WILSON COWAN DRAIN FLUVIAL GEOMORPHIC EXISTING CONDITIONS
MINTO MAHOGANY, MANOTICK

156380-25016-504

Report Prepared for:
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July 2017
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DISCLAIMER

We certify that this report is accurate and complete and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but is not guaranteed. We have exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

This report was prepared for Minto Communities Inc. The report may not be relied upon by any other person or entity without our written consent and that of Minto Communities Inc. Any uses of this report by a third party, or any reliance on decisions made based on it, are the responsibility of that party. We are not responsible for damages or injuries incurred by any third party, as a result of decisions made or actions taken based on this report.

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1 INTRODUCTION

Matrix Solutions Inc. was retained by Minto Communities Inc. to provide a fluvial geomorphic existing conditions assessment of the Wilson Cowan Municipal Drain and its Tributary within the Minto Mahogany development area (Figure 1). The Drain and Tributary are under consideration as receiving channels for future stormwater management practices. The purpose of this report is to identify the existing conditions of the two watercourses and provide erosion threshold estimates in support of stormwater management design.

The following work was completed in support of this study:

- a background review of past geomorphic and environmental studies of the site and current and historical aerial imagery
- a field investigation to understand the existing conditions (stability, form, function, and processes) and delineate study reaches
- detailed geomorphic surveys in the main branch of the Drain and within the Tributary for the purposes of quantifying erosion threshold estimates
- erosion threshold analyses of each channel using collected field data

1.1 Background Review

1.1.1 Available Reporting

The report entitled *Natural Resource Existing Conditions Report – Part Lot 4 and 5 Concession A Former Geographic Township of Rideau, City of Ottawa* (EcoTech, 2008) was completed to provide a biophysical inventory of the property in order to assess the existing woodlands and wetland features, delineate vegetation community boundaries, determine fisheries populations, conduct geomorphological survey of the watercourses, and determine potential land use restrictions.

Channel dimensions, velocities, and material composition were determined throughout the study area including the current subject reaches. Overall, the majority of the channels were found to have low channel bed slopes and were composed of silty clay. The results presented in the 2008 report have been compared to the results of this current assessment.

1.1.2 Historical Aerial Imagery

Based on available historical imagery dating back to 1976, little discernable change has occurred to the planform of the channel over the past 41 years. This is consistent with the stability found within the channel observed during the field investigation. Urban development has occurred downstream of the study area since 1976 but the land use through the study area and upstream has remained agricultural with little change.

