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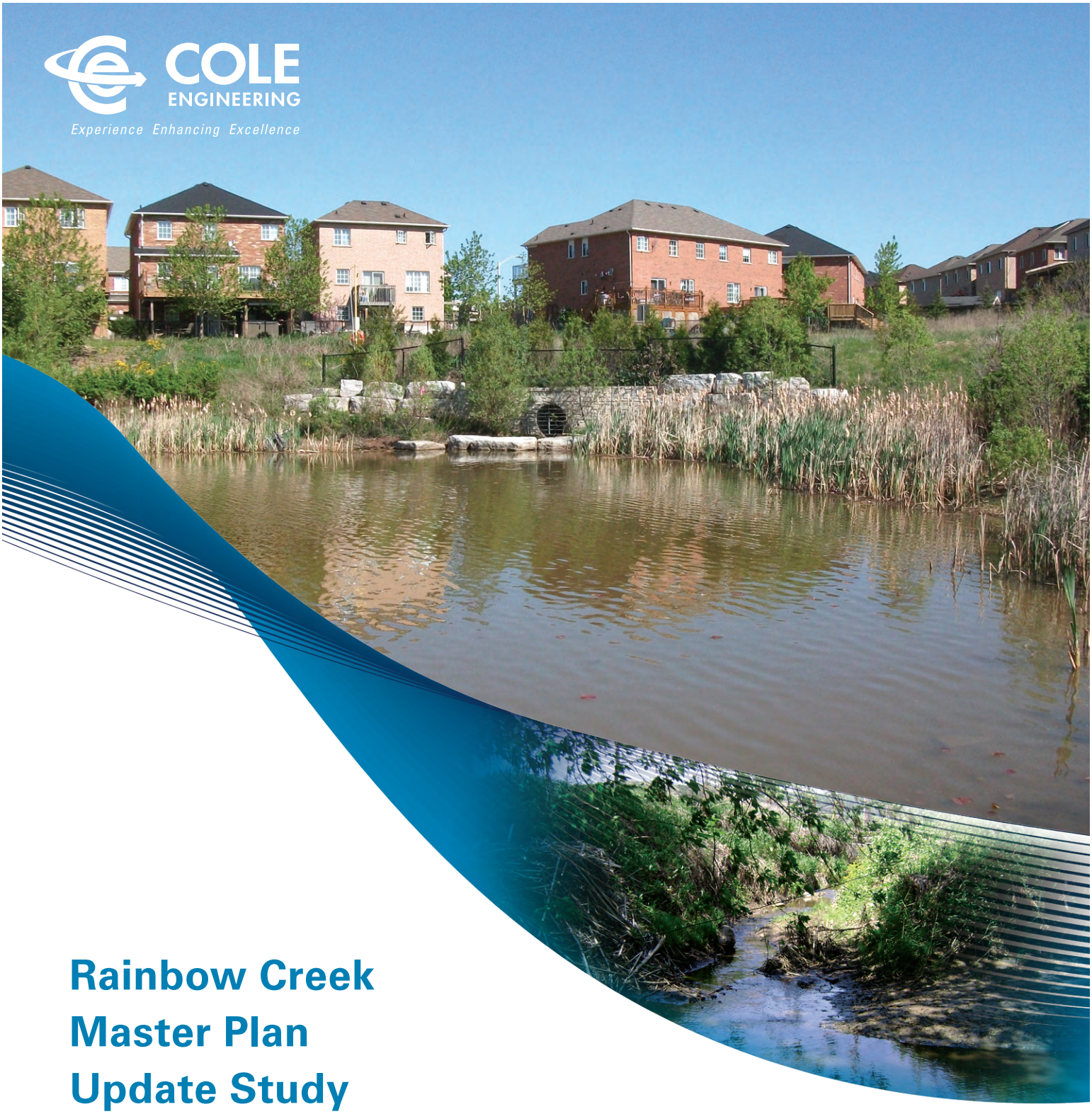

Rainbow Creek Master Plan Update Study

THE CITY OF VAUGHAN

JUNE 2014

COLE ENGINEERING GROUP LTD.

