City of Calgary Dewatered Biosolids Land Application Program

– Willow Biomass Proposal

May 2013

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DOCUMENT # 950-13

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ABBREVIATIONS

List of unit abbreviations used in this document:

bt – bulk tonnes

cm – centimetre

dt – dry tonnes

dt/ha – dry tonnes per hectare

g – gram

ha – hectare

kg – kilogram

kg/ha – kilogram per hectare

m – metre

m^3/d – cubic metre per day

mm/d – millimetres per day

MLD – megalitres per day

MPN 100 mL^{-1} – Most Probable Number per 100 millilitres

List of general abbreviations used in this document:

BNR – Biological Nutrient Removal

CAD – Computer Aided Design

CoC - City of Calgary

CoE – City of Edmonton

ECC – Edmonton-Calgary Corridor

ESRD – Alberta Environment and Sustainable Resource Development

Guidelines – Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (March 2001)

LONO – Letter of No Objection

N - Nitrogen

OM – Organic Matter

OMRR – British Columbia Organic Matter Recycling Regulation

P – Phosphorus

RFP – Request for Proposal

TOC – Total Organic Carbon

TKN – Total Kjeldahl Nitrogen

WWTP – Wastewater Treatment Plant

TABLE OF CONTENTS

1 PROGRAM BACKGROUND 1
1.1 Dewatered Biosolids Use Demonstrations Not Conforming to Alberta Guidelines 1
1.2 Calgary Willow Biomass Plantation Project 2
1.2.1 Project Overview 2
1.2.2 Regulatory Approval 3
2 SITE BACKGROUND 4
3 BIOSOLIDS INFORMATION 4
3.1 City of Calgary Biosolids Information 4
3.2 City of Calgary Biosolids Sampling and Results 5
4 BIOSOLIDS APPLICATION INTENTIONS 6
5 APPLICATION FORM FOR AUTHORIZATION TO SPREAD BIOSOLIDS TO LAND 6
6 DEVIATION FROM CURRENT BIOSOLIDS MANAGEMENT GUIDELINES 6
7 FIELD INVESTIGATION AND RECONNAISSANCE 7
7.1 Site Description 7
7.2 Soils 7
7.3 Pre-Application Soil Sampling and Results 8
7.3.1 Soil pH and texture 8
7.3.2 Plant available nitrogen 9
7.3.3 Alberta Tier 1 Metals 9
7.3.4 Post-application sampling 10
7.4 Distance of Land Application Site from Specified Features 10
7.5 Groundwater 10
7.5.1 Aquifers and wells 10
7.5.2 Groundwater flow 11
7.5.3 Willow water uptake 11
7.6 Classification of Land Units 11
8 BIOSOLIDS APPLICATION RATES 11
8.1 Application Rate Determination 12
8.1.1 Willow nutrient requirements 12
8.2 Biosolids Tonnage and Volume Estimates 12
8.3 Cumulative Addition of Biosolids Constituents 12
8.4 Nitrogen Addition to Soil 13
8.5 Phosphorus Addition to Soil 13
9 PLANTATION MONITORING PLAN 13
9.1 Soil Fertility 14
9.2 Willow Biomass 14
9.3 Potable Water Well Monitoring 15

10 STAKEHOLDER CONSULTATION 15
11 BIOSOLIDS TRANSPORTATION AND STOCKPILING 16
12 BIOSOLIDS APPLICATION METHOD 18
13 PROPOSED IMPLEMENTATION SCHEDULE 18
14 LAND USE FOLLOWING APPLICATION 18
15 REPORTING 18
16 REFERENCES 19
APPENDIX ONE – APPLICATION FORM 20
APPENDIX TWO – TABLES 23
APPENDIX THREE – FIGURES 58
APPENDIX FOUR – PHOTOGRAPHS 62

APPENDIX ONE – APPLICATION FORM

Authorization form for applying biosolids to land; adapted from the Alberta Guidelines.

APPENDIX TWO – TABLES

Table 1: Sampling and results; biosolids quality summary. 23
Table 2: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M. 24
Table 3: Soil sampling results of the north polygon from W4M. 24
Table 4: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M. 25
Table 5: Soil sampling results of the east polygon from W4M. 26
Table 6: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M. 27
Table 7: Soil sampling results of the west polygon from W4M. 28
Table 8: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M. 29
Table 9: Soil sampling results of the south polygon from W4M. 30
Table 10: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M. 31
Table 11: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M. 32
Table 12: Soil sampling results of the north polygon from W4M. 32
Table 13: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M. 33

Table 14: Soil sampling results of the east polygon from W4M. 34
Table 15: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M. 35
Table 16: Soil sampling results of the west polygon from W4M. 36
Table 17: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M. 37
Table 18: Soil sampling results of the south polygon from W4M. 38
Table 19: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M. 39
Table 20: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M. 40
Table 21: Soil sampling results of the north polygon from W4M. 40
Table 22: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M. 41
Table 23: Soil sampling results of the east polygon from W4M. 42
Table 24: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M. 43
Table 25: Soil sampling results of the west polygon from W4M. 44
Table 26: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M. 45
Table 27: Soil sampling results of the south polygon from W4M. 46
Table 28: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M. 47
Table 29: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M. 48
Table 30: Soil sampling results of the north polygon from W4M. 48
Table 31: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M. 49
Table 32: Soil sampling results of the east polygon from W4M. 50
Table 33: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M. 51
Table 34: Soil sampling results of the west polygon from W4M. 52
Table 35: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M. 53
Table 36: Soil sampling results of the south polygon from W4M. 54

Table 37: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M. 55

Table 38: Nitrogen additions to soil at proposed application rate of 25 dt/ha. 56

Table 39: Additions of biosolids constituents at proposed application rates. 56

Table 40: Anticipated project schedule. 57

APPENDIX THREE – FIGURES

Figure 1: Landowner authorization letter. 58

Figure 2: Proposed biosolids application area sitemap for section W4M. 59

Figure 3: Approximate location of pre-application soil sampling ellipses; samples collected in April 2013. 60

Figure 4: Proposed biosolids monitoring for W4M. 61

APPENDIX FOUR - PHOTOGRAPHS

Photograph 1: Dewatered biosolids resemble a degraded peat. 62

Photograph 2: A coppice willow plantation near , BC that has been fertilized with biosolids. 62

Photograph 3: Marginal land in Lamont County was fertilized with biosolids and planted with hybrid poplar. 62

Photograph 4: Dewatered biosolids applied (prior to incorporation) to marginal agricultural land at 63

Photograph 5: Dewatered biosolids are transported using end-dump trailers and stockpiled at a marginal land reclamation project near 63

Photograph 6: Biosolids being land applied using a conventional tractor and manure spreader. 63

1 PROGRAM BACKGROUND

Established in 1983, Calgro is the City of Calgary's (CoC) liquid-biosolids land application program. The program successfully provides fertilizer to local farmers and is a beneficial use option for CoC biosolids. While the Calgro program is well established, the CoC requires more capacity, diversity, operational flexibility and contingency in biosolids management. Increases in wastewater treatment capacity and tertiary treatment technologies have increased the production of biosolids over time, and on an annual basis this volume exceeds the capacity of the Calgro program, resulting in a net accumulation of biosolids at the Shepard Lagoons. Developing options for the accumulated biosolids and future increases in biosolids production was addressed in late 2012 when the CoC issued a request for proposals (RFP #12-1694) to manage dewatered and / or thickened biosolids from its Shepard Lagoons in a program outside the purview of Calgro for a period of five years. SYLVIS was the successful respondent to the RFP and intends to develop a demonstration program of dewatered biosolids applications to a willow biomass plantation established on marginal land as one of two options to increase land productivity, improve soil tilth and generate a valuable biomass product for potential use in CoC operations.

1.1 Dewatered Biosolids Use Demonstrations Not Conforming to Alberta Guidelines

Since 2008, the City of Edmonton (CoE) and their project partners have been developing new dewatered biosolids land application demonstrations to address challenges similar to those faced by the CoC. The goal of these new demonstrations in the Edmonton region, in combination with the existing biosolids uses, is to meet and eventually exceed the annual biosolids production from the region's two wastewater treatment plants, and address the accumulated biosolids in the Lagoons. It is pertinent to examine the progression of the Edmonton region biosolids program to avoid duplication of effort for the CoC's program development. Examining the Edmonton program will provide regulators at Alberta Environment and Sustainable Resource Development (ESRD) in the Southern Region with the same level of understanding as the Northern Region and Central Region for dewatered biosolids uses outside the purview of the current *Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands* (hereinafter referred to as the Guidelines).

A phased approach was taken in developing new land application options for Edmonton Region biosolids. Phase One consisted of an evaluation of use options; using environmental, economic, social and technical criteria to prioritize options for further investigation. The evaluation prioritized biosolids land application in mine reclamation, marginal agricultural land improvement, and biomass production (i.e. non-traditional agricultural crops such as hybrid poplar and short rotation coppice willow) as options for further investigation.

Phase Two involved sourcing project partners to demonstrate the beneficial and environmentally protective use of biosolids in the prioritized options. Proposals were submitted to ESRD's Northern Region and Central Region during this phase of the project to conduct demonstrations, as the projects fell outside the purview of the Guidelines. The individual projects and associated proposals were developed in consultation with ESRD and were

designed to answer specific research questions regarding biosolids use in the prioritized options. In total, SYLVIS has submitted eight proposals to conduct demonstration projects within Northern Region and Central Region jurisdiction. ESRD issued letters of no objection (LONO) for seven of the proposals, allowing SYLVIS to proceed with the establishment of the projects and as of May 2013, one project is awaiting the issuance of a LONO, pending review by ESRD.

Phase Three of the project involved the operational implementation of projects outside the scope of the Guidelines. Six projects were implemented in 2010, 2011 and 2012, followed by a period of post-implementation monitoring to assess the project objectives. A seventh project is to begin this year. SYLVIS has presented the results-to-date from these demonstrations to project partners, including ESRD, on an annual basis. The monitoring to date has indicated that the biosolids applications have not had any significant negative impact on environmental quality (e.g. soil / water quality or constituent uptake in plants). Statistically significant improvements in soil carbon, soil fertility, and crop yields were witnessed on most project sites; with improvements being more pronounced where land capacity was historically degraded such as on aggregate or coal mines. The demonstrations have been used to increase ESRD's organizational knowledge of biosolids end-use options, and the data and observations drawn from the projects will be used by ESRD to support future biosolids guideline development. These projects also offer examples of diversity and contingency in management for larger biosolids generators in Alberta.

1.2 Calgary Willow Biomass Plantation Project

The Northern Region biosolids demonstrations have led to the development of operational-scale application projects on marginal agricultural land with one specific outcome being the production of willow biomass. This proposal seeks to undertake a project of a similar type to those in the Northern Region but larger scale and in the Southern Region. As with previous demonstrations, this project seeks to demonstrate the environmentally protective and beneficial use of biosolids. Provided in the following subsections is an overview of the proposed willow biomass plantation project and the approach for ESRD approval through issuance of a LONO.

1.2.1 Project Overview

SYLVIS proposes a five-year willow biomass plantation development for the specific purpose of biosolids applications on property, with use of the plantation system tentatively planned for a further five years following the initial establishment phase (ten years total). The overall program objective for the CoC is to establish an even-aged willow stand where biosolids, harvest, and planting are being conducted annually on multiple sections of land. The benefit of this approach for the CoC is twofold:

- The CoC has a beneficial use option for biosolids that optimizes the nutrient additions, soil building and fertilizing potential of dewatered biosolids.
- The CoC has a secure source of renewable biomass for use in their future composting operation.

This proposal for biosolids applications to W4M is the first of a series of proposals to be submitted to ESRD to establish willow biomass plantations fertilized with biosolids on multiple sections of land in the Calgary area. The project, in its entirety, will eventually encompass 10 quarter sections. The plantations are developed over the course of three years. This will enable annual application of 5,000 dry tonnes of biosolids, with a return period of three years, which corresponds to the harvest cycle of the coppice willow system.

