AECOM

Appendix C

Greater Cardinal Creek Subwatershed Management Plan

- Conceptual Channel Naturalization Design at Old Montreal Road (under separate cover)

CARDINAL CREEK
CONCEPTUAL CHANNEL NATURALIZATION DESIGN

Cardinal Creek
City of Ottawa

Prepared for AECOM

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Our Project No. 12252.450

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1.0 INTRODUCTION

In support of the Cardinal Creek Class Environmental Assessment (EA), Geomorphic Solutions was retained to develop a conceptual channel realignment design for a 150 m section of Cardinal Creek immediately upstream of Old Montreal Road to address and mitigate present erosion concerns (**Figure 1**). The proposed channel design has been premeditated for potential future road widening and will improve connectivity with the upstream channel, while replicating the natural form and function of the valley system.

As part of the design, a dynamically stable channel and corridor is proposed, in which the natural form and function of the channel is mimicked to the greatest extent possible, given local constraints. The morphologically-limited existing channel will be replaced with a low gradient riffle and pool channel, with cross-sectional dimensions akin to that of a natural watercourse, conveying similar flows. To augment the stability afforded by natural means, simple bioengineered bank treatments are also proposed.

The objectives of the proposed natural corridor design are to enhance aquatic habitat by mimicking the natural channel planform and cross-sectional morphology. The morphology will enhance fish habitat by providing flow aeration through riffles, and relatively quiescent flows and lower water temperatures in pools. The formalized pools will act as refuge habitat for fish during low flow conditions. Trees and shrubs will provide cover and organic inputs, as well as improve erosion protection and overbank roughness. Within the corridor and along the floodplain, morpho-sedimentary features have been incorporated to mimic those along natural channels. Overall, the proposed design endeavours to restore the natural form and function of the system, while limiting the hazards to the existing and future infrastructure, and requirements associated with Old Montreal Road.

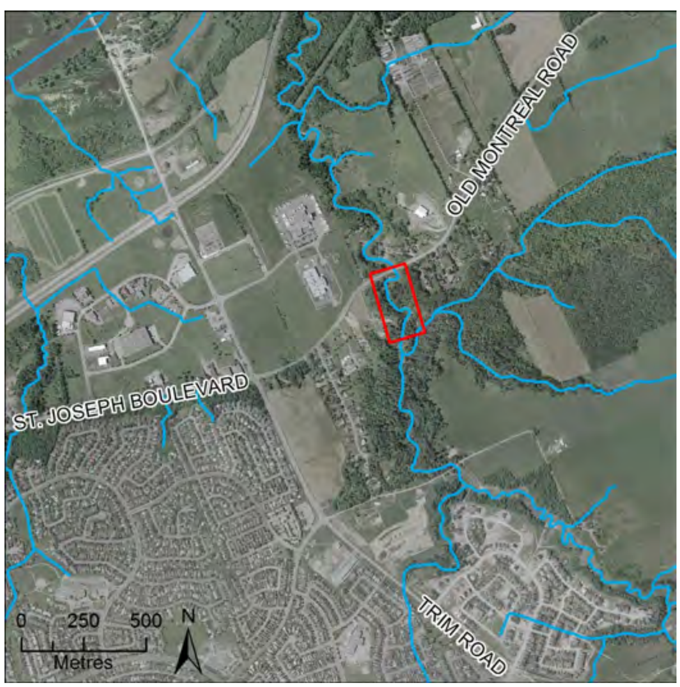

Figure 1: Study area (City of Ottawa, 2005)

2.0 HISTORICAL ASSESSMENT AND BACKGROUND REVIEW

Information pertaining to changes within the Cardinal Creek channel corridor and surrounding area downstream of Old Montreal Road was reviewed to develop the naturalization design. Additional background information pertinent to the channel design was also reviewed from previous reports.

2.1 Historical Assessment

This section presents an overview of historic conditions within the general study area with respect to land use, land cover and channel conditions. Historical analyses provide insight into the scale of natural and human-induced changes within a watershed, particularly the degree to which channel planform adjustment and land use has changed over time. Black and white aerial photographs were assessed for the years 1926 (1:15,000) and 1973 (1:10,000). These were obtained from the National Air Photo Library, and compared with 2005 colour digital imagery from the City of Ottawa (**Appendix A**).