70 Valleywood Drive
Markham, ON CANADA L3R 4T5
T. 905.940.6161 | 416.987.6161
F. 905.940.2064 | www.ColeEngineering.ca

Project Manager. Geoff Masotti, P.Eng.
T. 905.940.6161 Ext. 254
E. gmasotti@ColeEngineering.ca

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1.0 Introduction

In September of 2010, City of Vaughan Council adopted the new City-Wide Official Plan, a component of the Consolidated Growth Management Strategy – 2031. The Official Plan represents an update to the City of Vaughan's community planning policies in a manner consistent with the principles of sustainability. The City of Vaughan (the City) is now proceeding with the preparation of a City-Wide Storm Drainage / Stormwater Management (SWM) Master Plan Class Environmental Assessment Study (MPCEA) to complement the new Official Plan and direct the required storm water management infrastructure improvements to support the build-out of the new Official Plan. As part of the SWM Master Plan, the Rainbow Creek Master Plan is being updated to support the population growth identified in the City's OPA, specifically as it relates potential flooding and erosion impacts.

1.1. Location

Rainbow Creek is part of the Humber River Watershed. The Humber River Watershed covers approximately 900 km^2, and reaches from the Niagara Escarpment to Lake Ontario. There are five (5) subwatersheds in Humber Watershed:

1) West Humber
2) Main Humber
3) East Humber
4) Lower Humber
5) Black Creek

The Rainbow Creek Subwatershed is part of the Main Humber Subwatershed. The subwatershed boundaries and existing Rainbow Creek Sub-catchment area are illustrated in **Figure RC-1** following the report.

The Rainbow Creek Subwatershed covers approximately 48 km^2 and is drained by two (2) watercourses, namely, Rainbow Creek and Robinson Creek, which merge north of Highway 7 to form Plunkett Creek. Plunkett Creek outlet's to the Humber River North of Steeles Avenue. Most of the Rainbow Creek Subwatershed is located within the City of Vaughan, with a portion to the Northwest extending into the Town of Caledon and a portion to the west extending into the City of Brampton. As this study has been commissioned by the City as part of their growth strategies, this study has focussed on the portions of Rainbow Creek within City limits. However, certain assumptions related to growth in the City of Brampton and the Town of Caledon have been made based on the respective growth strategies as outlined in their Official Planning documentation.

1.2. Objectives

The objectives of the Rainbow Creek Master Drainage Plan update are described below:

- Recommend a storm drainage plan and SWM management criteria for Rainbow Creek and identify improvements required in the existing stormwater collection system;
- Conduct necessary field work to identify alternative SWM measures that would cost-effectively improve the storm water runoff quantity, quality, erosion potential and reduce future maintenance requirements and flooding;

- Select the preferred SWM, erosion control and flood control alternative(s) to be considered for future phased implementation;
- Develop draft policies and SWM criteria to be applied to existing, new development and re-development in the Rainbow Creek Subwatershed to help achieve identified SWM targets relating to quantity control, flood control and erosion;
- Establish / identify major system drainage patterns in areas of future development and identify pond locations and number of ponds required;
- Verify the need to proposed flood remediation works for Sites identified in 1989 MDP under existing, interim (2011) and full build out conditions of Rainbow Creek Watershed;
- Evaluate the impact of upstream development on flood vulnerable areas identified by the TRCA and make recommendations for flood remediation work;
- Identify and evaluate other flood vulnerable sites within the City of Vaughan and make recommendations for flood remediation work; and,
- Evaluate the impact of upstream development on the existing erosion problems and identify stream restoration where required.

1.3. Background

A number of studies developed within the study area by the City, the Toronto and Region Conservation Authority (TRCA) and other consultants were revised as part of this update.