Willow biomass growth and management operates on a three year cycle, coinciding with the Guideline minimum requirement for reapplication of biosolids. This first phase of the project has been designed to accept biosolids in the first, fourth, and seventh years with willow biomass harvested in the fourth, seventh and tenth years. The project, in its entirety, will eventually encompass ten quarter sections phased in over three years (2013-2015), and will potentially be used for biosolids management through 2023. This document serves as an overarching proposal for the entire program; procurement of the complete suite of land required for the program (tentatively for four quarter sections in 2014 and two quarter sections in 2015) will be completed through the submission of addenda containing the required information about the sites and soil analyses required by ESRD. Biosolids reapplications will be subject to the conditions in Appendix A of the Guidelines regarding plant available soil nitrogen, elapsed time between applications, and maximum cumulative additions of biosolids constituents to soil.

1.2.2 Regulatory Approval

In consultation with ESRD-Southern Region, SYLVIS has developed this willow biomass proposal document, based on past submissions to ESRD in the Northern Region and experience in generating land application plans (LAP) for the British Columbia Ministry of Environment under the Organic Matter Recycling Regulation (OMRR). This proposal was written to ensure that a clear understanding of the beneficial and environmentally acceptable use of biosolids to marginal soils is presented. Where possible the requirements of the Guidelines are met, and deviations are identified and discussed.

This document is a request to conduct operational-scale biosolids applications outside the purview of the Guidelines, to marginal agricultural soils in Wheatland County on land owned by ; other marginal land owned by is in Rocky View County. In reference to EPEA approval #17531-01-00, Subsection 4.3.2 (c), the City of Calgary as Approval Holder, may only undertake biosolids applications which fall outside the guidelines with authorization of the Director. The project will demonstrate the feasibility and environmental benefit of successive biosolids applications to marginal Chernozemic soils for woody biomass production. Biosolids are intended to be applied every three years as a soil amendment and fertilizer to promote the establishment and growth of a willow biomass plantation. This document is structured as an application for approval (see Appendix One for Approval Form) to ensure that ESRD and the requirements of the Guidelines are met; however, based on past experience and discussions with ESRD, this request falls outside the purview of the Guidelines. Based on the discussions, this proposal is best categorized as a demonstration, meeting the criteria of Section 67(3)(c) of the Environmental Protection and Enhancement Act. The response sought from ESRD is a LONO from the Regional Director to proceed with the applications as described in this proposal.

2 SITE BACKGROUND

owns hectares (ha) of agricultural land approximately km of Calgary. Agricultural production on land typically consists of a canola, wheat, and barley rotation. The agrologist for has identified that significant areas of their land base are deemed marginal under the Guidelines due to soil pH values below 6.5. The site proposed for biosolids applications in 2013 does not have any recent history (i.e. at minimum, within the past three years) of manure applications. Approximately 251 hectares of land on section W4M in Wheatland County has been allocated for biosolids applications and subsequent establishment of the first phase of a three-phase willow plantation. The site is located approximately km of the Shepard Lagoons in Calgary and is bounded on the north by Township Road and on the east by Range Road .

has authorized the use of their land for the application of biosolids under the direction of qualified professionals from SYLVIS (Figure 1, Appendix Three).

3 BIOSOLIDS INFORMATION

Dewatered biosolids are a thixotropically slumping semi-solid that visually resembles a degraded peat (Photograph 1, Appendix Four). Biosolids have a musty smell and emanate mild odours characteristic of the wastewater treatment process (ammoniacal and sulphuric) which are usually absent unless the biosolids are recently disturbed or applied, in which case the odours are faint and transient, lasting several days at a maximum. The following subsections provide information regarding the CoC's biosolids and outline the characteristics for use of biosolids.

3.1 City of Calgary Biosolids Information

The CoC operates three wastewater treatment plants (WWTP); the Bonnybrook, Fish Creek, and Pine Creek WWTPs which in 2012 transferred 15,038 dry tonnes (dt), 2,028 dt, 3,097 dt of biosolids to the Shepard Lagoons, respectively. The Shepard Lagoons, located on Section 11-23-29-W4M, hold biosolids for gravimetric settling prior to use in the Calgro program at 5.5 to 9.5% solids. The lagoons consist of six summer cells, two winter cells, two supernatant cells, and two decant cells; the cells are 4.5 m deep and compromise a total storage volume of 743,190 m^3. The cells contain approximately 333,600 m^3 (2010) of digested biosolids, with remaining storage capacity of 55.1%.

At present, the Calgro program applies an average (1991-2012) of approximately 15,700 dt/annum of biosolids; however, the previous two operational seasons have yielded a lower than average total application of biosolids due to wet weather. In 2012, 1,535 ha of productive agricultural land was applied with biosolids in the Calgro program, at an average application rate of 8.14 dt/ha. As with most liquid-to-land programs, Calgro is seasonally and operationally limited as to when biosolids can be applied: stockpiling of liquid biosolids is not feasible on application sites. Also, the application of biosolids must be coordinated with spring seeding or fall reaping, unless the land is fallow. Further limitation arises from the maximum application rate for CoC biosolids based on the ammonium nitrogen content which increases

the land base required for applications. Given these limitations the application window for liquid biosolids applications can be narrow and impact the annual capacity of the program, as evidenced in historic low annual applications (9,156 dt/annum in 1995 and 12,484 dt/annum in 2012) and maximum annual applications (20,950 dt/annum in 2003 and 20,674 dt/annum in 2001).

Projections from the CoC Planning Department anticipate increases in population accompanied by increases in wastewater and biosolids production. In anticipation of greater biosolids production and diminishing lagoon storage capacity, the CoC is exploring the opportunity to apply dewatered biosolids to marginally productive agricultural soils in the Calgary Region, to diversify their current land application program, provide contingency for annual and seasonal variation and ensure continued beneficial use of biosolids.

3.2 City of Calgary Biosolids Sampling and Results

Two biosolids samples were analyzed for limited parameters from the dewatered biosolids application program that was undertaken in 2012, while 28 samples of biosolids were collected from the Shepard Lagoon prior to land application in the Calgro program in 2012. Analysis was performed by either Exova, or the City of Calgary Water Resources Laboratory and the concentrations of nutrients and trace elements are assumed indicative of the biosolids to be used in the willow biomass program. The liquid biosolids samples were analyzed for solids content, aluminum, arsenic, boron, cadmium, chromium, copper, iron, lead, nickel, zinc, mercury, potassium, total phosphorus, total nitrogen (TKN) and ammonia-nitrogen. The dewatered biosolids were analyzed for solids content, nitrate-N, ammonium-N, Total Kjeldahl Nitrogen (TKN), boron and phosphorus.

The difference between dewatered biosolids and liquid biosolids is evidenced primarily in the concentration of TKN, which is substantially less in dewatered biosolids. This difference results from the removal of nitrogen in the centrate during dewatering; however, the trace element concentrations are assumed to remain relatively unchanged as they are part of the solids content, not the liquid. To best represent the material to be applied in the proposed willow biomass program, it was necessary to use the total solids, total-N, total-P and available-P from the dewatered biosolids analyses in 2012 and the 2012 Calgro trace element data to calculate the nitrogen-to-metals and phosphorus-to-metals ratios, as required under the Guidelines. The calculated ratios for each metal are provided in Table 1, Appendix Two. The 2012 biosolids analyses, taken as representative of the biosolids to be applied to lands, meet the quality based criteria specified in Table 1 of the Guidelines.

Best management practices for biosolids beneficial use suggest that sampling be conducted at a frequency of once every 1,000 dt. In the case of biosolids deliveries to , sampling will be a minimum of once every week (500 dt) for the first eight weeks of deliveries, to ensure consistent biosolids quality. Discreet 500 dt parcels of biosolids will be delineated and quarantined until analytical data is returned indicating guideline compliance. If consistency in biosolids quality is achieved within this timeframe then sampling will extend to once every two weeks, satisfying the 1,000 dt frequency as a best management practice. If consistency in biosolids quality is not achieved within eight weeks, weekly sampling will continue.

4 BIOSOLIDS APPLICATION INTENTIONS

The intention of biosolids applications on land is to increase soil productivity, and crop diversity through a novel crop rotation. This project will demonstrate the environmentally sound use of biosolids on marginally productive soils in willow biomass production. The project objectives are as follows:

- apply dewatered biosolids at agronomic rates to marginal agricultural soils;
- establish a willow biomass plantation;
- evaluate changes in soil fertility through successive biosolids applications over a period of up to ten years;
- evaluate willow biomass production as a logistically feasible and environmentally sound biosolids management option;
- evaluate dewatered biosolids land applications to marginal agricultural soils in the ESRD - Southern Region;
- assess the program annually to ensure that environmental impacts of the biosolids management option are minimized and fall within the ranges specified by the Alberta Guidelines;
- evaluate the ability to expand the project to achieve an even-aged biomass plantation, enabling annual applications and harvests throughout the project as a whole;
- develop an economically and logistically sound biosolids management option for the CoC; and
- produce a consistent supply of biomass for potential use in future CoC composting operations.

5 APPLICATION FORM FOR AUTHORIZATION TO SPREAD BIOSOLIDS TO LAND

In Appendix One, SYLVIS has provided the requisite information for authorization to apply biosolids to land as it would normally obtain for an application under the Guidelines. The application form in Appendix One of this document follows the requirements provided in Appendix B of the Guidelines. Additional information pertaining to the proposed biosolids land application sites is provided in the following sections.

6 DEVIATION FROM CURRENT BIOSOLIDS MANAGEMENT GUIDELINES

Recognizing that the proposed biosolids management option falls outside the purview of the current Guidelines, SYLVIS has provided ESRD with a specific understanding of where the proposed applications deviate from the Guidelines:

- the proposed biosolids land application is to a Class 4 site under the Alberta Guidelines due primarily to pH values below 6.5. pH at the site remains above 5.8 in all samples;

- at the proposed application rate, the total nitrogen application rate exceeds the maximum for a single application to a Class 3 site; and
- the 60-100 cm depth was precluded from one sample location due to impenetrable / rocky subsurface conditions.

While the proposed biosolids applications represent a deviation from biosolids management in Alberta, they are not novel approaches. Illustrated in Photograph 2, Photograph 3, and Photograph 4 in Appendix Four are a variety of successful biosolids projects in British Columbia and Alberta. These biomass production and marginal land improvement projects have successfully utilized biosolids at similar or higher rates in similar soils as compared to those proposed in this document.

The Alberta biosolids demonstration projects identified in Section 1.1 were undertaken on land that qualified as Class 4 under the Guidelines due to slope, soil texture and soil pH. The contributing physiochemical quality of soils being Class 4 is soil pH, which at the many of the sampling locations is measured to be below 6.5, which is similar to the previously approved demonstration projects near and near . Other site and soil criteria such as soil texture, slope and depth to potable aquifer are representative of Class 3, Class 1 and Class 1 sites as defined in the Guidelines, respectively.

7 FIELD INVESTIGATION AND RECONNAISSANCE

Prior to the submission of this request for approval, a field investigation of each quarter section was completed. The field investigation included soil sampling, site surveying and identifying important site features. A site map is provided in Figure 2 in Appendix Three. The map delineates the application areas and shows buffers from specific site features. The results of the field investigation can be found in the following subsections.

7.1 Site Description

The proposed biosolids application area is to four quarter sections comprising Section , Township , Range , West of the 4th Meridian in Wheatland County, Alberta. The section is currently under agricultural production, having been seeded to winter wheat in fall 2012. The section is bordered to the north by Township Road and to the east by Range Road . The northeast and southeast quarter sections have gas wells operated by that occupy a small portion of land and have summer-only access roads. There is a sparsely wooded area occupying less than one hectare midway along the north-south boundary between the northeast and northwest quarter sections. The site is relatively flat with any slopes having a gradient less than 2%.

7.2 Soils

The site comprises sections of Soil Polygons , , , and of the Alberta Soil Viewer mapping polygon system. The soils are predominantly Orthic and Rego Black Chernozems, coarse (C3) to Medium (M3-4) textured, from the , ,

and series. There may be localized areas of and series Chernozems within the site.

There are trace areas of Solonetzic soils and possibly one area of Series Orthic Humic Gleysol (less than 3% of the site combined for these two series). These specific soils have not been confirmed through soil sampling. The site slope is less than 1% overall, and can be considered flat to gently rolling with some small, localized depressional features.