In 1926, land use adjacent to the creek consisted of agriculture and orchards. Riparian forest cover was intermittent, and limited to the channel banks. The channel was moderate in sinuosity, and an oxbow was identified. Changes in surrounding land use occurred between 1926 and 1973, where rural residential houses were developed along Old Montreal Road. Forest cover was also found to have increased along the main channel within the valley. The oxbow identified in the 1926 aerial had been slightly in-filled, displaying wetland characteristics. The meander further upstream from Old Montreal Road had increased in concavity and had shifted slightly in a northwesterly direction. The channel width downstream of Old Montreal Road was also noticeably wider.

By 2005, residential development had occurred along Old Montreal Road. The orchard farm as seen in the 1926 and 1973 aerial photographs was converted into agricultural fields or residential dwellings. However, much of the forested area within the Cardinal Creek valley system had remained unchanged. Channel hardening occurred along the upstream side of Old Montreal Road where an armourstone wall had been implemented. The oxbow as identified in the 1926 and 1973 aerials had been in-filled, taking the form of an old meander scar. Immediately downstream from Old Montreal Road, the channel had widened, likely due to channel hardening along the channel banks further downstream.

2.1.1 Geology and Climate

Geology is one of the dominant factors that govern channel evolution. Channel form, in turn, is a product of flow regime and the availability and type of sediments within the stream corridor. The dynamic equilibrium of these inputs dictates channel form. More specifically, surficial geology influences the rate of channel change (e.g. migration), sediment input (i.e. amount and type), and channel geometry. It also impacts hydrology by influencing topography and permeability.

The majority of the Cardinal Creek watershed is comprised of lacustrine sediments (silt and clay), with outcrops of fractured bedrock in proximity to the Ottawa River (Chapman and Putnam, 1984). These surficial materials tend to create a dendritic flow pattern with numerous low order channels. The bedrock and cohesive sediments provide significant resistance to erosion. These factors are influenced by land use, physiography and riparian vegetation.

Climate, in particular precipitation, provides the energy for the system and directly influences basin hydrology and rates of channel erosion. Precipitation from climate normals (1971-2000) recorded at the University of Ottawa, located near the intersection of Laurier Avenue West and Nicholas Street, averaged 72 mm per month in winter (November to February inclusive) and 88 mm in summer (July and August; Environment Canada, 2011). This increase over the summer months is likely a result of convective thunderstorms. Regardless, the highest sustained flows tend to occur in the spring because of snowmelt or rain-on-snow events.

3.0 EXISTING CONDITIONS

3.1 Watershed Characteristics

Cardinal Creek has a total channel length of approximately 67 km including all tributaries and flows in a northwesterly direction into the Ottawa River. The watershed area contributing to the subject site is approximately bordered by Old Montreal Road to the north, Dunning Road to the east, Trim Road to the west and Regimbald Road to the south. Land use in the headwaters is predominantly agricultural and this activity has resulted in extensive networks of linear agricultural drains that form the upper portion of Cardinal Creek. The drainage density of Cardinal Creek is 2.18 km/km^2, and is indicative of the linear drainage pattern and impacts of agricultural activities. As Cardinal Creek flows towards the Ottawa River, land use transitions to residential development as the creek forms the eastern limit of urban development within the City of Ottawa.

3.2 Watercourse Reach Characteristics

3.1.1 Reach Delineation

Reach delineation is typically based on changes in channel planform and active geomorphological processes, which are directly related to local surficial geology, gradient, hydrology, land use, and riparian vegetation (Montgomery *et al,* 1997; Richards *et al*, 1997). Based on a previous study of the Cardinal Creek Watershed (Geomorphic Solutions, 2006), **Reach C10** was identified in the study area from Old Montreal Road to the tributary confluence.

A field assessment to characterize existing conditions was initially completed by Geomorphic Solutions in July 18-21, 2006. The assessment consisted of a geomorphic investigation of Cardinal Creek from the tributary confluence to Old Montreal Road. Bankfull channel dimensions, substrate and bank materials, estimated bank angle, terrestrial and aquatic vegetation cover; channel disturbances were also noted. Rapid visual assessment methods, which consisted of the Rapid Geomorphic Assessment (RGA) (MOE, 2003) and Rapid Stream Assessment Technique (RSAT) (Galli, 1996), and the Downs (2004) classification method were completed. A photographic inventory of site conditions at the time of survey was compiled as part of the field assessment and is provided in **Appendix B**.