These studies include:

- City of Vaughan Official Plan 2010 – Urban Strategies Inc., September 2010;
- North Kleinburg-Nashvillle Secondary Plan – The Planning Partnership in association with Plan B Natural Heritage, Bray Heritage, September 2010;
- The WVEA Plan – secondary plan for the West Vaughan Employment Area – Urban Strategies Inc., September 2010;
- Functional Servicing Report, West Vaughan Employment Area – Cole Engineering Consultants Limited, July 2012 (Draft);
- Functional Servicing Report, Kleinburg-Nashville – Cole Engineering Consultants Limited, July 2012 (Draft);
- The City of Brampton Official Plan, October 7, 2008;
- Highway 427 Industrial Secondary Plan (Area 47), Preliminary Land Use Concept, April 19, 2011;
- Brampton East Secondary Plan, Sub Area 1, The Neighbourhood of Castlemore Crossing, October 22, 2008;
- Town of Caledon Official Plan, December 31, 2008 Consolidation;
- Rainbow Creek, Master Drainage Plan, Town of Vaughan – Cosburn, Patterson, Wardman Limited Consulting Engineers, December 1989;
- Rainbow Creek Erosion Assessment, City of Vaughan – Stantec, April 2002 (Revised September 2002);
- Humber River Watershed Hydrology / Hydraulics and Stormwater Management Study – Aquafor Beech Limited, April 1997;
- Humber River Watershed Hydrology Update – Aquafor Beech Limited, November 2002;

- Digital Floodline Mapping for the Rainbow Creek Subwatershed Summary Report – Hatch Acres, June 2006; and,
- Hydrologic Study of Impacts on Flood Flows and Mitigation of Future Development in the Humber River – AMEC Environment and Infrastructure, June 2012 (Draft).

The planning documents (Official Plans, Secondary Plans, Master Plans and Functional Servicing Reports) for the City of Vaughan, the City of Brampton and the Town of Caledon were used to map land use for 2031. Key aspects of existing studies relevant to the Rainbow Creek Master Drainage Plan Update are summarized below.

1.3.1. Rainbow Creek, Master Drainage Plan, Town of Vaughan – Cosburn, Patterson, Wardman Limited Consulting Engineers, December 1989

This is the original Rainbow Creek Master Drainage Plan and addresses hydrologic and hydraulic impacts of urban drainage on flooding, erosion, water quality and fisheries and terrestrial resources within the watershed. Prior to this report there were no requirements for runoff control for developments within the Rainbow Creek Watershed, however developers were required to secure funds with the City of Vaughan in order to prepare and implement a Master Drainage Plan for the Rainbow Creek Subwatershed.

At the time of the study only seven percent (7%) of the watershed was developed, the future committed scenario was for 13% urbanisation of the watershed and the future foreseeable land use was 36.3% urbanisation of the watershed. No specific recommendations for pond locations were made since road patterns and minor system drainage patterns had not been established. The SWM criteria established through this study are runoff control facilities to control:

- 5-year flows to 40 L/s/ha;
- 100-year flows to 180 L/s/ha; and,
- Settle out particles 40 microns in size or greater.

This report was used to identify possible areas of concern within the Rainbow Creek Sub-catchment such as:

- Locations of historic flooding;
- Flood susceptible sites; and,
- Eroding sites and sites with erosion scars.

Three (3) locations of historic flooding and 12 flood susceptible sites were identified; these sites were included in the updated flood analysis for Rainbow Creek.

40 eroding sites or erosion scars were identified within the study area. The report states that no specific erosion criteria were given as there is a lack of technology to address the effectiveness of runoff control to minimize erosion. Erosion at these sites is addressed briefly in **Section 5.6** of this report and in more detail in the Rainbow Creek Fluvial Geomorphological and Erosion Assessment Report, by Water's Edge Environmental Solutions Team, December 2012.

