)		39.0	38.6		mg/kg	0.9	30	28-AUG-17
Zinc (Zn)		90	88		mg/kg	2.4	30	28-AUG-17
WG2601712-2 LCS								
Arsenic (As)			107.2		%		80-120	28-AUG-17
Cadmium (Cd)			98.9		%		80-120	28-AUG-17
Chromium (Cr)			106.0		%		80-120	28-AUG-17
Copper (Cu)			102.7		%		80-120	28-AUG-17
Lead (Pb)			102.0		%		80-120	28-AUG-17
Nickel (Ni)			103.6		%		80-120	28-AUG-17
Zinc (Zn)			103.3		%		80-120	28-AUG-17
WG2601712-1 MB								
Arsenic (As)			<0.10		mg/kg		0.1	28-AUG-17
Cadmium (Cd)			<0.020		mg/kg		0.02	28-AUG-17
Chromium (Cr)			<1.0		mg/kg		1	28-AUG-17
Copper (Cu)			<1.0		mg/kg		1	28-AUG-17
Lead (Pb)			<0.20		mg/kg		0.2	28-AUG-17
Nickel (Ni)			<0.50		mg/kg		0.5	28-AUG-17
Zinc (Zn)			<10		mg/kg		10	28-AUG-17
N-TOT-LECO-SK	**Soil**							
Batch R3814347								
WG2600661-1 DUP		**L1978697-3**						
Total Nitrogen by LECO		0.557	0.552		%	1.0	20	29-AUG-17
WG2600661-2 IRM		**08-109_SOIL**						
Total Nitrogen by LECO			0.115		%		0.085-0.135	29-AUG-17
WG2600661-4 MB								
Total Nitrogen by LECO			<0.020		%		0.02	29-AUG-17
N2/N3-AVAIL-SK	**Soil**							
Batch R3816380								
WG2604304-1 DUP		**L1978983-2**						
Nitrite-N		<0.40	<0.40	RPD-NA	mg/kg	N/A	50	31-AUG-17

Quality Control Report

Client: WSP Canada Group Limited
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: BRIAN MOONS

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
N2/N3-AVAIL-SK	**Soil**							
Batch R3816380								
WG2604304-1 DUP		**L1978983-2**						
Nitrate+Nitrite-N		<2.0	<2.0	RPD-NA	mg/kg	N/A	30	31-AUG-17
WG2604304-3 IRM		**SAL814**						
Nitrate+Nitrite-N			114.1		%		70-130	31-AUG-17
WG2604304-2 MB								
Nitrite-N			<0.40		mg/kg		0.4	31-AUG-17
Nitrate+Nitrite-N			<2.0		mg/kg		2	31-AUG-17
PH-1:2-SK	**Soil**							
Batch R3816229								
WG2604311-2 IRM		**SAL814**						
pH (1:2 soil:water)			8.09		pH		7.65-8.25	31-AUG-17
PO4-AVAIL-OLSEN-SK	**Soil**							
Batch R3812043								
WG2599642-1 DUP		**L1978598-7**						
Available Phosphate-P		6.2	7.0		mg/kg	12	30	25-AUG-17
WG2599642-3 IRM		**FARM2005**						
Available Phosphate-P			103.4		%		80-120	25-AUG-17
WG2599642-2 MB								
Available Phosphate-P			<1.0		mg/kg		1	25-AUG-17

Quality Control Report

Workorder: L1978983 Report Date: 01-SEP-17

Client: WSP Canada Group Limited
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: BRIAN MOONS

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Workorder: L1978983 Report Date: 01-SEP-17

Client: WSP Canada Group Limited
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: BRIAN MOONS

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Plant Available Nutrients							
Nitrate, Nitrite and Nitrate+Nitrite-N							
	1	22-AUG-17 09:00	31-AUG-17 16:38	3	9	days	EHT
	2	22-AUG-17 09:00	31-AUG-17 16:38	3	9	days	EHT
	3	22-AUG-17 10:00	31-AUG-17 16:38	3	9	days	EHT
	4	22-AUG-17 10:00	31-AUG-17 16:38	3	9	days	EHT
	5	22-AUG-17 10:20	31-AUG-17 16:38	3	9	days	EHT
	6	22-AUG-17 10:20	31-AUG-17 16:38	3	9	days	EHT
	7	22-AUG-17 10:45	31-AUG-17 16:38	3	9	days	EHT
	8	22-AUG-17 10:45	31-AUG-17 16:38	3	9	days	EHT

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1978983 were received on 22-AUG-17 14:55.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Chain of Custody (COC) / Analytical Request Form

ALS Environmental

www.alsglobal.com

Canada Toll Free: 1 800 668 9878

L1978983-COFC

COC Number: 14 -

Page 1 of 1

L1978983

Report To		Report Format / Distribution		Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)
Company:	WSP Group Canada Limited	Select Report Format: ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL)		R ☑ Regular (Standard TAT if received by 3 pm - business days)
Contact:	Brian Moons	Quality Control (QC) Report with Report ☐ Yes ☑ No		P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
Address:	1600 Buffalo Place	☐ Criteria on Report - provide details below if box checked		E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
		Select Distribution: ☑ EMAIL ☐ MAIL ☐ FAX		E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge
Phone:	204-477-6650	Email 1 or Fax brian.moons@wsp.com		Specify Date Required for E2,E or P:
		Email 2 darren.keam@wsp.com		

Invoice To	Same as Report To ☐ Yes ☑ No	Invoice Distribution	
	Copy of Invoice with Report ☐ Yes ☑ No	Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX	
Company:	WSP Group Canada Limited	Email 1 or Fax apwest@wsp.com	
Contact:	accounts payable	Email 2	
Project Information		**Oil and Gas Required Fields (client use)**	
ALS Quote #:	Q63821	Approver ID:	Cost Center:
Job #:	17M-00008-01	GL Account:	Routing Code:
PO / AFE:		Activity Code:	
LSD:		Location:	
ALS Lab Work Order # (lab use only)		**ALS Contact:** Judy D	**Sampler:** Brian Moons

Analysis Request

Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Available Phosphate-P by Olsen	Total nitrogen by combustion	Nitrate, Nitrite and Nitrate+Nitrite-N	pH by 1:2 soil:water extraction	Available potassium	As, Cd, Cr, Cu, Ni, Pb, Zn	Hg by CVAFS						Number of Containers
	W001 0-15	22-Aug-17	9:00	Soil	R	R	R	R	R	R	R						2
	W001 15-60		9:00	Soil		R	R										1
	W002 0-15		10:07	Soil	R	R	R	R	R	R	R						2
	W002 15-60		10:00	Soil		R	R										1
	W003 0-15		10:20	Soil	R	R	R	R	R	R	R						2
	W003 15-60		10:20	Soil		R	R										1
	W004 0-15		10:45	Soil	R	R	R	R	R	R	R						2
	W004 15-60		10:45	Soil		R	R										1

Drinking Water (DW) Samples[1] (client use)	Special Instructions / Specify Criteria to add on report (client Use)
Are samples taken from a Regulated DW System? ☐ Yes ☐ No	
Are samples for human drinking water use? ☐ Yes ☐ No	

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐

Ice packs Yes ☐ No ☐ Custody seal intact Yes ☐ No ☐

Cooling Initiated ☐

INITIAL COOLER TEMPERATURES °C			FINAL COOLER TEMPERATURES °C		
M29					

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by: Darren Moore	Date: 2017-08-22	Time: 14:55	Received by: AR	Date: AUG 22/17	Time: 2:55	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

NA-FM-0328e v09 Front/04 January 2014

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.