Results from Geomorphic Solutions (2006) showed that **Reach C10** of Cardinal Creek consisted of a confined channel within a meadow setting, with moderate sinuosity and gradient. The riparian community was characterized as fragmented with a few trees and dominated by shrubs and grass. Bank angles ranged between 60 – 90º (near vertical), and bank materials consisted of a mixture of clays and silts. Overhanging vegetation, exposed roots, and slumping banks were observed throughout the reach. Bankfull widths ranged from 4.0 m - 5.0 m, and bankfull depths ranged between 0.4 – 0.5 m. Riffle substrate was generally comprised of materials in the clay/silt to gravel size class. Fine silt was observed within the pools. Evidence of channel disturbance included the presence of woody debris along the channel margins and within the channel. Scouring of the channel bed and widening of the channel banks in association with the culvert at Old Montreal Road were documented. Channel hardening included rip-rap intermittently deposited along the valley wall.

Table 1. Field Observations for Reach C10.

Reach	Bankfull Width (m)	Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Pool	Riffle		
C10	4.0 - 5.0	0.4 - 0.5	Clay/silt	Clay / Silt - gravel	Meadow	Siltation in pools; woody debris present in channel and banks; good floodplain access; formation of islands at downstream section of reach; rip-rap along valley slope

Table 2. Rapid Assessment Summary for Reach C10.

Reach	RGA			RSAT			Downs Classification
	Score	Condition	Dominant form of Adjustment	Score	Condition	Limiting Factor	
C10	0.11	In Regime	Evidence of Planimetric Form Adjustment	24	Fair	Riparian Habitat Conditions	S – 'Stable'

3.1.2 Detailed Geomorphic Assessment

In addition to the general field assessments completed for **Reach C10** of Cardinal Creek by Geomorphic Solutions (2006), a topographic survey was completed on October 26, 2011 by AECOM to provide detailed information for design of the naturalized channel. Utilizing a differential level, the work involved surveying a longitudinal profile along the thalweg, and cross-sections. The survey also included break lines (e.g. bankfull, top of bank, bottom of bank) for design purposes. The survey completed by AECOM (October, 2011) examined the existing conditions as noted by Geomorphic Solutions in 2006, and verified that the planform characteristics and channel morphology had not changed. However, channel disturbances and hardening had occurred between the time of assessment carried out by Geomorphic Solutions (2006) and AECOM (October, 2011); a beaver dam had been built immediately downstream of Old Montreal Road creating a backwater effect, and ponding of sediment. The CSP culvert at Old Montreal Road had been extended, with armourstone protection surrounding the CSP.

Computed channel parameters were carried out under two conditions: where the channel was morphology was influenced by the existing beaver dam, and where it was not. The surveyed channel of **Reach C10** had an average channel gradient of 0.1% and 1.7%, respectively. The floodplain and valley walls were vegetated with mostly herbaceous plants, shrubs and grasses. The channel possessed poorly developed riffle and pool sequences. Within the channel, one partially vegetated island divided the flow with the right channel directing most of the flow. The bankfull channel (riffles and pools) averaged 6.6 m in width. The average bankfull depth was 0.59 m, resulting in a width-to-depth ratio of 11.14.

Overall, the surveyed channel within **Reach C10** was deemed S – 'Stable' as indicated by the rapid assessments (**Table 1**). The channel parameters from the detailed assessment represent representative channel conditions both assuming the influence of the beaver dam on the local energy grades and ignoring the influence of the beaver dam are shown in **Table 3**. A detailed summary of the detailed geomorphic field data collected within **Reach C10** has been provided in **Appendix C**.

Table 3. Measured and Computed Channel Parameters.

Channel Parameter	Existing Cardinal Creek	
	Beaver Dam	Without Beaver Dam
Bankfull width (m)	6.6	6.6
Average bankfull depth (m)	0.59	0.59
Maximum bankfull depth (m)	0.85	0.85
Bankfull width-to-depth ratio	11	11
Gradient (%)	0.10	1.70
Roughness (Manning's n)	0.037	0.037
Mean bankfull velocity (m/s)	0.54	2.2
Bankfull discharge (m^3/s)	2.1	8.7
Froude number	0.22	0.92
Maximum shear (N/m^2)	8.3	142
Unit stream power (W/m^2)	4.0	279
Max. grain size entrained (m)	0.010	0.15
Mean grain size entrained (m)	0.010	0.10

3.3 Fisheries

Based on information provided by Fisheries and Oceans Canada (DFO) regarding Species at Risk (SAR), it was confirmed that there are no SAR within these reaches of Cardinal Creek. All naturalization design elements will, however, consider the eco-hydraulic requirements and local habitat targets.