1.3.2. Humber River Watershed Hydrology / Hydraulics and Stormwater Management Study – Aquafor Beech Limited, April 1997 and the Humber River Watershed Hydrology Update – Aquafor Beech Limited, November 2002

These reports update the Hydrologic and Hydraulic modeling for Rainbow Creek. The unit flow rates which are currently used as the requirement for runoff control were established in this report. These unit flow rates were used to size ponds for the 2031 and 2051 development scenarios. A map showing the area for each set of unit flow rate equations is located in **Appendix B**. The equations used for the Rainbow Creek sub-watershed are:

- Q_{2yr} (L/s/ha) = 9.506 – 0.719*LN (Area);
- Q_{5yr} (L/s/ha) = 14.652 – 1.136*LN (Area);
- Q_{10yr} (L/s/ha) = 17.957 – 1.373*LN (Area);
- Q_{25yr} (L/s/ha) = 22.639 – 1.741*LN (Area);
- Q_{50yr} (L/s/ha) = 26.566 – 2.082*LN (Area); and,
- Q_{100yr} (L/s/ha) = 29.912 – 2.316*LN (Area).

1.3.3. Digital Floodline Mapping for the Rainbow Creek Subwatershed Summary Report – Hatch Acres, June 2006

The current flood elevations for Rainbow Creek were established in this report. The Rainbow Creek portion of the HEC RAS model form this report was updated and used to delineate flood lines for Rainbow Creek.

1.3.4. Hydrologic Study of Impacts on Flood Flows and Mitigation of Future Development in the Humber River – AMEC Environment and Infrastructure, June 2012 (Draft)

This report is currently being completed for the TRCA and will provide guidance for flood flow mitigation throughout the Humber River Watershed. Given the scope of their analysis the model for the overall Humber River is less detailed than that of Rainbow Creek, however it is important for planning and regulation purposes that both models give similar results. To this end we have been working with AMEC, through the TRCA, to keep our methodology consistent with that used in the Humber River analysis. The models and methodology from the Humber River analysis were used as the base for the Rainbow Creek Hydrology Model.

2.0 Methodology

The overall Humber River Hydrology Model is currently being updated by AMEC as commissioned by the TRCA. The Draft PCSWMM model prepared by AMEC for the Humber River was obtained through the TRCA and updated with detailed information provided by the City. The modeling software (PCSWMM) and infiltration method (Green Ampt) were those used in the Humber River Model. The Links and nodes for our existing conditions were taken directly from the AMEC Model. At the time of completion of this study, the TRCA had not completed Humber River Watershed Update or determined the overall impacts of development within Vaughan on the overall Humber River. Further recommendations and/or flood management criteria may required to be considered based in the final results of TRCA's work.

Three (3) model scenarios were used to determine the long term effects of development on the Watershed. The scenarios chosen are consistent with those used in the Draft Humber River Model.

The baseline scenario is used to determine the current or acceptable conditions in a watershed. The baseline scenario for the Rainbow Creek Watershed is a combination of existing land use (**Figure RC-2** following the report) and development approved in the previous City of Vaughan Official Plan. This is consistent with the baseline scenario used in the Draft Humber River Model. The land use used for the baseline condition is shown on **Drawing LU-1**, located in **Appendix A**.

The second scenario is the projected 2031 Development condition within the City of Vaughan, Town of Caledon and the City of Brampton as per the respective growth strategies. This model is used to determine SWM criteria for developments in the current City OPA. Land use used for the 2031 scenario is illustrated on **Drawing LU-2**, located in **Appendix A**.

The third scenario is the projected 2051 development. This scenario is not part of an official plan; it is designed to show the potential impact of full build-out of the remaining City White Belt Lands, as shown on **Drawing LU-3**, located in **Appendix A**. This scenario is meant to demonstrate the long term sustainability of the SWM criteria recommended in the Master Plan report.