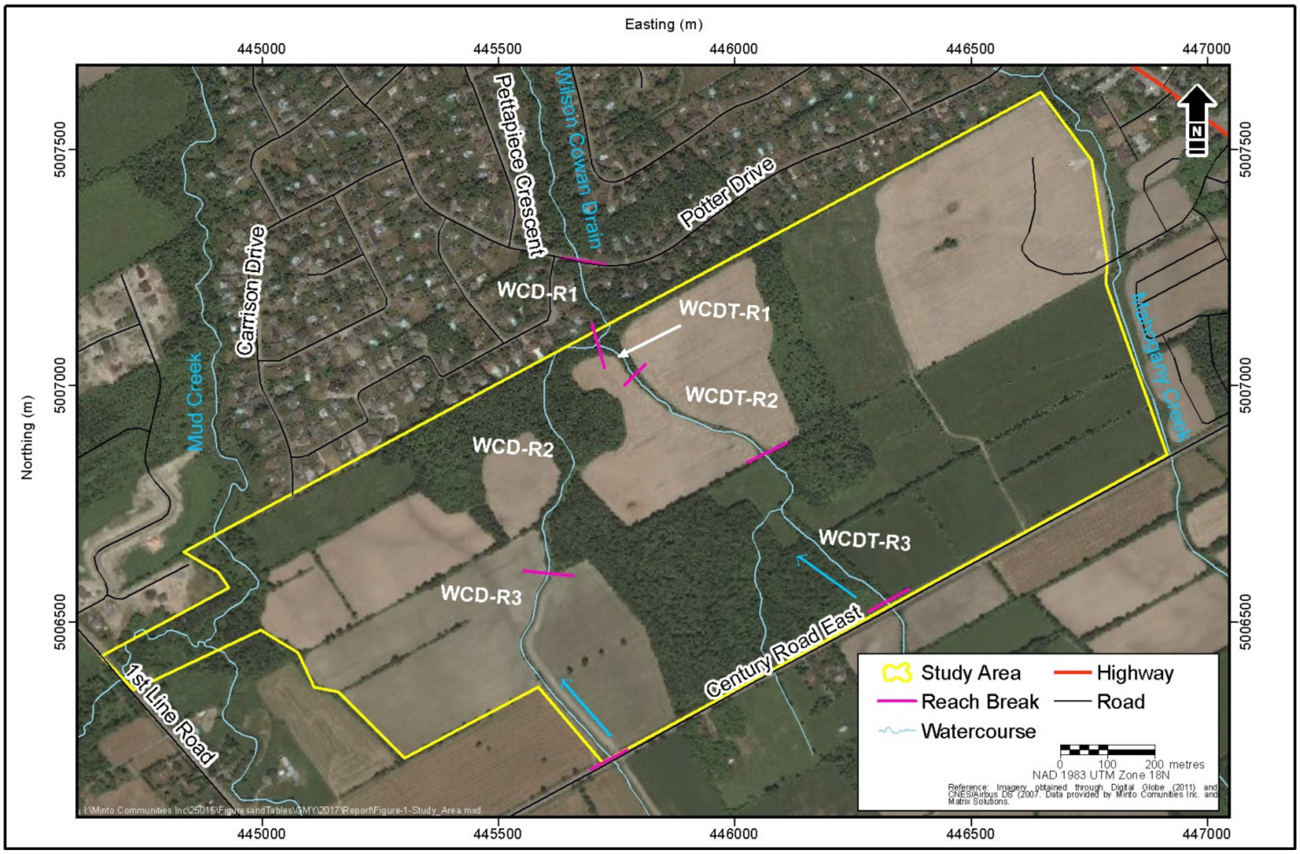

FIGURE 1 Study Area and Subject Watercourses

2 EXISTING CONDITIONS

The channels were investigated on April 12 and 13, 2017 to identify forms of natural channel adjustment, note general channel properties, and take measurements of channel geometry. During the initial site visit on April 12, channel conditions along the study reaches were evaluated using an established synoptic survey: the Rapid Geomorphic Assessment (RGA). A summary of this assessment is provided in Table 1. Detailed surveys of the Wilson Cowan Drain and its Tributary were completed on April 13 in locations displaying the greatest potential for erosion. Each survey included five cross-sections and a longitudinal profile of the centre of channel.

2.1 Rapid Geomorphic Assessment

The RGA was designed by the Ontario Ministry of Environment (2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planimetric adjustment. Examples of these include the presence of bar forms, exposed infrastructure, head cutting due to knickpoint migration, fallen or leaning trees and exposed tree roots, channel scour along the bank toe, transition of the channel from single thread to multiple thread, and cut-off channels. Overall, the index produces values that indicate whether the channel is in regime (score ≤ 0.20), stressed (score 0.21 to 0.40), or adjusting (score ≥ 0.41).

TABLE 1 Summary of RGA Results for the Mahogany Site

Reach	Aggradation	Degradation	Widening	Planimetric Adjustment	Condition
WCD-R1	0.22	0	0.25	0	In Regime
WCD-R2	0.22	0	0	0	In Regime
WCD-R3	0.22	0	0.13	0	In Regime
WCDT-R1	0.11	0.29	0.25	0	In Regime
WCDT-R2	0.11	0	0	0	In Regime
WCDT-R3	0.11	0	0	0	In Regime