7.3 Pre-Application Soil Sampling and Results

Pre-application soil sampling was conducted in early-April, prior to spring thaw, using a mechanized soil sampling auger system to collect the required samples. The project timeline and anticipated biosolids delivery schedule necessitated sampling in winter conditions; however, pre- and post-application monitoring will be conducted in the spring and fall, following and prior to winter soil conditions, respectively.

Pre-application soil samples were collected in a manner similar to that prescribed by the Guidelines. Composite samples at depths of 0-15 cm and 15-30 cm were taken from an ellipse within land units delineated throughout the project area. The sampling ellipses were delineated to capture the greatest amount of area within the constraints of buried services throughout the site. Sampling buffers are maintained from buried services for reasons of safety. Composite samples comprised of six equal volume subsamples were collected from each ellipse at the depth profiles 0-15 cm and 15-30 cm. Grab samples from 30-60 cm and 60-100 cm at one point along the ellipse were also collected with the exception of one sampling location whereby sampling past 60 cm was not possible due to ground conditions precluding sampling to depth. Sampling to depth from this location will be attempted during the spring of 2013, and results will be issued to ESRD as an addendum to this proposal. The location of each sample point along the ellipses delineated in the project area is provided on an aerial photograph in Figure 3.

Soil samples are related to individual soil polygons and soil series such that they may be considered representative of the broader soils conditions on site. Results of the pre-application soil sampling are discussed in the following subsections with analytical sampling results provided in Appendix Two. All data are entered as reported by Evova Laboratories, Edmonton, AB.

7.3.1 Soil pH and texture

Analytical results of soil sampling demonstrated that the soils are largely sandy loam or loamy sand with soil pH values of 5.8 to 8.8 in the 0-15 cm profile; 6.2 to 8.7 in the 15-30 cm profile; 7.1 to 9.7 in the 30-60 cm profile; and 7.2 to 10.0 in the 60-100 cm profile. The general trend across all quarter sections was increasingly basic conditions at depth in the sampled profile. This trend in pH is indicative of longstanding agricultural practices whereby nutrient addition and organic matter removal have tended to cause the upper soil to acidify. The following tables present the analytical results of soil sampling for parameters specified in the Guidelines:

- Table 3, Table 5, Table 7, and Table 9 for the northwest quarter section;
- Table 12, Table 14, Table 16, and Table 18 for the northeast quarter section;
- Table 21, Table 23, Table 25, and Table 27 for the southeast quarter section; and

- Table 30, Table 32, Table 34, and Table 36 for the southwest quarter section.

Soil pH values at seven of the 16 sampling polygons in the 0-15 cm profile were below 6.5. The Guideline soil pH requirement for biosolids applications is equal to or greater than 6.5 in the 0-15 cm profile. In the 15-30 cm profile, only two of the 16 polygons returned pH values below 6.5. The soil pH conditions below 30 cm were neutral to moderately basic for all polygons sampled. The increasing pH will mitigate leaching of trace elements through the soil profile.

Recent biosolids applications to marginal agricultural soils in , Alberta have demonstrated that biosolids applications to soil with pH less than 6.5 are beneficial and environmentally acceptable (i.e. no demonstrable adverse environmental impact). Preliminary results from monitoring and research at the site (applied with biosolids in fall 2011 and fall 2012) indicate increased and / or sustained yield within areas applied with biosolids at a rate of 25 dt/ha as compared to control areas. Soil sampling in 2013 will assess changes in trace element concentrations and crop uptake on a lime / no-lime trial on lands applied with biosolids in 2012.

Results from biosolids applications on degraded soils at the Site (W5M) indicated that at higher biosolids application rates of up to 64 dt/ha, small but significant increases in the soil concentration of several trace elements (cadmium, chromium, copper, mercury, silver and zinc) known to be present in biosolids were detected. These results were expected and are in line with the anticipated additions of these trace elements predicted prior to application. The additions of all Tier 1 Metals were below the cumulative addition limits established in the Guidelines. All of the values for the pre- and post-application soils were well below Alberta's Soil Remediation Guidelines Tier 1 limits for fine-textured agricultural soil.

7.3.2 Plant available nitrogen

Calculating the plant available nitrogen is a requirement of the Guidelines; the plant available soil nitrogen in the uppermost 1.5 m must be below 250 kg-N/ha. The calculated plant available nitrogen for all sampling ellipses was below the Guideline limit. The plant available nitrogen calculated for each sampling ellipse can be found in Table 2, Table 11, Table 20, and Table 29 in Appendix Two. Biosolids applications will assist in replenishing soil-nitrogen stores as the willow biomass plantation is established and draws on the plant available nitrogen in the soil. The organically bound nitrogen in the applied biosolids will provide slow release fertilization in the growing seasons without biosolids applications.

7.3.3 Alberta Tier 1 Metals

The sampled soils at all depths and sampling locations on section W4M were several times to orders-of-magnitude lower than the Alberta Tier 1 Soil and Groundwater Remediation Guideline values for coarse agricultural soils. The analytical results for Tier 1 metals in the sampled soils are presented in:

- Table 4, Table 6, Table 8, and Table 10 for the northwest quarter section;
- Table 13, Table 15, Table 17, and Table 19 for the northeast quarter section;

- Table 22, Table 24, Table 26, and Table 28 for the southeast quarter section; and

Table 31,

- Table 33, Table 35, and Table 37 for the southwest quarter section.

7.3.4 Post-application sampling

Post-application soil monitoring will proceed on a semi-annual basis in spring and fall to provide data to assess the project objectives. Post-application analysis will include:

- Alberta Tier 1 Metals;
- Electrical conductivity, pH, organic matter, soil carbon; and
- Potassium, phosphorus, nitrate-N, ammonium-N, TKN.

7.4 Distance of Land Application Site from Specified Features

The proposed land application of biosolids on land achieves all required distances from specified Features as per Table 5 in the Guidelines. The following list identifies measured distances to nearest features on the proposed application site:

- Watercourses, surface water, drainages: 500 m
- Wells: 140 m (neighbour)
- Residential zone ( ): >1 km
- Occupied dwelling: 140 m
- Public building or perimeter: >1 km
- School: >1 km
- Cemetery, playground, park, campground: >1 km

An assessment of the site prior to biosolids application may identify additional surface water features within the project area. These areas will be delineated and appropriately buffered from biosolids applications.

7.5 Groundwater

The site falls within the Edmonton-Calgary Corridor (ECC), and the area is well canvassed in the ECC groundwater atlas (Barker et. al. 2011), as well as the Wheatland County Regional Groundwater Assessment (HCL, 2003). The following subsections identify key groundwater observations as presented in the Atlas and Regional Groundwater Assessment.

7.5.1 Aquifers and wells

The site is located on a reasonably thin surficial deposit above bedrock, and is not located above any of the known bedrock valleys that might lead to a substantial surficial aquifer. The known bedrock aquifers under the site are the Lower Lacombe Aquifer and Haynes Aquifer. Nearby potable water wells reside at 125 feet, indicating likely water extraction from the Lower Lacombe Aquifer. A total of five licensed wells pull a total maximum of 125 m^3/d from the Lower Lacombe Aquifer, while 24 licensed water wells divert a maximum of 883 m^3/d from the deeper Haynes Aquifer.

7.5.2 Groundwater flow

Based on topography, major drainage basin location, and maps of the potentiometric surface, groundwater flow is generalized in the east-northeast direction. Groundwater flow and direction have not been determined for the site through direct observations or measurements.

Assessment of the potentiometric surface graphs between 10 and 40 metres of the ground surface indicate that this section is neither a significant recharge nor discharge area (Barker et. al., 2011).

Although there was standing water sporadically distributed in depressional areas from melting snow during the site investigation, groundwater was not encountered during the site investigation. While sampling to a depth of 1 m did not encounter water infiltrating the bore hole nor was the sample wet; thus, based on the available groundwater literature and field observations there was no evidence of a high groundwater table. As per the Alberta guidelines, biosolids will not be applied to areas where the seasonal water table is determined to be within 1 m of the surface. Required buffer distances to all known wells are achieved and exceeded as per information in Section 7.4 above.

7.5.3 Willow water uptake

With significant below-ground biomass resources, woody species are generally considered to be capable of greater transpiration rates than most agricultural crops. Recent studies have indicated transpiration rates (as measured by sap flow rates) between 7 mm/d and 18 mm/d on the Canadian prairies (Mirck and Volk, 2009; Mirck, Murphy and Schroeder, 2011). Willow rings have been demonstrated to effectively manage water saturation pockets through harvest and regeneration. Woody species also significantly mitigate leaching with early bud burst and growth which generally enables water uptake well in advance of neighbouring crops, which need to be seeded to achieve root penetration and uptake. Research indicates that a willow plantation will likely be a water transpiration sink, and not a leaching source.

7.6 Classification of Land Units

The Guidelines provide a four-tier system for classification of biosolids application sites based on soil pH and texture, slope, and depth to potable aquifers. Class 1 sites having the least restrictive biosolids application requirements and Class 4 sites not permitting biosolids applications. The soils on property are designated as Class 4 due solely to soil pH values below 6.5. The soil texture is Class 3 determined by sandy loams and loamy sand and depth to potable aquifer and slope achieve Class 1 criteria.

8 BIOSOLIDS APPLICATION RATES

The following subsections detail the 2013 biosolids application rate to soils and estimate the nitrogen and biosolids constituent loading as a result of applications. This application rate will be used for subsequent applications of biosolids to section W4M.

8.1 Application Rate Determination

The maximum annual biosolids application rate for property is based on an established rate for fertilization of woody biomass of 25 dt/ha. The calculated rates of nitrogen addition to soil on property from biosolids applications can be found in Table 38.

8.1.1 Willow nutrient requirements

Short rotation willow biomass crops produce significant amounts of biomass, and have correspondingly high nutrient requirements. Biomass production is anticipated to range between 8 and 12 tonnes of dry matter per hectare per year. Above and belowground biomass should ensure an in-plant accumulation of up to 100 kg-N/ha/yr, however research has shown that nitrogen retention in short rotation willow coppice can be more than 200 kg of available N per hectare per year due to the combined N sinks of denitrification, soil sequestration, and woody biomass accumulation (Aronsson and Perttu, 2001). These nutrient requirements align well with the proposed application rates of 25 dt per hectare per year, which contain an equivalent amount of available nitrogen of between 150 and 250 kg/ha in the first year, and mineralization which produces slightly lesser amounts in following years. It is anticipated that re-applications on a three year basis following harvesting will replenish available N stores, without risk of leaching, as significant carbon increases in the soil should result in a higher C:N ratio, enabling further N sequestration.

8.2 Biosolids Tonnage and Volume Estimates

The total biosolids tonnage required in 2013 for the demonstration area of 251 hectares will not exceed 6,275 dt. Based on a calculated moisture content of 17.5%, a bulk density of 1,000 kg/m^3 and a maximum application rate of 25 dt/ha the calculated maximum volume of biosolids is 35,850 m^3.

The biosolids will be dewatered using a polymer as a flocculant. The flocculant, which aids dewatering, also improves the water retention properties of dewatered biosolids, reducing the potential for leaching or rapid dissolution of the material in the soil. The MSDS for the polymer will be provided to ESRD upon selection.

Biosolids applications in years four and seven will mimic the 2013 application rate, and maximum dry tonnage / volume estimates.

8.3 Cumulative Addition of Biosolids Constituents

At the maximum application rate of 25 dt/ha no constituent is expected to exceed 15.8% of its cumulative loading under the requirements for Class 3 agricultural land in the Guideline, Class 3 limits being the most restrictive and used here as a conservative approach for constituent additions to soil. Calculated cumulative additions based on biosolids analyses and proposed application tonnages are provided in Table 39 in Appendix Two.

8.4 Nitrogen Addition to Soil

Nitrogen (N) cycling in undisturbed soils typically reaches a steady state with inputs from organic residues and fixation, and losses due to volatilization, plant uptake, and erosion. Agricultural cultivation and removal of biomass introduces an imbalance to N cycling in soil, in particular in the repeated removal of N in crop plant matter. Over time cultivation and crop production degrade the soil N reserve, necessitating supply of N with fertilizers if improved agricultural production is desired.