3.0 Model Parameters

3.1. Links and Nodes

The links in PCSWMM represent the main channel and branches of Rainbow Creek, nodes represent locations where flows enter the creek. The Links and nodes for the Rainbow Creek Model were taken from the Humber River Watershed Model, (AMEC 2012). As the Rainbow Creek Model has incorporated additional detailed hydrology extra nodes were added to the model. The channel was also modified in some locations based on survey data collected by Cole Engineering.

3.2. Drainage Boundaries

The existing drainage boundaries were delineated from a digital elevation model (DEM) that was conditioned using detailed topography survey work and using Cole Engineering's MicroDrainge tool. This tool defines the area draining to a specified point based on a DEM, stream path, flow direction and flow accumulation. The DEM surface contains topographic information and is conditioned to reflect known road crossings such as bridges and culverts. The stream path, flow direction and flow accumulation files contain data on overland flow and the small streams and ditches which collect and convey runoff. Drainage area plans for the Baseline Scenario (**DAP-1**), 2031 Scenario (**DAP-2**) and the 2051 Scenario (**DAP-3**) are located in **Appendix A**. Tables listing the model parameters used for each drainage area are located in **Appendix B**.

For the baseline model (existing and approved development to 2012) these boundaries were updated using approved drainage area plans for existing and approved ponds with the Rainbow Creek Subwatershed.

For the 2031 model drainage boundaries in the West Vaughan Employment Area and the Kleinburg-Nashville Development were modified to match the drainage areas in the functional servicing reports (Draft City of Vaughan Stormwater Management Master Plan, Cole Engineering Ltd., 2012).

For the 2051 model drainage boundaries in the White Belt Area were defined base on existing topography. These areas were further refined based on factors that would limit development such as natural features and utilities corridors.

3.3. Land use

For the purpose of this study existing land use was determined using 2011 aerial photography provided by the City. Land uses that have been approved as part of the 2008 Official Plan have been added to the existing land use in order to create a 2012 land use layer. This layer was use for the existing conditions model, as approved developments will not be subject to the SWM criteria recommended in this report. The existing land use is shown on the Existing Land Use Map (**Drawing LU-1**) located in **Appendix A**. The parameters used in modeling each type of land use are located in **Appendix B**.

The 2031 land use determined using the following sources:

City of Brampton

- The City of Brampton Official Plan, October 7, 2008;
- Highway 427 Industrial Secondary Plan (Area 47), Preliminary Land Use Concept, April 19, 2011; and,
- Brampton East Secondary Plan, Sub Area 1, The Neighbourhood of Castlemore Crossing, October 22, 2008.

Town of Caledon

- Town of Caledon Official Plan, December 31, 2008 Consolidation.

For areas within the City of Vaughan, 2031 development was based on the proposed land use for the West Vaughan Employment Area and Kleinburg-Nashville communities. Functional Servicing Reports for these areas are being prepared as part of the ongoing City of Vaughan SWM Plan which is being prepared by Cole Engineering. The 2031 land use is shown on the 2031 Land Use Map (**Drawing LU-2**), located in **Appendix A**.

For 2051 future full built-out of the White Belt Lands was assumed to be fully developed. As there is no official plan for 2051, land use was assumed based on the land use for the surrounding areas. For example the White Belt Block adjacent to the commercial development was assumed to be commercial developments in 2051. Areas which are currently zoned for open space conservation, environmentally protected areas, greenbelt areas and flood line buffer zones were assumed to remain in their natural state. It was assumed that no changes would be made to the utility corridor. The 2051 land use is shown on the 2051 Land Use Map (**Drawing LU-3**), located in **Appendix A**.

As there was no detailed design information available for the Highway 427 extension corridor it was modelled as open space for all three (3) scenarios for consistency. As the objective of this study is to determine the impacts of future growth in the City, maintaining a consistent land use for the highway lands allows for the comparison of peak flows directly related to future growth within the City and not outside influences.

3.4. Soils Mapping

The Green-Ampt Hydrology method uses three (3) soil parameters, namely Hydraulic conductivity, Suction head, and, initial deficit.