2.1.1 Wilson Cowan Drain

The Wilson Cowan Drain was divided into three reaches (WCD-R1 to WCD-R3) based on land use, channel form, and channel function. Overall the channel is highly stable under existing conditions. The channel is straight and likely historically dredged to serve its function as a municipal drain. The system is aggradational throughout with a large amount of its bed composition consisting of agricultural runoff, as made evident by its composition (sandy silt), and in some locations, based on its organic content (top soil compared to typical alluvial sediment). Throughout the watercourse, the bed material was loose and, in reach WCD-R3, the soil was both loose and unconsolidated. To accommodate municipal drain requirements for surrounding lands, the channel's relatively large cross-sectional area and low slope have resulted in a mainly depositional system. In some locations, immediately adjacent to agricultural lands, concentrated runoff volumes carrying loose sediment have created small gullies that flow into the drain. The bed sediment at and immediately downstream of these locations were composed of sandy and silty, highly organic material.

WCD-R1 represents the furthest reach of channel downstream from the confluence with the Tributary. This reach was assessed to the nearest downstream edge of property. This was the extent of where access was permitted at the time of the survey. Based on aerial imagery, this reach extends to Potter Drive, at which point the channel widens significantly before narrowing through an approximately

35 m wide wetland floodplain, dominated by tall grasses, to Bankfield Road. WCD-R1 has a bankfull width of 7.4 m and a bankfull depth of 1 m. The channel bottom was composed of soft but consolidated silty clay and had a low channel slope. Where present, coarser materials were embedded and there was evidence of deposition in and around woody debris. These processes are indicative of aggradation. Although some evidence of widening was noted in the form of organic debris and falling trees, these observations were likely not a result of channel widening, but rather naturally falling trees and branches broken from high winds.

Upstream of the confluence with the Tributary, to the end of the surrounding woodlot (approximate 600 m channel length), WCD-R2 is similar to its upstream neighbour in form and function but has a slightly smaller cross-sectional profile, with a 5.5 m bankfull width and 0.85 m bankfull depth. The majority of the bank and bed below the bankfull level were exposed and lacking in vegetation. This reach is assumed to the most susceptible to erosion, given its bare bed and banks, which suggests that this stretch of channel represents the least depositional reach of the system.

WCD-R3 extends from the end of the woodlot to the site boundary at Century Road East (approximate 470 m reach length). In this reach, the bankfull width and depth were approximately 6.3 m and 1.3 m, respectively. The channel bed in this location was composed of soft, unconsolidated silt, and organic soil with a large amount of instream vegetation, dominated by cattails. The material and condition of the drain suggested a high sediment load from neighbouring agricultural lands. Through this reach, there is little to no riparian buffer and the majority of the banks are lined with tall grasses.

2.1.2 Wilson Cowan Drain Tributary

The Tributary to the Wilson Cowan Drain was also divided into three reaches (WCDT-R1 to WCDT-R3). The Tributary exhibited a good deal of stability throughout and was found to be in regime along its entire length. The downstream (approximately 90 m) portion of the channel was composed of a steep step/riffle sequence to the confluence with the main branch of the Wilson Cowan Drain. Upstream of this area, the channel contained short, less defined banks that were void of channel processes. This is typical of intermittent or ephemeral streams. These upstream reaches were flooded at the time of the survey due to recent rains and snow melt. The bed of the channel in these low gradient portions of the channel contained instream grasses or decaying leaves.

Through WCDT-R1, small round boulders were observed along the banks and overbanks of the channel. The steps/riffles were mostly composed of these larger stone sizes. Between larger boulder steps, the bed was mostly composed of gravels and sands, except in locations where channel obstructions (woody debris, etc.) had formed pockets of fine sand and silt deposits from surrounding agricultural lands. The average bankfull width and depth of the reach were 4.0 m and 0.3 m, respectively.

WCDT-R2 extended from WCDT-R1, 350 m upstream to the edge of the woodlot. In this area the channel was an average of 6 m wide and 0.7 m deep and contained instream grasses and a low channel gradient. The channel bottom was composed of a silty clay substrate.