The reserve of soil N is held in different chemical forms, only some of which are available to support plant growth. Organic N (bound to organic molecules) tends to persist for longer but is not immediately available for plant uptake; ammonium-N and nitrate-N are both available to plants but are mobile and more subject to volatilization, microbial uptake and leaching loss. Organic N provides a longer-term stock of available N that is released slowly due to decomposition and conversion.

Biosolids addition to soil increases the supply of available N forms (primarily ammonium-N) but the bulk of biosolids N is in the form of slow-release organic N. This type of organic N fertilization is suitable for soils with a relatively low native reserve of N and can help to increase the supply of available N during several successive growing seasons without excessively increasing available N content in the soils. The additional N reserve introduced with biosolids application is beneficial in long-term plant cultivation such as woody biomass plantations, where repeated short-term applications of available N to promote growth are impractical.

8.5 Phosphorus Addition to Soil

Like N addition to soil, the addition of available P is a small fraction of the total P value. The high nutrient requirement in the willows will ensure that a large quantity of the available P is sequestered in plant tissues.

A study is currently being conducted using Edmonton biosolids applied to marginal agricultural land and the impacts on soil fertility. Using the same application rate as proposed in this demonstration (25 dt/ha) to agricultural soils with similar available phosphorus concentrations as the proposed biomass site, available P concentrations in the soil post-biosolids applications averaged 58 mg/kg using the Modified Kelowna soil test. The P concentrations measured in this trial are commensurate with the agronomic threshold for phosphorus of 60 mg/kg recommended by Alberta Agriculture Food and Rural Development (AAFRD 2006). A caveat to the information presented is that the concentration of available P in the Edmonton biosolids is roughly double that of the CoC biosolids. Available P values in soil will be monitored during the course of the trial, using the Modified Kelowna method, as per guideline requirements.

9 PLANTATION MONITORING PLAN

The monitoring plan for the willow biomass plantation will assess changes in soil fertility and evaluate improvements in willow biomass production with successive applications of biosolids over up to ten years. The project will be designed with appropriate replication of treatments and sufficient sample collection to ensure statistical robustness. The following subsections

detail the annual components that will form the basis for monitoring and reporting on the plantation.

9.1 Soil Fertility

To assess the impacts of biosolids applications in improving soil fertility, soil samples will be collected twice annually for the duration of the project. Within each quarter section four ellipses will be established to collect composite soil samples from depth ranges of 0-15cm and 15-30 cm in the spring and fall. The buffer areas where no biosolids are applied will serve as a control and controls will be delineated within the biosolids application areas. Sampling within the controls will mirror the sampling within the biosolids treatment areas, to facilitate comparison between applied and non-applied areas. In Figure 4, the centre of an intended sampling ellipse is marked from which six sub samples will be collected for each depth profile.

Soil samples will be analyzed for typical soil fertility parameters including:

- total and available nitrogen;
- available phosphorus;
- potassium;
- pH, EC and SAR;
- organic carbon and total C;
- organic matter; and
- available Ca, Cu, Fe, Mg, Mn, Na, and Zn.

In the fall of each year, the soil will be analyzed for the Alberta Tier 1 metals to monitor the unlikely possibility of increases in the Tier 1 suite of metals, including selenium and boron.

Results of soil fertility and trace element monitoring will be presented annually in a report to ESRD and the CoC.

An annual assessment of SAR and EC will be undertaken. Biosolids applications, with their relatively low EC and high cation concentrations, are anticipated to ameliorate high SAR conditions (where they exist). Given the proposed application rates, this improvement is anticipated to be very minor. This is the focus of a demonstration project in the Northern Region, and the results will be referenced for the benefit of both regional directorships.

9.2 Willow Biomass

Willow tree health will be visually assessed throughout each growing season following initial planting in 2014 for form characteristics, growth and general plant health observations. Willow biomass will be assessed by collecting, drying, and weighing the above ground plant material from a specific number of plants, typically 10-20 plants, in a defined sampling quadrat prior to harvest only. One sampling quadrat will be defined roughly at the centre of each soil sampling ellipse, totaling four quadrats per quarter section.

Fresh willow biomass tissue samples will also be collected, composited, and analyzed for the following chemical parameters:

- macro and micro nutrients (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo, Zn);

- trace elements (including Tier 1 Metals); and
- total carbon.

These samples will aid to determine if the rate of uptake and utilization of biosolids by the crop has a significant impact on the long term sustainability of the project.

Results of the willow biomass assessments will be presented to ESRD and CoC in a report annually, in conjunction with soil fertility results, beginning at the end of the first growing season (2014).

9.3 Potable Water Well Monitoring

Impacts of biosolids applications on potable water well will not be directly evaluated as part of the research project, however development of a data set to ensure biosolids application is not adversely impacting local potable water wells is planned. Potable water wells within a one kilometre radius of the application site will be identified. The owners of the wells will be notified of the project, and an offer to sample their well water prior to and during the project will be made. Water samples are proposed to be collected, in triplicate, prior to the commencement of biosolids hauling, to establish baseline water quality. Water samples within the one kilometre radius of this project site will then be collected twice annually (spring and fall) for a period of two years following biosolids applications (to occur in 2013). At the conclusion of two years of monitoring, data will be evaluated and a decision made on future monitoring.

Water will be analyzed for conventional potable water parameters including:

- routine parameters (pH, EC, Ca, Mg, Na, K, Fe, Mn, Cl, nitrate/nitrite, sulfate, hydroxide, carbonate, bicarbonate, alkalinity, total dissolved solids, hardness, and ionic balance);
- inorganic / non-metallic parameters (ammonium-N, dissolved phosphorus, TKN, total phosphorus and organic carbon)
- microbiological parameters (total and fecal coliforms); and
- dissolved and total metals.

The water samples will also be assessed for caffeine, which is soluble and highly mobile, and would be considered a compound unique to biosolids as compared to other likely local sources. Other potential sources of caffeine such as septic fields will be identified to contextualize other sources of infiltration.

Water analyses will be provided to the landowners, and summary data and any anomalies will be provided to CoC and ESRD as part of the monitoring program.

10 STAKEHOLDER CONSULTATION

SYLVIS is committed to taking a proactive approach to stakeholder consultation to ensure that stakeholders are engaged, aware, and educated regarding the operational implementation of biosolids projects in proximity to their home or business. SYLVIS has aligned their stakeholder consultation for the proposed willow biomass biosolids management project with the CoC's

Stakeholder Engagement Framework for Land Application of Dewatered Biosolids (CoC, April 2013).

SYLVIS has identified residences within a one kilometre radius of the proposed willow biomass plantation. SYLVIS will provide introductory letters to each resident with a commitment to meet face-to-face if requested not less than three weeks before operational project commencement. If requested, SYLVIS will also provide relevant background information to address any concerns raised by residents. Contact information for CoC officials, and SYLVIS staff will be made available through several different channels including the 3-1-1 information line, on the CoC's website and on signage posted on the operational site. A summary of well data and operational information will be provided to stakeholders, as discussed in Section 9.3. SYLVIS will review annually stakeholder engagement initiatives and activities to ensure the needs and concerns of stakeholders are being appropriately addressed.

Through a proactive approach to stakeholder engagement SYLVIS intends to foster community confidence in the dewatered biosolids management program, ensuring biosolids projects on land are a respected, beneficial, and responsible part of the community.

11 BIOSOLIDS TRANSPORTATION AND STOCKPILING

Biosolids will be transported to the application site using covered end dump trailers. Following biosolids unloading, the end gates will be pressure washed as necessary on site to ensure the trucks are clean prior to returning to public roads. Routine inspection of the haul route will be conducted to ensure that biosolids are not being tracked offsite.

Biosolids will be stockpiled within the land application area prior to application: an example of how stockpiling will be conducted is illustrated in Photograph 5, Appendix Four. The stockpile area will be designed to be an all-weather stockpile that can accept biosolids under adverse conditions. Biosolids stockpiling will be conducted in a manner that minimizes the movement of material during storage, including the construction of containment berms as a best management practice. In 2009, SYLVIS drafted a set of best management practices for dewatered biosolids stockpiling for review by ESRD, and a proposal to conduct a pilot study to investigate the efficacy of the best management practices.

The best management practices for stockpiling of biosolids, accepted by ESRD in October 2009 through issuance of a LONO (File#639-GEN-MUN), will be adhered to in the construction of stockpile locations and structures on land. Stockpiling will occur on private land that is fenced. Signage will be strategically placed to ensure that children do not enter the stockpile area or play nearby; if children playing on land is identified in the stakeholder consultation as a common occurrence than a snow-fence will be erected with T-bars to support it.

The best management practices proposed were:

General requirements

- construction of berms or similar works of sufficient height to manage leachate and prevent the escape of dewatered biosolids;

- maintenance of the stockpile area that maintains site aesthetics;
- sufficient signage that describes that the stockpile consists of biosolids, intended beneficial use, and contact information;
- stockpiles may not be placed on coarse sand or gravel as determined by texture analysis;
- stockpiles must be covered during the growing season in areas of Alberta that exceed average precipitation of greater than 600 mm over this period; and,
- stockpiled biosolids must be beneficially utilized within nine months of stockpile establishment.

Buffers

Feature	**Minimum Buffer Zone Distance (m)**
Property boundaries	10
Surface water features	30
Water used for domestic purposes	30
Water wells	20
Water table	1
Areas zoned residential or devoted to urban use	500
Occupied dwellings	60
Public buildings	60
School yard boundaries (year around)	200
Cemeteries, playgrounds, parks and campgrounds	200

Reporting

An application to land apply biosolids with intentions of stockpiling must describe how the above conditions will be adhered to.

A LONO was issued by ESRD to conduct the study, which involved the stockpiling of approximately 700 dt of biosolids from November 2009 to May 2010. The study found that while the concentrations of some constituents increased, that the increases were not statistically significant and, at most, were commensurate with changes in soil quality following an agronomic application of biosolids. Buffers, maintenance and berms sufficiently contained the biosolids and ensured environmentally protective biosolids management. The aforementioned best management practices will be adhered to for biosolids stockpiling within this project. Details on the pilot study in the region are available upon request.

Stockpiling of biosolids specific to this project will be completed in accordance with the general requirements, buffer distances, and additional controls to limit access as described above.

12 BIOSOLIDS APPLICATION METHOD

The dewatered biosolids will be applied with conventional agricultural manure spreading equipment: Photograph 6, Appendix Four provides an example. Immediately following application (i.e. within 24 hours), the biosolids will be incorporated using a cross-cut disc, harrow or similar farm implement to incorporate to an optimal depth of approximately 5-10 cm.

13 PROPOSED IMPLEMENTATION SCHEDULE

The proposed biomass plantation herein is for applications to approximately 251 ha, forming the first component of a multi-year project spanning 10 quarter sections and up to 10 years. Table 40 is an anticipated project schedule for the completion of tasks related to biosolids applications in 2013, establishment of a willow plantation in 2014, ongoing monitoring to assess the project outcomes, and harvest in 2016. It is expected that each successive biosolids reapplication will follow a similar progression to the first four years, as outlined in Table 40.

14 LAND USE FOLLOWING APPLICATION

An area of approximately 251 hectares of agriculture land has been selected for use in the first phase of this biosolids land application program on property. The site is currently seed to winter wheat, which will be harvested in Fall 2013. Biosolids will be transported and stockpiled on the site from June to October 2013 on an area taken out of agricultural production; biosolids will be applied post-harvest in 2013. In spring 2014 the land will be planted with willow. There are up to three applications possible throughout the potential 10 year maximum lifespan of the project. At the proposed application rates and over the timeframe of the project as proposed, these applications are anticipated to have a minor impact on soil trace elements concentrations, while providing significant amounts of organic matter to the site, along with agronomically based nitrogen application quantities. Phosphorus uptake by the biomass is anticipated to mitigate any excess plant available P that may be present after applications, with organic matter sequestration being another major mechanisms of P and N sequestration.