These values were assigned based on Table 26.2 of the User's Guide to SWMM5 (12th edition, 2008). Soils information was obtained from:

- The Soil Survey of York County, Report No. 19 of the Ontario soil Survey, Agriculture Canada – Research Branch in conjunction with the Ontario Ministry of Agriculture and Food, 1955; and,
- The Soil Survey of Peel County, report No. 18 of the Ontario soil Survey, Agriculture Canada – Research Branch in conjunction with the Ontario Ministry of Agriculture and Food, 1953.

Figure RC-3, following the report, shows the soils within the Rainbow Creek Subwatershed. A table listing the soils parameters used for each soil type is located in **Appendix B**.

3.5. Stormwater Management Facilities

Information on the existing SWM facilities was taken from the City of Vaughan's System Wide Maintenance Software (SWMSoft) database. SWMsoft was developed to provide easy access to all the drawings, reports, pictures, inspections and maintenance information about each facility and facility component. The inventory of SWM facilities within the City of Vaughan was previously completed by Clarifica Inc. in 2007. A total of 53 facilities with a permanent pool storage component were surveyed and added to the SWMsoft database as part of the initial survey. The City has continued to update this database as new ponds are assumed by the City.

The available information for the ponds in the SWMsoft database ranges from full reports and drawings to brief verbal descriptions. For ponds with incomplete data stage storage curves were created based on the SWMsoft survey drawings. Stage-discharge curves were calculated using the SWM criteria that was in place at the time the pond was constructed. 12 ponds were added to the model using information from the City of Vaughan SWMsoft database. 10 additional ponds were added to the model using information on approved developments provided by the City.

Information for the three (3) existing ponds within the Town of Caledon was taken from Town of Caledon's SWMsoft database. As with the City of Vaughan SWMsoft database not all the ponds have complete information, so stage-storage and stage-discharge curves were calculated based on the available information. Only one (1) pond was added to the existing conditions model for the City of Brampton; this pond is under construction as part of the neighbourhood of Castlemore Crossing. This pond represents two (2) ponds shown in the Brampton East Secondary Plan and was assumed to provide quantity and quality control for flows from Sub-catchments BR-01 and BR-02.

Existing ponds are shown on the Existing Land Use Map (**Drawing LU-1**), located in **Appendix A**. Please refer to **Appendix B**, for details on the references and assumptions used to model each pond.

For the 2031 scenario 16 ponds and 14 on-site storage locations were added within the City of Vaughan. Design parameters for these ponds and on-site storage units were taken from the Functional SWM Plan for the West Vaughan Employment Area and Kleinburg-Nashville development Area. These ponds and on-site storage areas have been designed to demonstrate a feasible design for SWM in these areas. The Visual Otthymo V-2.4 (VO2) modeling files used to calculate the stage-storage-outflow curves for these ponds / on-site storage units are located in **Appendix B**.

Eight (8) ponds were added to the model within the City of Brampton and the Town of Caledon. These ponds are for modeling purposes only and may not be in the locations show on Secondary plans or in the official plans for the Town of Caledon and the City of Brampton. These ponds have been added to the model so as to have the same design criteria applied to the entire watershed. The VO2 modeling files used to calculate the stage-storage-outflow curves for these ponds / on-site storage units are located in **Appendix B**.

All 2031 ponds have been designed to control post development flows to the Unit flow rates recommended in the Humber River Watershed Hydrology / Hydraulics and S Study – Aquafor Beech Limited, April 1997. A copy of the Unit flow rate equations for Rainbow Creek is located in **Appendix B**.

15 ponds / storage units were added within the City of Vaughan for the 2051 scenario. The 2051 scenario is not as detailed as the 2031 modeling, locations and types of storage have not been defined for individual areas. As with the 2031 ponds the 2051 ponds / storage units have been designed to control post development flows to Unit flow rates. The VO2 modeling files used to calculate the stage-storage-outflow curves for these ponds / on-site storage units are located in **Appendix B**.