WCDT-R3 begins adjacent to a woodlot with a channel width and depth of 3.3 m and 0.30 m, respectively. In this location the channel did not contain instream vegetation and the beds and banks were composed of highly organic soils and decaying leaves. During the time of the investigation (April 12, 2017), a level of flooding was observed throughout this reach. In some locations large ponds had formed, submerging overbank trees. In the upstream 300 m of channel to Century Rd. East, the flooding expanded to form a 30 m wide pond and no defined channel was observed. No evidence of fluvial processes was observed where a defined channel was present, and EcoTech Environmental Consultants Inc. (2008), observed little to no flow within the channel in May and June 2007, suggest that the channel through this reach is intermittent or ephemeral.

2.2 Detailed Survey

2.2.1 Profile and Cross-sections

A detailed geomorphic survey was completed of approximately 170 m of the main branch of the Wilson Cowan Drain (WCD-R2). The length of the Wilson Cowan Drain surveyed had a low average bed slope of approximately 0.01%. Points surveyed of bankfull locations suggested that water elevations at during bankfull flows produce water elevation slopes between 0.05% and 0.14%, which are more consistent with channel slopes observed by EcoTech Environmental Consultants Inc. (2008) and more representative of the average channel slope. Given the uniformity of the channel, the five cross-sections collected were representative of the watercourse.

The entire 90 m length of WCDT-R1 was surveyed as it exhibited the most forms of channel adjustment and is likely to see the most rapid response to changing flow conditions given its bed steepness and exposed boulder step sequence. Five cross-sections were collected as part of the survey. The average channel slope of the surveyed area was 1.2%.

Values of discharge, velocity, and shear stress provided in Table 2 were quantified using a panelled approach between surveyed points of each cross-section and averaged. Manning’s n values were chosen based on channel conditions and the roughness associated with the channel materials observed.

TABLE 2 Average Bankfull Cross-section Parameters

Parameter	WCD-R2	WCDT-R1
Width (m)	5.52	3.76
Average Depth (m)	0.54	0.27
Maximum Depth (m)	0.85	0.41
Width: Depth	10.38	14.08
Cross-sectional Area (m^2)	3.06	0.99
Representative Bed Slope (%)	0.05	1.2
Left Bank Angle (^{o})	26	18
Right Bank Angle (^{o})	20	17
Discharge (m^3/s)	1.68	1.46
Average Velocity (m/s)	0.46	1.25
Maximum Velocity (m/s)	0.66	1.86
Average Shear Stress (N/m^2)	2.55	30.20
Maximum Shear Stress (N/m^2)	4.13	47.6
Manning's n	0.030	0.037

2.2.2 Sediment Characteristics

The bed material through the surveyed section of WCD-R2 was composed of clayey silt with trace sands. The material was characterised in the field as a loose, lean, clayey soil. The banks, up to the bankfull level were mainly composed of this lean, clayey soil but more compact than the bed material.

Through WCDT-R1 the step feature materials were composed of very coarse gravel (3 to 6 cm) to small boulders (25 to 50 cm). Between these areas of coarser material, the material was mostly composed of gravels embedded in sandy silt with trace clays. For the threshold analysis, coarse gravels to small cobbles were considered as these are representative of the mean grain size of the reach.

3 EROSION THRESHOLD ANALYSIS

3.1 Methods

The general procedure for estimating erosion thresholds is to calculate a critical flow, shear stress, or permissible velocity at which a sediment particle of a given grain size will begin to mobilize. Once a suitable value is determined, a model is used which increases the volume of the channel incrementally until values of shear stress or water velocity equal critical values. Matrix uses established entrainment relationships to calculate erosion thresholds based on critical shear stress and permissible velocity (velocity at which the channel lining will begin to actively erode). The model results are then examined for convergence and compatibility with field observations. Selection of appropriate thresholds is also based on an understanding of site conditions and of the assumptions and range of conditions under which the entrainment relationships are applicable.