15 REPORTING

The CoC intends to augment their annual biosolids report with reporting on this project, providing information commensurate with the requirements for Calgro. As this program differs from Calgro in that it is new and has an extensive monitoring and research component, SYLVIS will prepare annual reports for the CoC and ESRD that will summarize annual operations, present results of research and monitoring, and recommendations for program modification/improvements, as required. At the end of the five year initial term for this program, SYLVIS will prepare a comprehensive final report. SYLVIS intends to engage the City of Calgary and ESRD to determine the specific layouts of the different reports following operational project initiation.

It has been standard practice for SYLVIS to present to ESRD annually on the projects underway in the region. SYLVIS would welcome the opportunity to periodically provide presentations to Southern Region ESRD staff if deemed beneficial.

16 REFERENCES

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APPENDIX ONE – APPLICATION FORM

This document provides the information requested in Appendix B of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Alberta Environment and Sustainable Resource Development, 2001). The titles of the headings reflect those of the Guideline.

1. ALBERTA ENVIRONMENT REGION HAVING JURISDICTION

Alberta Environment and Sustainable Resource Development

Southern Region - Calgary District
Craig Reich, BES, CET
Municipal Approvals Coordinator
Water Approvals Group
2938 - 11 Street, NE
Calgary, Alberta T2E 7L7
Tel: 403.297.7887
Fax: 403.297.2749

2. NAME, ADDRESS AND PHONE NUMBER OF DISCHARGING MUNICIPALITY

City of Calgary
Natasha Harckham, MSc, PAg
Calgro Program Specialist – Soil Scientist
Strategic Services, Water Resources
The City of Calgary, Mail Code #433
Water Centre, 625 – 25 Avenue SE
P.O. Box 2100, Station M
Calgary, Alberta T2P 2M5
Tel: 403.268.4796

3. BIOSOLIDS INFORMATION

Biosolids Type: Anaerobically digested and centrifuge dewatered semisolid

Average Biosolids Total Solids Content: 17.5% confirmed with dry matter analysis at regular frequency

Volume of biosolids proposed for land treatment: A maximum of 35,850 m^3 (6,275 dry metric tonnes at 1,000 kg/m^3 and 17.5% solids)

4. BIOSOLIDS APPLICATION DETAILS

Location of Proposed Application Site:

Section , Township , Range , West of the 4^{th} Meridian

Has Biosolids Been Applied to the Site Previously? No

Application Dates: First application in late summer / early fall 2013

Potential second application in fall 2017

Potential third application in fall 2020

Biosolids will be applied in accordance with the Guidelines with respect to weather limitations.

Proposed Method of Application:

Land application with conventional agricultural equipment (e.g. tractors and manure spreaders) followed immediately by incorporation with agricultural implements.

5. BIOSOLIDS HAULING CONTRACTOR (CURRENTLY CONTRACTED FOR 2013)

6. APPLICATION SITE INFORMATION

Does the proposed site meet all distance criteria in Table 5 of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (check boxes below)?

Feature	Minimum Distance Requirement (Surface Application)	Achieves Minimum Distance?	
Watercourses, Drainage Courses, Surface Waters	30 m	☒ Yes	☐ No
Water Wells	20 m	☒ Yes	☐ No
Areas Zoned Residential or Urban Use	500 m	☒ Yes	☐ No
Occupied Dwellings	60 m	☒ Yes	☐ No
Public Building Perimeters	10 m	☒ Yes	☐ No
Public Buildings	60 m	☒ Yes	☐ No
School Yard Boundaries (in session)	200 m	☒ Yes	☐ No
School Yard Boundaries (out of session)	20 m	☒ Yes	☐ No
Cemeteries, Playgrounds, Parks, Campgrounds	200 m	☒ Yes	☐ No

All minimum distances are met or exceeded.

Current use of the proposed site:

Agriculture (seeded to winter wheat)

Intended / projected use of the proposed site over the next three growing seasons:

Improved productivity agriculture transitioning to a willow biomass plantation

7. LANDOWNER CONTACT INFORMATION

8. BIOSOLIDS APPLICATION SCHEDULE

Proposed date of Commencement: 2013/06/01

Proposed Date of Termination: 2023/01/01 (applications in 2013, 2017, 2020). The proposed end date is tentative and contingent on future decisions regarding biosolids management to be made at the CoC's discretion.

9. APPLICATION SITE MAP

Figure 2 in Appendix Three provides a detailed map of the proposed land application site. The map delineates the following:

- appropriate buffers from specified features; and
- application site boundaries.

10. LANDOWNER AUTHORIZATION

A letter authorizing the use of dewatered biosolids on property can be found in Figure 1, Appendix Three.

APPENDIX TWO – TABLES

Table 1: Sampling and results; biosolids quality summary.

Constituent	Units	Shepard Lagoons Thickened Biosolids	Biosolids Nitrogen / Metal Ratio (wt/wt)	Nitrogen / Metal Ratio Guideline Minimum[(a)]	Biosolids Phosphorus / Metal Ratio (wt/wt)	Phosphorus / Metal Ratio Guideline Minimum[(a)]
Total Solids	%	18.5[(b)]	-	-	-	-
Total Nitrogen	%	4.81[(b)]	-	-	-	-
Ammonium – N	%	0.65[(b)]	-	-	-	-
Total Phosphorus	%	3.4[(b)]				
Available P	%	0.5[(b)]	-	-	-	-
Cadmium	mg/kg	1.724[(c)]	27,900	**1,500**	19,722	**600**
Chromium	mg/kg	66.08[(c)]	728	**20**	515	**8**
Copper	mg/kg	480.5[(c)]	100	**15**	71	**6**
Lead	mg/kg	40.09[(c)]	1,200	**20**	848	**8**
Mercury	mg/kg	1.19[(c)]	40,420	**3,000**	28,571	**1,100**
Nickel	mg/kg	31.80[(c)]	1,513	**100**	1,069	**40**
Zinc	mg/kg	945.1[(c)]	51	**10**	36	**4**

[(a)] Minimum ratios specified for the most restrictive, Class 3 sites in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

[(b)] These numbers represent the average of two samples collected from the Shepard Lagoons during the 2012 dewater biosolids program.

[(C)] These numbers represent the average of 28 samples collected from April to October 2012 for use in the Calgro program.

Table 2: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M.

Location	Plant Available Nitrogen[(a)] (kg-N/ha)
North polygon	211
East polygon	183
West polygon	149
South polygon	157

(a) Plant available nitrogen calculated as per the requirements in Section 2.2(c)(iii) of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

Table 3: Soil sampling results of the north polygon from W4M.

Constituent	North Polygon of W4M[(a,b)]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	8.3	8.7	9.4	9.5	-
Nitrate – N	13	10	3	6	mg/kg
Ammonium – N	7.4	3.8	1.4	1.6	mg/kg
Available – P	22	12	<5	<5	mg/kg
Sand (50 mm – 2 mm)	80.0	78.0	75.4	60.4	%
Clay (<2 mm)	8.0	10.6	12.0	21.0	%
Silt (2 mm – 50 mm)	12.0	11.4	12.6	18.6	%
Texture Class	Loamy Sand	Sandy Loam	Sandy Loam	Sandy Clay Loam	-

(a) Samples collected on April 4 and 8, 2013 in accordance with the procedures detailed in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 4: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M.

Constituent	North Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.5	2.9	5.2	5.2	17	mg/kg
Barium (non-barite)	85	100	134	341	750	mg/kg
Barite-barium	16.9	17.1	34.0	46.9	10,000	mg/kg
Beryllium	0.3	0.2	0.3	0.4	5	mg/kg
Boron (hot water soluble)	0.41	0.40	0.72	0.67	2	mg/kg
Cadmium	0.14	0.13	0.16	0.22	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.10	<0.10	0.4	mg/kg
Chromium (total)	6.7	7.1	12.6	14.8	64	mg/kg
Cobalt	3.4	3.8	6.7	6.8	20	mg/kg
Copper	14	18	10	12	63	mg/kg
Lead	<5	<5	6	6	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.02	0.03	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	6.7	7.7	20.1	19.2	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.1	0.2	0.2	20	mg/kg
Thallium	0.06	0.07	0.12	0.12	1	mg/kg
Tin	1	1	<1	<1	5	mg/kg
Uranium	<0.5	<0.5	1.2	1.1	23	mg/kg
Vanadium	12.7	13.3	24.8	26.9	130	mg/kg
Zinc	26	27	42	45	200	mg/kg

(a) Soil samples collected on April 4 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 5: Soil sampling results of the east polygon from W4M.

Constituent	East Polygon		W4M[a,b]		Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	8.8	8.4	7.9	8.7	-
Nitrate – N	16	14	5	4	mg/kg
Ammonium – N	2.4	5.9	<0.3	0.7	mg/kg
Available – P	30	14	10	<5	mg/kg
Sand (50 mm – 2 mm)	70.6	69.0	92.4	73.4	%
Clay (<2 mm)	15.6	16.0	4.0	10.4	%
Silt (2 mm – 50 mm)	13.8	15.0	3.6	16.2	%
Texture Class	Sandy Loam	Sandy Loam	Sand	Sandy Loam	-

(a) Samples collected on April 4 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 6: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M.

Constituent	East Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.4	2.5	3.5	4.8	17	mg/kg
Barium (non-barite)	152	151	62	153	750	mg/kg
Barite-barium	22.8	26.3	14.6	31.9	10,000	mg/kg
Beryllium	0.3	0.3	0.2	0.3	5	mg/kg
Boron (hot water soluble)	1.34	0.80	<0.20	<0.20	2	mg/kg
Cadmium	0.21	0.18	0.09	0.15	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	10.0	9.3	5.9	9.5	64	mg/kg
Cobalt	5.1	5.0	3.4	5.1	20	mg/kg
Copper	18	18	3	6	63	mg/kg
Lead	5	5	<5	5	70	mg/kg
Mercury (inorganic)	0.01	0.01	<0.01	0.02	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	10.7	10.1	7.1	14.8	50	mg/kg
Selenium	0.5	0.3	<0.3	<0.3	1	mg/kg
Silver	0.1	0.1	0.1	0.2	20	mg/kg
Thallium	0.09	0.12	0.07	0.11	1	mg/kg
Tin	1	1	2	1	5	mg/kg
Uranium	0.6	0.6	<0.5	0.5	23	mg/kg
Vanadium	16.4	15.8	12.4	18.2	130	mg/kg
Zinc	38	35	20	31	200	mg/kg

(a) Soil samples collected on April 4 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 7: Soil sampling results of the west polygon from W4M.

Constituent	West Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.5	6.6	9.7	8.3	-
Nitrate – N	9	8	2	2	mg/kg
Ammonium – N	12.5	10.6	0.8	0.4	mg/kg
Available – P	20	14	<5	<5	mg/kg
Sand (50 mm – 2 mm)	82.6	84.0	82.0	84.0	%
Clay (<2 mm)	9.6	8.0	7.6	6.0	%
Silt (2 mm – 50 mm)	7.8	8.0	10.4	10.0	%
Texture Class	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	-

(a) Samples collected on April 4 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 8: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M.

Constituent	West Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.0	3.1	4.8	2.3	17	mg/kg
Barium (non-barite)	88	79	106	99	750	mg/kg
Barite-barium	26.7	21.6	13.0	16.3	10,000	mg/kg
Beryllium	0.3	0.3	0.3	0.2	5	mg/kg
Boron (hot water soluble)	0.32	0.32	<0.20	0.50	2	mg/kg
Cadmium	0.15	0.10	0.14	0.15	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.10	<0.1	0.4	mg/kg
Chromium (total)	7.1	6.7	9.2	6.6	64	mg/kg
Cobalt	3.6	3.4	4.5	3.4	20	mg/kg
Copper	10	8	7	6	63	mg/kg
Lead	<5	<5	<5	<5	70	mg/kg
Mercury (inorganic)	<0.01	<0.01	0.02	<0.01	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	7.0	7.3	14.0	7.4	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	<0.1	<0.1	0.1	0.4	20	mg/kg
Thallium	0.07	0.07	0.09	0.06	1	mg/kg
Tin	1	1	<1	2	5	mg/kg
Uranium	<0.5	<0.5	<0.5	<0.5	23	mg/kg
Vanadium	13.7	12.7	19.4	13.1	130	mg/kg
Zinc	28	23	32	30	200	mg/kg

(a) Soil samples collected on April 4 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 9: Soil sampling results of the south polygon from W4M.