4.0 CHANNEL NATURALIZATION DESIGN

4.1 Design Consideration and Constraints

In developing this channel design, current conditions and future right-of-way constraints and considerations were taken into account. These constraints and considerations included:

Hazard mitigation – due to the location of the existing channel, the proposed corridor will be relocated to reduce the threat to the adjacent Old Montreal right-of-way. The corridor must continue to convey existing flows up to the Regional storm event. Similarly, the natural tendency of the channel to migrate must be addressed to ensure long-term stability.

Channel corridor – The proposed width of the valley floodplain will be sufficient to support the natural tendencies of the flow pattern with sufficient naturalized area to provide a functional corridor. Upon inclusion of the valley slopes, the naturalized cross-section, bedform and floodplain features will be developed in consideration of the valley gradient and morpho-sedimentary processes.

Natural corridor function – one of the replicated and enhanced functions targeted in the design of the new channel corridor will be will maintain a hydraulic connection between the channel and floodplain, thereby enhancing local recharge, to the greatest extent possible.

Natural channel variability – The channel will be designed to be spatially complex with respect to morphology and hydraulics. Riffle and pool sequences will allow for limited natural instream energy dissipation, thereby reducing erosive energy. This channel variability will also offer an enhanced fish habitat.

Riparian habitat – The immediate riparian zone will be designed to provide long-term stability afforded by the vegetation and conditions favourable to resident fish species. Some riparian plantings immediately adjacent to the watercourse will be integrated with the bioengineered bank treatments as part of the natural corridor design.

Water quality – The design will provide enhanced downstream water quality by providing seasonal storage of water and fine sediment. A native riparian seeding and planting plan will improve the buffering capacity to overland flow prior to reaching the channel.

4.2 Design Approach

The main objective of the proposed channel design is to restore natural form and function to a portion of Cardinal Creek, and to enhance aquatic and terrestrial habitats, while addressing constraints and hazards associated with existing and future road right-of-way requirements. Geomorphological analyses, in combination with results of the field assessments, determined the appropriate channel form and elements in the design. In a “natural” channel design, the watercourse is intended to adjust in plan and to a lesser extent through bed adjustments, as this is part of a natural self-maintenance function, in which the channel adjusts to attain equilibrium with the existing flow and sediment regime. A dynamically stable channel requires a balance between erosive forces (a function of discharge and channel slope) and resisting forces (a product of the channel substrate and local vegetation). The channel configuration (i.e., cross-section, profile and planform) controls the distribution of erosive and resisting forces and the rate at which energy is dissipated. The bankfull channel form also dissipates energy during bankfull flows and below, while access to a floodplain allows energy dissipation during higher flows. In this case, channel realignment with riffle-pool sequences and bioengineered elements is proposed. One section of the channel realignment will reactivate the meander scar, which was identified in the Historical Assessment. The selected alignment was based on the following considerations:

- Maintenance of channel length;
- Reduced impact on forest cover;
- Retention of a significant portion of the cross-section of the valley; and,
- Allows for future channel migration and retain a significant portion of the meander belt width.

Further to the above, the conceptual channel design also accounts for a future 44.5 m right-of-way centred on the current Old Montreal Road centerline (to include a transitway) based on a 2.5H:1V slope for the roadway embankment. Conceptual design drawings are included in **Appendix D**.

4.3 Channel Corridor

The proposed channel naturalization provides an opportunity to restore a more natural planform the section of Cardinal Creek. A watercourse in its undisturbed state without external human controls tends to migrate laterally within a floodplain, which is formed by the migrating channel. In this design, the channel corridor floor (i.e., floodplain) will be widened to account for natural migration tendencies while providing stable valley slopes. A bankfull channel will be constructed within a floodplain to allow flows to access the overbank area during high flow conditions. Rather than concentrating erosive flow energy within a channel, this will allow excess energy to be partially dissipated in the overbank area.