Through WCD-R2, loose, lean, clayey soils dominate the bed composition. For coarse materials, the median grain size (D_{50}) is commonly used in the determination of an erosion threshold value. In cases where fine, cohesive materials are considered, a median grain size would produce unrealistically low values of critical shear stress as the cohesion between these finer particles would not be taken into consideration. Although fine-grained particles are typically more vulnerable to erosion, the cohesion between the silt and clay particles adds resistance to shear stresses depending on the compactness and void ratio of the soil and must be taken into account in the threshold analysis. In the case of WCD-R2, the analysis must rely on relationships developed through studies of maximum permissible shear stresses for cohesive sediment. The method by Chow (1959) provides estimates of critical shear stress based on the void ratio or compactness of various cohesive materials (Figure 2).

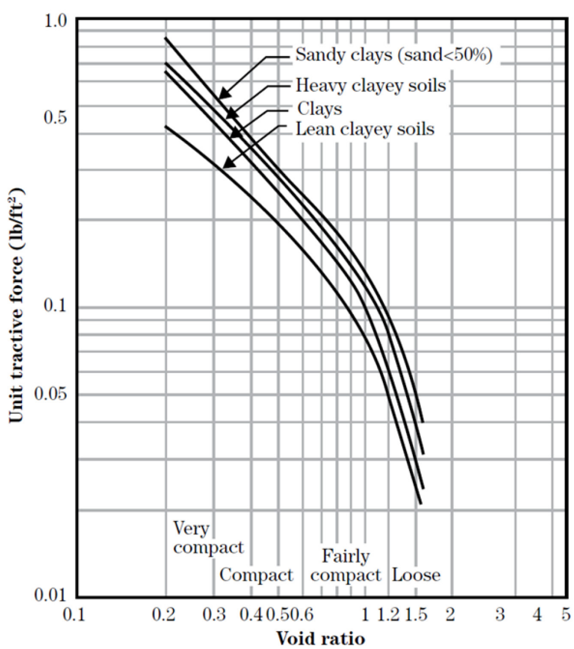

FIGURE 2 Allowable Shear Stress in Cohesive Material (Chow 1959)

In contrast, WCDT-R1 is dominated by non-cohesive, granular sediment. The Modified Shields Curve (Yalin and da Silva, 2001) was used to estimate a critical shear stress for incipient motion of the coarse gravels and small cobbles observed on site. The Modified Shields Curve applies to fluvial sediment transport rather than cohesive clays and muds (Figure 3).