Constituent	South Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.3	6.8	8.3	8.5	-
Nitrate – N	10	6	4	4	mg/kg
Ammonium – N	10.0	5.0	0.5	<0.3	mg/kg
Available – P	14	8	<5	<5	mg/kg
Sand (50 mm – 2 mm)	74.0	77.0	82.0	80.4	%
Clay (<2 mm)	11.6	9.6	6.0	10.0	%
Silt (2 mm – 50 mm)	14.4	13.4	12.0	9.6	%
Texture Class	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand	-

(a) Samples collected on April 4 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 10: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M.

Constituent	South Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.8	3.0	3.4	5.2	17	mg/kg
Barium (non-barite)	108	102	125	99	750	mg/kg
Barite-barium	31.6	24.5	22.2	20.1	10,000	mg/kg
Beryllium	0.4	0.3	0.3	0.3	5	mg/kg
Boron (hot water soluble)	0.53	0.49	0.38	<0.20	2	mg/kg
Cadmium	0.16	0.12	0.08	0.11	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	7.3	7.8	6.6	10.2	64	mg/kg
Cobalt	3.8	4.0	4.2	5.0	20	mg/kg
Copper	15	10	5	7	63	mg/kg
Lead	<5	<5	<5	6	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.01	0.01	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	8.1	7.6	8.0	14.4	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.1	<0.1	0.1	0.1	20	mg/kg
Thallium	0.07	0.08	0.07	0.11	1	mg/kg
Tin	<1	1	2	1	5	mg/kg
Uranium	0.5	<0.5	<0.5	<0.5	23	mg/kg
Vanadium	13.6	14.4	15.6	20.4	130	mg/kg
Zinc	30	28	26	35	200	mg/kg

(a) Soil samples collected on April 4 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 11: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M.

Location	Plant Available Nitrogen[(a)] (kg-N/ha)
North polygon	105
East polygon	134
West polygon	159
South polygon	99[(b)]

(a) Plant available nitrogen calculated as per the requirements in Section 2.2(c)(iii) of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) The south polygon on W4M precluded sampling to a depth of greater than 60 cm; stated point of refusal was recorded at 60cm. The plant available-N is reported here is for the uppermost 60cm of soil only.

Table 12: Soil sampling results of the north polygon from W4M.

Constituent	North Polygon of W4M[(a,b)]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.1	6.6	9.0	10.0	-
Nitrate – N	7	5	2	3	mg/kg
Ammonium – N	5.1	0.6	0.9	0.6	mg/kg
Available – P	42	15	<5	<5	mg/kg
Sand (50 mm – 2 mm)	72.6	76.6	73.4	67.4	%
Clay (<2 mm)	9.6	10.0	13.0	16.0	%
Silt (2 mm – 50 mm)	17.8	13.4	13.6	16.6	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	-

(a) Samples collected on April 2, 3 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 13: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M.

Constituent	North Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.3	4.0	4.8	5.1	17	mg/kg
Barium (non-barite)	123	124	103	278	750	mg/kg
Barite-barium	33.2	30.6	26.0	38.6	10,000	mg/kg
Beryllium	0.4	0.3	0.6	0.3	5	mg/kg
Boron (hot water soluble)	0.39	0.34	0.29	0.24	2	mg/kg
Cadmium	0.20	0.12	0.09	0.16	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.10	0.4	mg/kg
Chromium (total)	8.9	9.0	10.7	12.9	64	mg/kg
Cobalt	4.5	4.9	5.9	6.9	20	mg/kg
Copper	25	19	8	10	63	mg/kg
Lead	<5	<5	6	5	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.03	0.04	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	12.1	9.3	14.2	20.8	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.1	0.1	0.3	0.3	20	mg/kg
Thallium	0.09	0.10	0.14	0.15	1	mg/kg
Tin	<1	1	<1	<1	5	mg/kg
Uranium	0.5	<0.5	0.6	0.6	23	mg/kg
Vanadium	16.1	17.0	21.1	24.2	130	mg/kg
Zinc	36	30	30	35	200	mg/kg

(a) Soil samples collected on April 2, 3 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 14: Soil sampling results of the east polygon from W4M.

Constituent	East Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	7.1	7.5	7.4	7.4	-
Nitrate – N	12	6	3	3	mg/kg
Ammonium – N	7.8	4.8	1.2	0.6	mg/kg
Available – P	21	8	6	<5	mg/kg
Sand (50 mm – 2 mm)	73.0	69.0	87.4	82.0	%
Clay (<2 mm)	11.6	15.6	5.6	8.0	%
Silt (2 mm – 50 mm)	15.4	15.4	7.0	10.0	%
Texture Class	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand	-

(a) Samples collected on April 2, 3 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 15: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M.

Constituent	East Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.8	3.2	3.4	5.5	17	mg/kg
Barium (non-barite)	127	171	91	251	750	mg/kg
Barite-barium	30.8	32.0	20.7	36.5	10,000	mg/kg
Beryllium	0.2	0.4	0.2	0.4	5	mg/kg
Boron (hot water soluble)	0.29	0.33	<0.20	0.25	2	mg/kg
Cadmium	0.23	0.14	0.08	0.11	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	8.1	9.4	7.2	14.8	64	mg/kg
Cobalt	4.2	4.8	3.9	7.0	20	mg/kg
Copper	23	18	4	7	63	mg/kg
Lead	<5	<5	<5	<5	70	mg/kg
Mercury (inorganic)	0.02	0.01	<0.01	0.02	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	8.4	10.0	7.2	16.4	50	mg/kg
Selenium	<0.3	0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.2	0.2	0.2	20	mg/kg
Thallium	0.09	0.11	0.08	0.14	1	mg/kg
Tin	<1	1	2	2	5	mg/kg
Uranium	0.6	0.9	<0.5	<0.5	23	mg/kg
Vanadium	15.5	17.2	14.6	26.8	130	mg/kg
Zinc	38	32	23	33	200	mg/kg

(a) Soil samples collected on April 2, 3 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 16: Soil sampling results of the west polygon from W4M.

Constituent	West Polygon of W4M [a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	5.8	6.2	7.1	7.2	-
Nitrate – N	10	7	5	4	mg/kg
Ammonium – N	8.3	0.8	0.8	<0.4	mg/kg
Available – P	37	15	7	5	mg/kg
Sand (50 mm – 2 mm)	69.0	75.0	79.0	80.0	%
Clay (<2 mm)	8.6	9.6	9.6	9.6	%
Silt (2 mm – 50 mm)	22.4	15.4	11.4	10.4	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Loam	Loamy Sand	-

(a) Samples collected on April 2, 3 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 17: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M.

Constituent	West Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.5	2.7	4.4	4.3	17	mg/kg
Barium (non-barite)	124	115	207	196	750	mg/kg
Barite-barium	42.8	36.5	40.0	40.6	10,000	mg/kg
Beryllium	0.3	0.2	0.3	0.3	5	mg/kg
Boron (hot water soluble)	0.38	0.40	0.36	0.33	2	mg/kg
Cadmium	0.24	0.16	0.11	0.10	1.4	mg/kg
Chromium (hexavalent)	<0.10	<0.10	<0.10	<0.1	0.4	mg/kg
Chromium (total)	7.2	7.6	11.1	11.3	64	mg/kg
Cobalt	4.0	4.6	6.3	6.2	20	mg/kg
Copper	9	27	10	10	63	mg/kg
Lead	<5	<5	<5	<5	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.01	0.01	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	7.2	8.0	12.7	16.6	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.2	0.2	0.2	20	mg/kg
Thallium	0.08	0.09	0.12	0.12	1	mg/kg
Tin	<1	<1	1	1	5	mg/kg
Uranium	<0.5	<0.5	<0.5	<0.5	23	mg/kg
Vanadium	13.0	13.8	20.4	21.4	130	mg/kg
Zinc	36	36	39	36	200	mg/kg

(a) Soil samples collected on April 2, 3 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 18: Soil sampling results of the south polygon from W4M.

Constituent	South Polygon of W4M[a,c]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm[b]	
pH	6.7	7.6	8.8	-	-
Nitrate – N	17	10	<2	-	mg/kg
Ammonium – N	12.0	2.8	0.4	-	mg/kg
Available – P	17	10	<5	-	mg/kg
Sand (50 mm – 2 mm)	71.0	74.0	80.4	-	%
Clay (<2 mm)	12.6	10.6	10.0	-	%
Silt (2 mm – 50 mm)	16.4	15.4	9.6	-	%
Texture Class	Sandy Loam	Sandy Loam	Loamy Sand	-	-

(a) Samples collected on April 2, 3 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) The south polygon on W4M precluded sampling to a depth of greater than 60 cm; stated point of refusal was recorded at 60cm.

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 19: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M.

Constituent	South Polygon of W4M[a,d]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm[c]		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	-	20	mg/kg
Arsenic	2.8	3.6	4.8	-	17	mg/kg
Barium (non-barite)	131	122	108	-	750	mg/kg
Barite-barium	37.5	24.5	23.0	-	10,000	mg/kg
Beryllium	0.3	0.4	0.3	-	5	mg/kg
Boron (hot water soluble)	0.66	0.60	0.32	-	2	mg/kg
Cadmium	0.24	0.17	0.16	-	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	-	0.4	mg/kg
Chromium (total)	8.3	9.6	9.1	-	64	mg/kg
Cobalt	4.6	5.0	4.5	-	20	mg/kg
Copper	29	22	7	-	63	mg/kg
Lead	<5	5	<5	-	70	mg/kg
Mercury (inorganic)	0.02	0.01	0.02	-	6.6	mg/kg
Molybdenum	<1	<1	<1	-	4	mg/kg
Nickel	9.6	11.4	14.2	-	50	mg/kg
Selenium	<0.3	<0.3	<0.3	-	1	mg/kg
Silver	0.2	0.2	0.2	-	20	mg/kg
Thallium	0.1	0.10	0.11	-	1	mg/kg
Tin	<1	1	1	-	5	mg/kg
Uranium	0.5	0.5	<0.5	-	23	mg/kg
Vanadium	15.5	17.7	19.8	-	130	mg/kg
Zinc	37	34	32	-	200	mg/kg

(a) Soil samples collected on April 2, 3 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) The south polygon on W4M precluded sampling to a depth of greater than 60 cm; stated point of refusal was recorded at 60cm.

(d) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. The 30-60 cm sample is a grab samples taken at one of the ellipse subsample points.

Table 20: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M.

Location	Plant Available Nitrogen[(a)] (kg-N/ha)
North polygon	130
East polygon	96
West polygon	222
South polygon	127

(a) Plant available nitrogen calculated as per the requirements in Section 2.2(c)(iii) of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

Table 21: Soil sampling results of the north polygon from W4M.

Constituent	North Polygon of W4M[(a,b)]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	7.2	7.9	8.7	8.7	-
Nitrate – N	10	9	6	3	mg/kg
Ammonium – N	1.6	2.8	<0.3	<0.3	mg/kg
Available – P	27	18	14	7	mg/kg
Sand (50 mm – 2 mm)	81.0	72.0	84.0	87.4	%
Clay (<2 mm)	7.6	9.6	5.6	7.0	%
Silt (2 mm – 50 mm)	11.4	18.4	10.4	5.6	%
Texture Class	Loamy Sand	Sandy Loam	Loamy Sand	Loamy Sand	-

(a) Samples collected on April 5, 8 and 9, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 22: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M.

Constituent	North Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.8	3.2	3.6	4.1	17	mg/kg
Barium (non-barite)	103	111	132	81	750	mg/kg
Barite-barium	24.9	22.8	27.4	18.9	10,000	mg/kg
Beryllium	0.2	0.3	0.2	0.2	5	mg/kg
Boron (hot water soluble)	0.30	0.30	0.26	0.20	2	mg/kg
Cadmium	0.16	0.15	0.13	0.10	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	7.4	8.2	7.3	7.2	64	mg/kg
Cobalt	3.6	4.1	4.1	3.7	20	mg/kg
Copper	6	9	5	5	63	mg/kg
Lead	<5	<5	<5	<5	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.01	0.01	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	6.5	8.5	11.4	10.9	50	mg/kg
Selenium	0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.2	0.2	0.2	20	mg/kg
Thallium	0.1	0.10	0.07	0.07	1	mg/kg
Tin	1	<1	2	2	5	mg/kg
Uranium	<0.5	0.6	<0.5	<0.5	23	mg/kg
Vanadium	14.6	15.3	14.9	15.4	130	mg/kg
Zinc	30	31	27	26	200	mg/kg

(a) Soil samples collected on April 5, 8 and 9, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 23: Soil sampling results of the east polygon from W4M.