A meander belt width delineation was completed for **Reach C10** by Geomorphic Solutions in 2006. The desktop-based belt width dimension of 112 m reflects a straight line drawn tangential to the maximum lateral extent of governing meander bends, following the central tendency of the reach. Using the Williams (1986) method:

$$Bw = 4.3\ W_b^{1.12} \qquad \text{[Eq. 1]}$$

where Bw is meander belt width, Wb is bankfull width and A is bankfull cross sectional area. A 10% buffer has also been added to the final predicted meander belt width to provide a meander belt width of 123 m.

Note that this is greater than the valley floor. As such, the system is confined. Therefore, the future widening of Old Montreal Road should limit intrusion into the valley. In addition, offset protection may be required to provide a channel set-back from the top of the future roadway embankment.

4.4 Bankfull Channel

The conceptual channel design includes alternating bedform morphology (i.e. riffle and pool sequences) within the bankfull channel. Riffles invariably have a higher grade than the bankfull channel, and therefore are comprised of bed materials that are sufficiently large to be generally stable up to bankfull flows. Pools are deeper sections of channel where energy is dissipated as flows exit the riffles. This channel configuration allows for water aeration through the riffle sections and relatively quiescent flows in the pool sections for fish refuge during high flow events.

The dimensions of the proposed bankfull channel are modeled to convey the bankfull/design discharge before spilling onto the floodplain. This will reduce in-channel flow energy and decrease the potential for channel erosion. Proposed riffle and pool geometries, as well as anticipated bankfull flow conditions, for two scenarios: a condition incorporating the influence of the existing beaver dam and a condition ignoring the influence of the beaver dam are provided in **Table 4.** .

Table 4. Parameters of the Bankfull Channel.

Channel Parameter	Proposed Cardinal Creek			
	Scenario 1		Scenario 2	
	Riffle	Pool	Riffle	Pool
Bankfull width (m)	7.00	7.45	7.00	7.45
Average bankfull depth (m)	0.59	0.75	0.59	0.75
Maximum bankfull depth (m)	0.80	1.20	0.80	1.20
Bankfull width-to-depth ratio	11.86	9.92	11.86	9.92
Gradient (%)	0.10	0.10	1.70	0.72
Roughness (Manning's n)	0.037	0.033	0.037	0.033
Mean bankfull velocity (m/s)	0.54	0.70	2.23	1.85
Bankfull discharge (m^3/s)	2.24	3.92	9.23	10.36
Froude number	0.23	0.26	0.93	0.68
Maximum shear (N/m^2)	7.84	11.77	133.36	82.37
Unit stream power (W/m^2)	3.92	7.72	274.70	142.97
Max. grain size entrained (m)	0.01	0.01	0.14	0.08
Mean grain size entrained (m)	0.01	0.01	0.10	0.05

4.5 Bioengineered Treatments

Bioengineered treatments seek to provide enhanced and diverse habitat conditions while reducing erosion potential. The following range of treatments has been incorporated into the proposed channel design.

Morpho-sedimentary Features

Morpho-sedimentary features will be gained through the development of soil horizons naturally found above the parent material and characteristic of those produced through soil-forming processes. These organic and mineral horizons are a function of a range of geological, chemical, and biological processes that occur over long time periods. The lowest mineral horizon is generally unaltered by weathering and made up of the parent rock as well as other mineral materials. Ultimately, the replication of these natural processes will ensure long-term stability by providing an enhanced medium for vegetation growth and sources of sediment for the watercourse.

Live Root Wads

In order to further stabilize the backfilled channels and mitigate future secondary channel formation, live root wads will be installed along the designed channel banks in key locations. The root wads consist of the root fan or ball, and a portion of the tree trunk. They are typically installed at the toe of the channel bank and secured with live stake plantings. The bank is often backfilled with stone to provide further bank protection and stability. This treatment acts to deflect erosive flows away from the channel bank while providing ideal aquatic habitat. Live rood wads will also act to collect sediment and debris, further protecting the channel bank from erosion.

Brush Mattresses

A brush mattress is a bank treatment that consists of a mattress of pioneering species that are anchored to the bank with stakes and usually includes some form of toe protection. This bioengineering element will create structural channel bank protection that will minimize bank erosion by reducing erosion rates. Over time sediment will be captured to allow for root growth and formation thereby providing vegetative stabilization. The establishment of the plants will also act to impede flow velocities along the bank, thus protecting the bank. Terrestrial and aquatic habitat will be generally enhanced due to the additional vegetation. Further growth will also provide shade to the stream and food inputs into the channel.