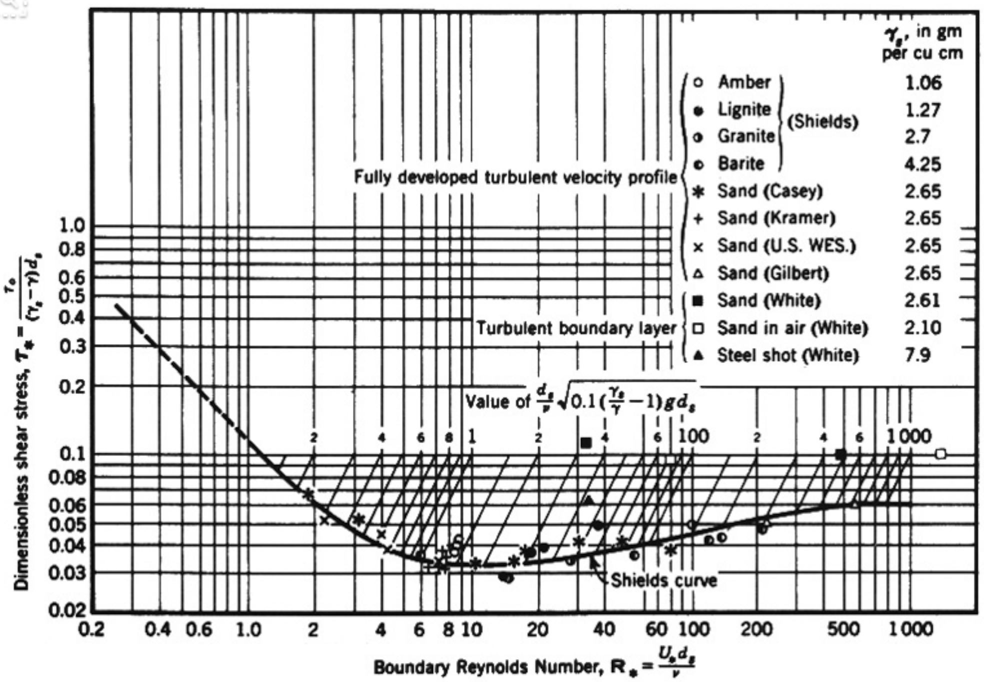

FIGURE 3 Shields Diagram for Initiation of Motion

Once the critical shear stresses were determined based on the methods described above, the thresholds were then calculated for each cross-section using the average cross-sectional dimensions. The hydraulic inputs to the iterative model are provided in Table 2. Bed and bank shear stresses were estimated using the method described by Javid and Mohammadi (2012) which accounts for secondary currents and variable eddy viscosity.

3.2 Results

3.2.1 Wilson Cowan Drain – Main Channel

Based on the method by Chow (1959), the range of loose, lean, clayey soils was considered in this analysis. The range of results is provided in Table 3. Critical shear stresses range from 1.01 to 2.39 N/m^2 for loose, lean, clayey soils. Based on field observations, water clarity was high during the field visit and little evidence of active sediment transport was noted. At the time of the survey, centre of channel wetted depths averaged 0.34 m. Based on these observations, it is assumed that the erosion threshold is only exceeded above this water level. A critical discharge of 0.29 m^3/s, equivalent to a critical average depth of approximately 0.40 m, is recommended.

TABLE 3 WCD-R2 Erosion Threshold Results Summary

Parameter	Low Range	High Range	Recommended Values
Approximate Bankfull Discharge (m^3/s)	1.68	1.68	-
Critical Shear Stress (N/m^2)	1.01	2.39	1.85
Critical Discharge (m^3/s)	0.10	0.45	0.29
Critical Average Depth (m)	0.21	0.53	0.40
Critical Average Velocity (m/s)	0.22	0.35	0.30

3.2.2 Wilson Cowan Drain - Tributary

When considering WCDT-R1, two grain sizes were considered to provide a range of critical shear stresses based on the Modified Shields Curve (Yalin and da Silva, 2001). Coarse gravels to small cobbles (3 to 7 cm diameter) were chosen as the representative material of the channel. This material represents the lower distribution within the riffles/steps and the embedded materials in the pools and transition zones between steps. During the field investigation, sediment transport was observed from adjacent agricultural lands (possible tile drain outlet locations), but observations of instream material transport were made. This suggests that the erosion threshold of the representative bed material occurs above the average water level observed (0.13 m). A value in the middle of the range considered (0.19 m) is recommended. This equates to a critical discharge of 0.24 m^3/s. The range of results and recommended values are provided in Table 4.

TABLE 4 WCDT-R1 Erosion Threshold Results Summary

Parameter	Low Range	High Range	Recommended Values
Approximate Bankfull Discharge (m^3/s)	1.46	1.46	-
Critical Shear Stress (N/m^2)	13.24	30.90	22.39
Critical Discharge (m^3/s)	0.11	0.39	0.24
Critical Average Depth (m)	0.12	0.26	0.19
Critical Average Velocity (m/s)	0.60	0.88	0.76

4 CONCLUSIONS AND RECOMMENDATIONS

A fluvial geomorphic assessment of the Wilson Cowan Drain and its Tributary through the Minto Mahogany development area was completed. As part of this study, the existing conditions of the watercourses were discussed and erosion threshold discharges were estimated for both channels to support future stormwater management practices.

Field observations of channel process noted that both channels exhibited depositional characteristics, with significant sediment inputs from surrounding agricultural lands. In low lying areas, gullying was present along channel banks where sediment heavy surface runoff from agricultural fields has caused the slope failures. These gullies provide significant sediment sources that make up the majority of the bed material through the site, especially in the main branch of the Wilson Cowan Drain. The channel showed no signs of active erosion.