Constituent	East Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.3	6.5	7.8	8.4	-
Nitrate – N	3	4	3	3	mg/kg
Ammonium – N	1.3	0.9	<0.3	0.7	mg/kg
Available – P	32	21	<5	<5	mg/kg
Sand (50 mm – 2 mm)	82.6	78.6	86.4	77.4	%
Clay (<2 mm)	5.6	7.6	6.4	8.0	%
Silt (2 mm – 50 mm)	11.8	13.8	7.2	14.6	%
Texture Class	Loamy Sand	Loamy Sand	Loamy Sand	Sandy Loam	-

(a) Samples collected on April 5, 8 and 9, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 24: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M.

Constituent	East Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.9	3.5	4.3	5.0	17	mg/kg
Barium (non-barite)	70	97	114	323	750	mg/kg
Barite-barium	21.2	28.6	26.3	40.3	10,000	mg/kg
Beryllium	0.2	0.2	0.2	0.3	5	mg/kg
Boron (hot water soluble)	0.22	0.24	<0.20	<0.20	2	mg/kg
Cadmium	0.10	0.10	0.11	0.14	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	6.5	7.6	9.0	12.9	64	mg/kg
Cobalt	4.4	4.4	4.5	6.8	20	mg/kg
Copper	5	7	5	7	63	mg/kg
Lead	<5	<5	<5	<5	70	mg/kg
Mercury (inorganic)	<0.01	<0.01	0.01	0.02	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	8.4	9.1	12.0	17.4	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.1	0.1	0.2	0.2	20	mg/kg
Thallium	0.08	0.11	0.08	0.09	1	mg/kg
Tin	1	1	2	2	5	mg/kg
Uranium	<0.5	<0.5	<0.5	<0.5	23	mg/kg
Vanadium	12.6	16.0	18.4	28.0	130	mg/kg
Zinc	23	27	26	34	200	mg/kg

(a) Soil samples collected on April 5, 8 and 9, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 25: Soil sampling results of the west polygon from W4M.

Constituent	West Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	5.9	6.3	7.5	8.5	-
Nitrate – N	6	10	5	7	mg/kg
Ammonium – N	10.3	7.4	0.6	0.8	mg/kg
Available – P	33	16	6	<5	mg/kg
Sand (50 mm – 2 mm)	73.0	75.0	83.4	70.0	%
Clay (<2 mm)	9.2	8.6	5.6	17.0	%
Silt (2 mm – 50 mm)	17.8	16.4	11.00	13.0	%
Texture Class	Sandy Loam	Sandy Loam	Loamy Sand	Sandy Loam	-

(a) Samples collected on April 5, 8 and 9, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 26: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M.

Constituent	West Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	2.9	3.3	4.3	5.3	17	mg/kg
Barium (non-barite)	96	73	66	179	750	mg/kg
Barite-barium	30.7	19.7	17.8	36.5	10,000	mg/kg
Beryllium	0.2	0.2	0.2	0.4	5	mg/kg
Boron (hot water soluble)	0.30	0.24	0.21	0.42	2	mg/kg
Cadmium	0.12	0.10	0.10	0.21	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	7.2	6.8	7.0	11.8	64	mg/kg
Cobalt	3.9	3.9	4.9	5.7	20	mg/kg
Copper	8	6	5	10	63	mg/kg
Lead	<5	<5	<5	6	70	mg/kg
Mercury (inorganic)	<0.01	<0.01	0.01	0.03	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	6.9	6.9	9.6	18.7	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.3	0.2	0.2	0.2	20	mg/kg
Thallium	0.1	0.1	0.07	0.12	1	mg/kg
Tin	<1	1	1	<1	5	mg/kg
Uranium	0.5	0.5	0.8	0.9	23	mg/kg
Vanadium	13.7	13.1	14.9	22.9	130	mg/kg
Zinc	28	22	24	38	200	mg/kg

(a) Soil samples collected on April 5, 8 and 9, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 27: Soil sampling results of the south polygon from W4M.

Constituent	South Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	7.6	8.2	9.0	9.4	-
Nitrate – N	3	4	4	4	mg/kg
Ammonium – N	8.0	3.5	0.4	<0.4	mg/kg
Available – P	10	6	<5	<5	mg/kg
Sand (50 mm – 2 mm)	66.0	69.0	83.4	77.4	%
Clay (<2 mm)	13.6	13.6	7.0	10.0	%
Silt (2 mm – 50 mm)	20.4	17.4	9.6	12.6	%
Texture Class	Sandy Loam	Sandy Loam	Loamy Sand	Sandy Loam	-

(a) Samples collected on April 5, 8 and 9, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 28: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M.

Constituent	South Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.3	3.9	3.4	3.6	17	mg/kg
Barium (non-barite)	182	197	205	249	750	mg/kg
Barite-barium	29.3	25.1	26.3	31.2	10,000	mg/kg
Beryllium	0.3	0.4	0.3	0.3	5	mg/kg
Boron (hot water soluble)	0.84	0.56	0.48	1.61	2	mg/kg
Cadmium	0.23	0.22	0.13	0.14	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.10	0.4	mg/kg
Chromium (total)	10.5	12.2	12.3	12.7	64	mg/kg
Cobalt	5.6	6.3	6.3	6.2	20	mg/kg
Copper	11	13	6	7	63	mg/kg
Lead	5	6	<5	<5	70	mg/kg
Mercury (inorganic)	0.02	0.02	0.01	0.01	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	11.0	13.4	13.0	15.9	50	mg/kg
Selenium	0.4	0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.3	0.2	0.2	20	mg/kg
Thallium	0.13	0.14	0.10	0.1	1	mg/kg
Tin	1	<1	1	<1	5	mg/kg
Uranium	0.5	0.5	<0.5	<0.5	23	mg/kg
Vanadium	19.7	22.0	23.2	24.8	130	mg/kg
Zinc	42	42	36	40	200	mg/kg

(a) Soil samples collected on April 5, 8 and 9, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 29: Plant available nitrogen results, calculated in accordance with the Guidelines, for the uppermost 1.5 m of soil on W4M.

Location	Plant Available Nitrogen[(a)] (kg-N/ha)
North polygon	122
East polygon	150
West polygon	89
South polygon	105

(a) Plant available nitrogen calculated as per the requirements in Section 2.2(c)(iii) of the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

Table 30: Soil sampling results of the north polygon from W4M.

Constituent	North Polygon of W4M[(a,b)]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.6	7.5	8.5	9.3	-
Nitrate – N	8	7	<2	<2	mg/kg
Ammonium – N	8.9	7.0	0.9	0.7	mg/kg
Available – P	14	10	<5	<5	mg/kg
Sand (50 mm – 2 mm)	66.0	63.0	79.4	64.4	%
Clay (<2 mm)	12.0	15.6	10.0	19.0	%
Silt (2 mm – 50 mm)	22.0	21.4	10.6	16.6	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	-

(a) Samples collected on April 4, 5 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 31: Soil sampling results for Alberta Tier 1 metals in the north polygon of W4M.

Constituent	North Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.3	4.1	5.7	4.6	17	mg/kg
Barium (non-barite)	186	191	91	126	750	mg/kg
Barite-barium	49.7	30.2	16.3	19.4	10,000	mg/kg
Beryllium	0.3	0.4	0.3	0.4	5	mg/kg
Boron (hot water soluble)	0.70	0.49	0.27	0.28	2	mg/kg
Cadmium	0.20	0.20	0.14	0.18	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	11.7	13.0	10.6	11.0	64	mg/kg
Cobalt	5.8	6.7	6.2	5.3	20	mg/kg
Copper	16	14	9	10	63	mg/kg
Lead	6	6	6	6	70	mg/kg
Mercury (inorganic)	0.02	0.02	0.01	0.03	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	11.6	13.9	15.1	16.1	50	mg/kg
Selenium	0.4	0.4	<0.3	<0.3	1	mg/kg
Silver	0.2	0.2	0.3	0.3	20	mg/kg
Thallium	0.12	0.14	0.12	0.12	1	mg/kg
Tin	<1	<1	1	<1	5	mg/kg
Uranium	0.6	0.6	1.4	0.8	23	mg/kg
Vanadium	20.9	23.0	21.1	20.3	130	mg/kg
Zinc	45	40	36	40	200	mg/kg

(a) Soil samples collected on April 4, 5 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 32: Soil sampling results of the east polygon from W4M.

Constituent	East Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	7.2	7.3	9.0	9.4	-
Nitrate – N	12	7	4	4	mg/kg
Ammonium – N	3.8	4.5	0.4	0.4	mg/kg
Available – P	19	10	<5	<5	mg/kg
Sand (50 mm – 2 mm)	65.0	64.6	64.0	69.4	%
Clay (<2 mm)	13.2	15.6	20.0	10.0	%
Silt (2 mm – 50 mm)	21.8	19.8	16.0	20.6	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Clay Loam	Sandy Loam	-

(a) Samples collected on April 4, 5 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 33: Soil sampling results for Alberta Tier 1 metals in the east polygon of W4M.

Constituent	East Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.5	4.3	4.4	3.9	17	mg/kg
Barium (non-barite)	207	193	370	486	750	mg/kg
Barite-barium	31.9	19.5	51.7	55.1	10,000	mg/kg
Beryllium	0.3	0.4	0.4	0.3	5	mg/kg
Boron (hot water soluble)	0.74	0.63	0.39	<0.20	2	mg/kg
Cadmium	0.24	0.18	0.17	0.17	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	11.9	12.3	16.5	15.6	64	mg/kg
Cobalt	6.1	6.4	7.9	7.0	20	mg/kg
Copper	13	12	11	10	63	mg/kg
Lead	6	6	6	<5	70	mg/kg
Mercury (inorganic)	0.02	0.02	0.03	0.03	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	12.0	13.8	21.3	17.9	50	mg/kg
Selenium	0.4	0.4	0.3	<0.3	1	mg/kg
Silver	0.4	0.3	0.3	0.2	20	mg/kg
Thallium	0.11	0.13	0.14	0.10	1	mg/kg
Tin	1	<1	1	1	5	mg/kg
Uranium	0.6	0.9	1	0.8	23	mg/kg
Vanadium	21.8	21.9	31.0	29.4	130	mg/kg
Zinc	44	40	42	39	200	mg/kg

(a) Soil samples collected on April 4, 5 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 34: Soil sampling results of the west polygon from W4M.

Constituent	West Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.1	7.5	8.4	8.7	-
Nitrate – N	8	4	<2	2	mg/kg
Ammonium – N	5.0	1.5	1.0	<0.3	mg/kg
Available – P	20	9	<5	<5	mg/kg
Sand (50 mm – 2 mm)	68.0	66.0	75.4	68.4	%
Clay (<2 mm)	12.6	15.6	10.0	11.0	%
Silt (2 mm – 50 mm)	19.4	18.4	14.6	20.6	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	-

(a) Samples collected on April 4, 5 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 35: Soil sampling results for Alberta Tier 1 metals in the west polygon of W4M.