Vegetated Buttress

A vegetated buttress consists of a combination of rocks and vegetation designed to provide bank protection and promote flow training and deflection. A vegetated buttress is proposed along the eroded channel bank at the toe of the embankment. The stones are hydraulically sized to sufficiently protect the banks and rockfill treatment. The treatment also offers aquatic habitat benefits through the provision of woody vegetation along the bank, which is limited under existing conditions.

The vegetated buttress will be constructed to limit encroachment into the channel and reduction of channel cross-sectional area. A slope of 2:1 was selected for the treatment, which is typical for geotechnically stable rock buttresses. This moderately steep slope was chosen to reduce encroachment, while ensuring stability. The outside embankment will require re-grading for installation of the vegetated buttress to avoid alteration of the channel cross sectional area and the need to alter the point bar. The toe stones will be embedded well into the channel bed to ensure that the treatment will not be undermined due to downcutting.

Bank Treatments

The outside bank of meander bends experiences relatively higher erosive flows, which under natural conditions leads to meander bend migration and erosion. Where appropriate, these banks will be stabilized with a root wad revetment bioengineered treatment.

4.6 Riparian Zone

To provide habitat enhancements, a restoration planting plan following pertinent guidelines is recommended that utilizes native species found in the surrounding the natural area. Live staking along the top of the channel banks is recommended to provide shading and stability. Willow and dogwood species should be planted at a high density to ensure a dense population of fast-establishing vegetation. The live staking method is favoured over shrub plantings as a high success rate can be achieved at a lower cost than bare root or potted shrub plantings. Seeding of deep rooting native grasses and other herbaceous species are also proposed on all disturbed areas of the site to provide habitat benefits and uptake of nutrients. An extensive planting plan including tree and shrub species should also be completed for the remaining corridor area. The plantings are intended to enhance the overall aquatic and terrestrial habitat, and provide additional bank stabilization, while minimizing the sedimentation potential. A planting plan that anticipates potential erosion locations, such as the outside bends of channels should include flood tolerant native shrubs. Where appropriate, the use of local soils with native seed banks will be incorporated along the corridor.

4.7 Temporary Erosion Control

Newly constructed channels are particularly vulnerable to erosion between the initial excavation and the establishment of vegetation along channel banks. While low-flow conditions should not exacerbate erosion, higher flows and precipitation events during construction can cause erosion. To alleviate the potential for erosion, the application of biodegradable erosion control blanket (e.g., coir cloth or jute mat) along the banks of the channel is proposed until vegetation has been fully established.

5.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

The proposed channel design provides riffles and pools that will naturally adjust to the annual range of flows conveyed. To assist with the proper implementation of the channel naturalization design the following recommendations are provided:

- Assessment of beaver dam and its permanence, presently existing downstream of Old Montreal Road to confirm appropriate design parameters for the constructed channel;
- Confirmation of sub-surface conditions;
- Detailed field assessment to update existing conditions and confirm design discharge and bankfull dimensions;
- Refine bankfull channel dimensions and hydraulics based on design discharge at detailed design;
- Confirmation of the upstream and downstream tie-in invert elevations to define valley and channel gradient at detailed design;
- Confirm, refine and prescribe bioengineered treatments and offset protection within corridor, along channel banks, and at crossing infrastructure at detailed design;
- Confirm construction timing constraints (i.e. fisheries and breeding birds); and
- Develop recommendations for construction implementation (ie. methods, phasing, etc.) and post-construction monitoring.

Should you have any comments or require clarification on any matter pertaining to the channel design, please contact the undersigned.

Respectfully Submitted,

GEOMORPHIC SOLUTIONS

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APPENDIX A
AERIAL PHOTOGRAPHS

Year: 1926 Location: Ottawa, ON. Easting: N/A Northing: N/A	Aerial ID: HA10543 Scale: 1:15,000 Source: NAPL

Year: 1973

Location: Ottawa, ON.

Easting: N/A
Northing: N/A

Aerial ID: 1973.1.6000

Scale: 1:10,000

Source: NAPL

Year: 2005 Location: Ottawa Easting: 463277.90 m Northing: 5037799.64 m	Aerial ID: N/A Scale: N/A Source: City of Ottawa