The upstream reaches of the Tributary were low gradient depositional channels that are likely intermittent or ephemeral. The downstream reach was found to be much steeper with a step/riffle-pool sequence to its confluence with the main branch of the Drain. This channel was also found to be in regime and stable with little evidence of active erosion. Based on conditions during the site investigation (high water table and post freshet), the thresholds of upstream reaches are rarely exceeded as flows generally spill into the surrounding floodplain before attaining sufficient energy to cause erosion and natural channel processes.

Erosion thresholds were estimated using the methods by Chow (1959) and the Modified Shields Curve (Yalin and da Silva, 2001) to approximate the critical shear stress of the materials of each watercourse. Based on channel geometry and composition critical discharge values of 0.29 and 0.24 m^3/s for the Wilson Cowan Drain and its Tributary, respectively, are recommended for future stormwater management practices.

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APPENDIX A
Site Photographs and Detailed Survey Locations

Matrix Solutions Inc.
April 12, 2017

1. WCD-R1: View looking downstream from Century Road. Agricultural fields on both sides of drain. Note presence of instream vegetation.

Matrix Solutions Inc.
April 12, 2017

2. WCD-R1: View looking upstream towards Century Road. Riparian zone consists of tall grasses and intermittent shrubs.

Matrix Solutions Inc.
April 12, 2017

3. WCD-R2: View looking downstream. Riparian zone consists of deciduous trees and grasses. Note the lack of vegetation along both bank toes.

Matrix Solutions Inc.
April 12, 2017

4. WCD-R2: Gully formation originating from agricultural field resulting in sandy depositional feature.

Matrix Solutions Inc.
April 12, 2017

5. WCD-R2: Wooden retaining wall behind houses along Watterson St. No active erosion observed.

Matrix Solutions Inc.
April 12, 2017

6. WCD-R2: Confluence of tributary (right side of photo) with the main channel of Wilson Cowan Drain.

Matrix Solutions Inc.
April 12, 2017

7. WCD-R1: View looking downstream. Some fallen trees, not due to erosion.

Matrix Solutions Inc.
April 12, 2017

8. WCD-R1: View looking downstream at step-pool formation. Large stones (potentially placed) across channel creating small drop.