Constituent	West Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.2	4.5	4.6	4.7	17	mg/kg
Barium (non-barite)	146	202	301	468	750	mg/kg
Barite-barium	44.2	45.5	46.7	62.6	10,000	mg/kg
Beryllium	0.3	0.4	0.4	0.3	5	mg/kg
Boron (hot water soluble)	0.36	0.33	0.34	0.32	2	mg/kg
Cadmium	0.17	0.14	0.13	0.14	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.1	<0.1	0.4	mg/kg
Chromium (total)	9.4	12.2	15.6	16.1	64	mg/kg
Cobalt	5.1	6.2	7.4	8.2	20	mg/kg
Copper	12	13	10	10	63	mg/kg
Lead	5	6	5	<5	70	mg/kg
Mercury (inorganic)	0.01	0.02	0.02	0.02	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	8.7	13.4	20.8	20.0	50	mg/kg
Selenium	<0.3	0.4	<0.3	<0.3	1	mg/kg
Silver	0.3	0.2	0.2	0.2	20	mg/kg
Thallium	0.1	0.13	0.13	0.11	1	mg/kg
Tin	<1	<1	1	1	5	mg/kg
Uranium	0.5	0.6	<0.5	0.6	23	mg/kg
Vanadium	17.8	22.1	29.8	31.4	130	mg/kg
Zinc	34	35	42	42	200	mg/kg

(a) Soil samples collected on April 4, 5 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 36: Soil sampling results of the south polygon from W4M.

Constituent	South Polygon of W4M[a,b]				Units
	0–15 cm	15–30 cm	30–60 cm	60–100 cm	
pH	6.0	6.6	9.7	9.7	-
Nitrate – N	4	4	3	3	mg/kg
Ammonium – N	2.0	1.4	0.5	1.6	mg/kg
Available – P	21	11	<5	<5	mg/kg
Sand (50 mm – 2 mm)	70.0	64.0	68.4	74.4	%
Clay (<2 mm)	10.6	13.6	13.0	14.0	%
Silt (2 mm – 50 mm)	19.4	22.4	18.6	11.6	%
Texture Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	-

(a) Samples collected on April 4, 5 and 8, 2013 in accordance with the procedures detailed in the Guideline for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 37: Soil sampling results for Alberta Tier 1 metals in the south polygon of W4M.

Constituent	South Polygon of W4M[a,c]				Coarse Agricultural Soil Metal Limits[b]	Units
	0-15cm	15-30cm	30-60cm	60-100cm		
Alberta Tier 1 Metals						
Antimony	<0.2	<0.2	<0.2	<0.2	20	mg/kg
Arsenic	3.3	4.2	4.5	4.9	17	mg/kg
Barium (non-barite)	163	172	441	259	750	mg/kg
Barite-barium	40.2	31.5	47.2	33.6	10,000	mg/kg
Beryllium	0.4	0.3	0.5	0.3	5	mg/kg
Boron (hot water soluble)	0.33	0.35	0.61	0.77	2	mg/kg
Cadmium	0.16	0.15	0.16	0.17	1.4	mg/kg
Chromium (hexavalent)	<0.1	<0.1	<0.10	<0.10	0.4	mg/kg
Chromium (total)	9.9	11.5	15.4	11.1	64	mg/kg
Cobalt	5.3	6.2	7.0	6.1	20	mg/kg
Copper	10	10	9	9	63	mg/kg
Lead	5	5	<5	5	70	mg/kg
Mercury (inorganic)	0.01	0.01	0.02	0.03	6.6	mg/kg
Molybdenum	<1	<1	<1	<1	4	mg/kg
Nickel	8.9	12.0	19.0	17.8	50	mg/kg
Selenium	<0.3	<0.3	<0.3	<0.3	1	mg/kg
Silver	0.2	0.2	0.2	0.2	20	mg/kg
Thallium	0.13	0.14	0.16	0.12	1	mg/kg
Tin	<1	<1	1	<1	5	mg/kg
Uranium	0.5	0.5	0.7	0.6	23	mg/kg
Vanadium	18.9	21.6	30.7	22.3	130	mg/kg
Zinc	35	37	40	37	200	mg/kg

(a) Soil samples collected on April 4, 5 and 8, 2013 in accordance with the procedures specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Government of Alberta, 2001).

(b) Alberta Tier 1 metals limits for coarse grained agricultural soil (Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010).

(c) 0-15 cm and 15-30 cm are each composite samples consisting of six equal volume subsamples collected along a specified sampling ellipse. 30-60 cm and 60-100 cm samples are grab samples taken at one of the ellipse subsample points.

Table 38: Nitrogen additions to soil at proposed application rate of 25 dt/ha.

Parameter	Value 25 dt/ha	Units
Application Rate	25	dt/ha
Total Nitrogen	1,203	kg/ha
Available Nitrogen[(a)]	150-225[a]	kg/ha

[a)] Represents estimated range of first-year available N.

Table 39: Additions of biosolids constituents at proposed application rates.

Constituent	2012 Calgary Biosolids (mg/kg)	25 dt/ha		Class 3 Cumulative Limit (kg/ha)[a]
		Addition to Soil (kg/ha)	% of Cumulative Limit	
Cadmium	1.724	0.043	5.4%	**0.8**
Chromium	66.08	1.65	3.3%	**50**
Copper	480.5	12.0	12.0%	**100**
Lead	40.09	1.00	2.0%	**50**
Mercury	1.19	0.030	14.9%	**0.2**
Nickel	31.8	0.80	6.6%	**12**
Zinc	945.1	23.6	15.8%	**150**

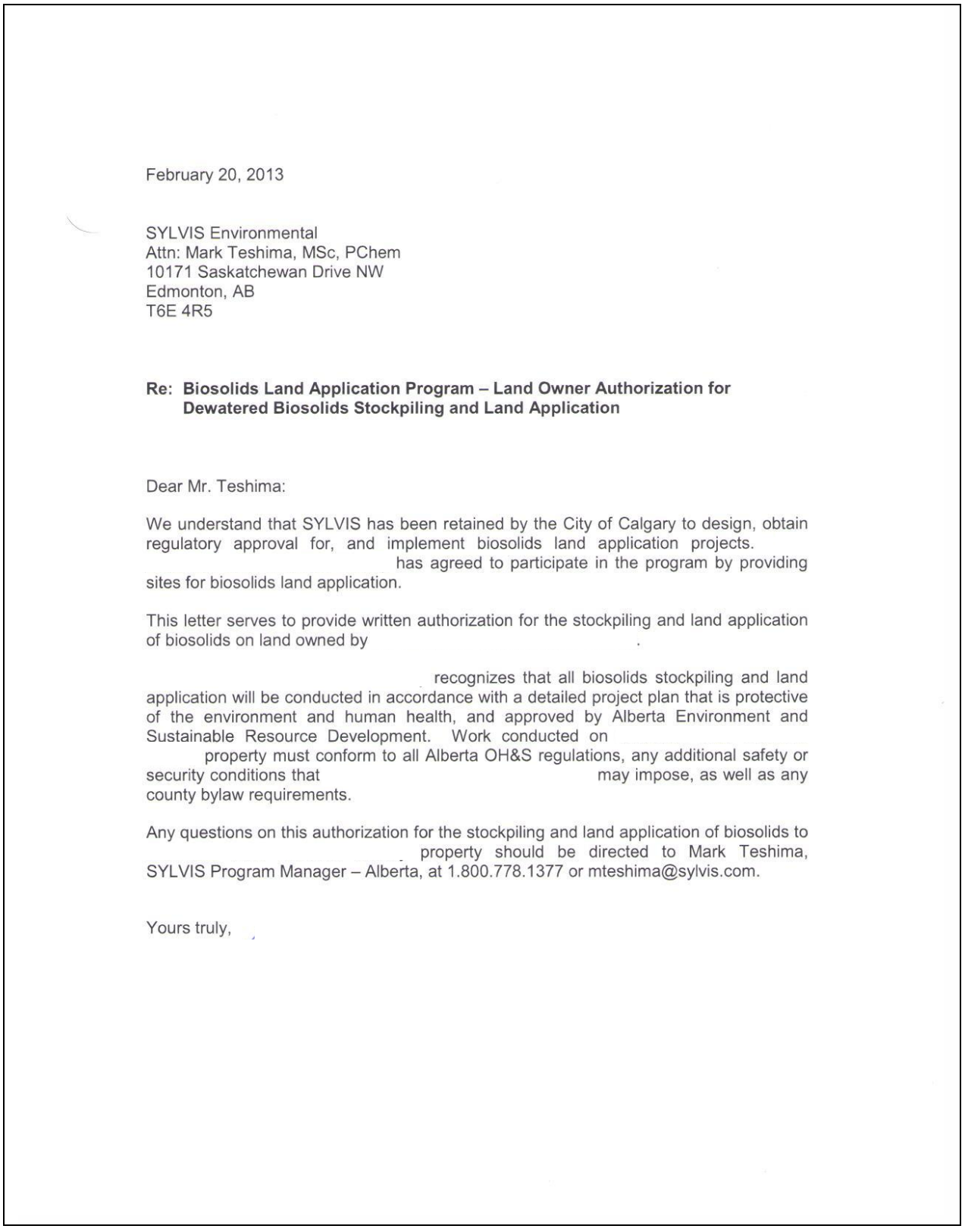
[(a)] Most restrictive, Class 3 land cumulative limits specified in the Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Alberta Environment, March 2001).

Table 40: Anticipated project schedule.

Task	Expected Implementation Date
First Year – 2013	
Review of project plan by project partners	March
Pre-application soil sampling	April
Submission and approval of proposal to ESRD	April / May
Operational project initiation	June 15
Site delineation	May / June
Application site infrastructure upgrades	May / June
Biosolids delivery	June 1 – October 31
Biosolids deliveries termination	October 31
Biosolids application and incorporation	September –November (tentative)
Post application soil sampling	October / November
Annual environmental reporting	December
Project management	Ongoing
Second Year – 2014	
Submit addendum to ESRD for 2014 application areas	January
Environmental monitoring (spring soil sampling)	May
Willow planting	May / June
Coppicing	October
Environmental monitoring (fall soil sampling)	October
Annual environmental reporting	December
Project Management	Ongoing
Third Year – 2015	
Submit addendum to ESRD for 2015 application areas	January
Environmental monitoring (spring soil sampling)	May
Willow maintenance	June / July / August
Environmental monitoring (fall soil sampling)	October
Annual environmental reporting	December
Project Management	Ongoing
Fourth Year – 2016	
Environmental monitoring (spring soil sampling)	May
Willow maintenance	June / July / August
Environmental monitoring (fall soil sampling)	October
Willow harvest and biomass sampling for analysis	November / December
Annual environmental reporting	
Project Management	Ongoing
Fifth Year – 2017	
Repeat project cycle beginning with biosolids applications	

APPENDIX THREE – FIGURES

Figure 1: Landowner authorization letter.



February 20, 2013

SYLVIS Environmental
Attn: Mark Teshima, MSc, PChem
10171 Saskatchewan Drive NW
Edmonton, AB
T6E 4R5

Re: Biosolids Land Application Program – Land Owner Authorization for Dewatered Biosolids Stockpiling and Land Application

Dear Mr. Teshima:

We understand that SYLVIS has been retained by the City of Calgary to design, obtain regulatory approval for, and implement biosolids land application projects. has agreed to participate in the program by providing sites for biosolids land application.

This letter serves to provide written authorization for the stockpiling and land application of biosolids on land owned by .

recognizes that all biosolids stockpiling and land application will be conducted in accordance with a detailed project plan that is protective of the environment and human health, and approved by Alberta Environment and Sustainable Resource Development. Work conducted on property must conform to all Alberta OH&S regulations, any additional safety or security conditions that may impose, as well as any county bylaw requirements.

Any questions on this authorization for the stockpiling and land application of biosolids to property should be directed to Mark Teshima, SYLVIS Program Manager – Alberta, at 1.800.778.1377 or mteshima@sylvis.com.

Yours truly,

Figure 2: Proposed biosolids application area sitemap for section W4M.

Figure 3: Approximate location of pre-application soil sampling ellipses; samples collected in April 2013.

Figure 4: Proposed biosolids monitoring for W4M.

APPENDIX FOUR – PHOTOGRAPHS

Photograph 1: Dewatered biosolids resemble a degraded peat.

Photograph 2: A coppice willow plantation near , BC that has been fertilized with biosolids.

Photograph 3: Marginal land in Lamont County was fertilized with biosolids and planted with hybrid poplar.

Photograph 4: Dewatered biosolids applied (prior to incorporation) to marginal agricultural land at .

Photograph 5: Dewatered biosolids are transported using end-dump trailers and stockpiled at a marginal land reclamation project near .

Photograph 6: Biosolids being land applied using a conventional tractor and manure spreader.