Matrix Solutions Inc.
April 12, 2017

9. WCD-R1: View looking upstream from Watterson St. Large quantities of instream vegetation.

Matrix Solutions Inc.
April 12, 2017

10. WCDT-R1: View looking upstream. Substrate consists of small-large cobble within a riffle-pool sequence.

Matrix Solutions Inc.
April 12, 2017

11. WCDT-R1: Woody debris build up in channel.

Matrix Solutions Inc.
April 12, 2017

12. WCDT-R1: Tributary within wooded buffer with agricultural fields on both sides.

Matrix Solutions Inc.
April 12, 2017

13. WCDT-R2: View looking upstream. Shows transition from agricultural field to beginning of wooded buffer.

Matrix Solutions Inc.
April 12, 2017

14. WCDT-R2: Channel has lost definition and has much lower grade.

Matrix Solutions Inc.
April 12, 2017

15. WCDT-R3: Where channel enters wooded area it regains some definition.

Matrix Solutions Inc.
April 12, 2017

16. WCDT-R3: Water spreads out and creates small pond.

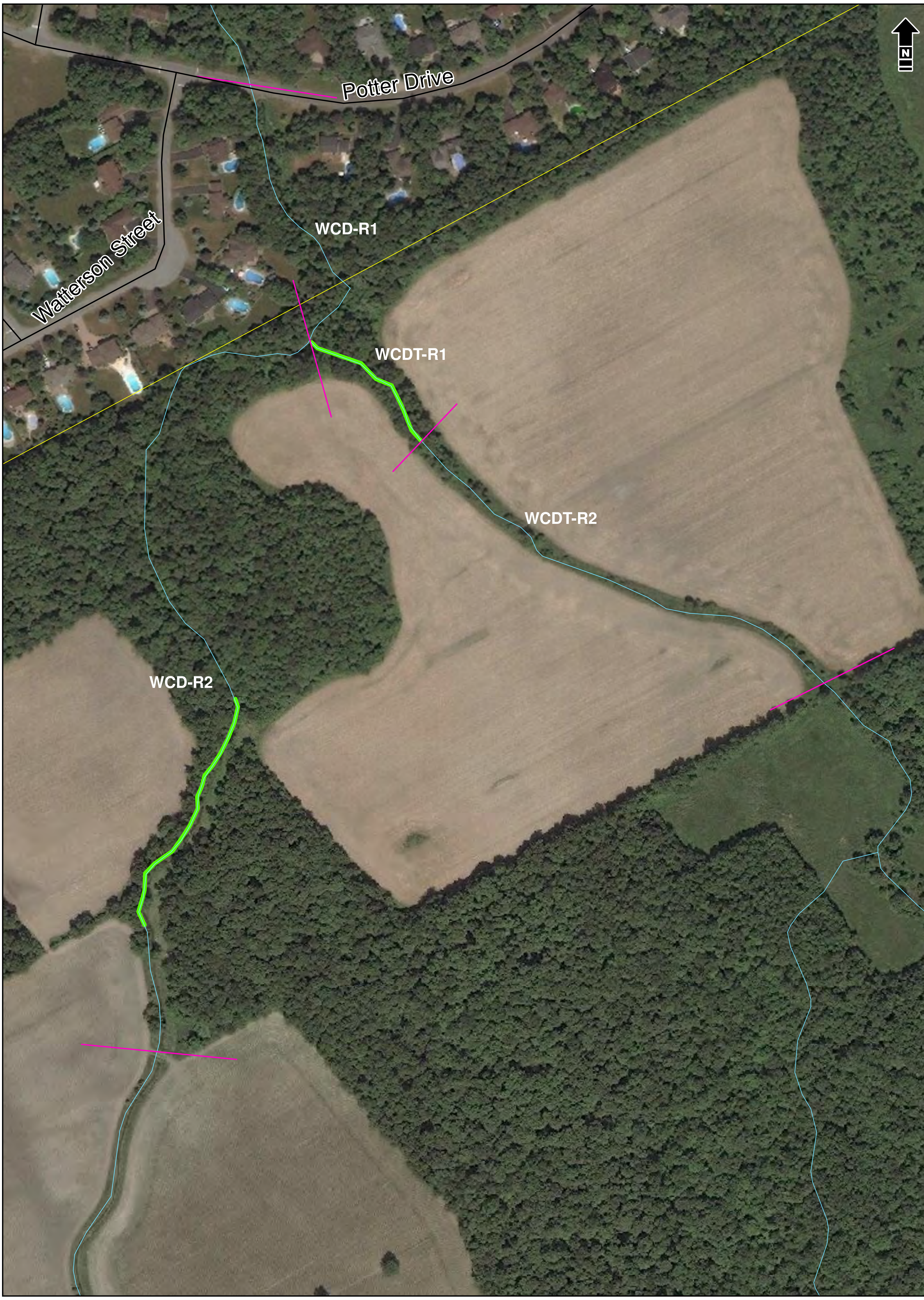
Matrix Solutions Inc.
April 12, 2017

17. WCDT-R3: Channel remains undefined and flooded up to culvert under Century Rd.

I:\Minto Communities Inc\25016\FiguresandTables\GMY\2017\Report\Figure-B-Geomorphic_Detailed_Survey_Locations.mxd

Easting (m)

Northing (m)



- Study Area
- Survey Location
- Reach Break
- Watercourse
- Road

1:2,600 m
25 0 25 50
NAD 1983 UTM Zone 18N

Reference:Imagery obtained through DigitalGlobe (2011) and CNES/Airbus DG (2007). Data obtained from Minto Communities Inc. and Matrix Solutions

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Minto Communities Inc.
Mahogany

Geomorphic Detailed Survey Locations

Date:	Project:	Technical:	Reviewer:	Drawn:
02 May 2017	25016-504	J. Parish	M. McCombs	E. Wilkinson

Figure
B