4.0 Models

4.1. Quantity Control Model

Analysis of the Humber River Watershed as a whole (Hydrology / Hydraulics and SWM Study, Humber River Watershed, Aquafor Beech Limited, April 1997) has shown that controlling post-development flows to pre-development levels for tributaries draining directly to the main Branches of the Humber River will not provide the required peak flow reduction for the Humber River. In order to maintain pre-development flows within the Humber River unit flow rates equations were developed for different locations within the Humber Watershed, which result in post to pre-development peak flow control for the Humber River. These unit flow rates provide a consistent means of pre-development peak flow estimation and ensure target peak flows are met within individual sub-basins.

As Rainbow Creek is part of the Humber Watershed any changes to the quantity control requirements for Rainbow Creek would have to be evaluated in terms of there effect on the Humber River. As the analysis of the Humber River is outside the scope of the current project, the quantity control analysis has been limited to verifying that unit flow rates will provide sufficient quantity control within Rainbow Creek. The 2-year through 100-year 12 hour AES design storms used in the Aquafor Beech Study were used for this analysis. The results of this analysis are discussed in **Section 5.1**.

4.2. Regional Regulatory Event Model

The regulatory flood event for the Rainbow Creek sub-catchment is Hurricane Hazel, which is the regional storm for much of Southern Ontario. Hurricane Hazel hit Southern Ontario in November 1954, the storm consisted of two (2) days of low intensity rain (2 mm/hr) followed by 13 hours of higher intensity rainfall. The first two (2) days of rain saturated soils and filled SWM facilities. Historically it has been assumed that the effect of the initial rainfall would cause pervious areas to be equivalent to impervious areas during the last day of the storm and therefore increased the impervious area would have no effect on regional flows.

In order to generate peak flows for the regional event all SWM facilities are removed from the model. This is a conservative approach based on the assumption that the initial rainfall will fill these facilities and runoff will be essentially uncontrolled during the final days of the storm. The model was run for five (5) days, to allow water from the upper reaches of the watershed to reach the outlet. The results of this analysis are discussed in **Section 5.2**.

4.3. Erosion Control Model

For the erosion analysis in Rainbow Creek Water's Edge Environmental Solutions Team (Water's Edge) was hired to calculate erosion thresholds for reaches downstream of proposed SWM facilities. These thresholds represent the flow at which erosion will begin occurring for a specific reach. Locations downstream of proposed SWM facilities were chosen as the SWM facilities will concentrate flow from a large area and release it over a longer period of time than would occur under natural conditions. This concentrated low flow can increase the length of time that erosive flow occurs if the downstream reach has a low erosion threshold.

A continuous model with 33 years of rainfall data was run and the number of exceedances (number of events generating flows which exceed the erosion threshold) and hours of exceedance (total hours the erosion threshold is exceeded) was graphed at each location. This modeling was completed for the baseline condition and then for the 2031 land use scenario with the following erosion control criteria for the proposed ponds:

- 24 hour drawdown time for the first 25 mm;
- 48 hour drawdown time for the first 25 mm;
- 72 hour drawdown time for the first 25 mm;
- 5 mm on-site detention; and,
- 10 mm onsite detention.

The results of this modeling are discussed in **Section 5.5**.

5.0 Results

5.1. Quantity Control Model

The quantity control model was run using 2-year through 100-year storms with the 12-hour AES distribution. The model was run for the base condition, the 2031 Scenario and the 2051 scenario. The results for the 2-year and 100-year events are summarized in **Table 5.1** and **Table 5.2**. Results for the 5-year, 10-year, 25-year and 50-year design storms can be found in **Appendix C**.

Table 5.1 – Results of the Quantity Control Hydrology Model – 2year-12 hour AES Design Storm

Name	Maximum Total Inflow (m^3/s)		% Decrease in Flow	Maximum Total Inflow (m^3/s)		% Change in Flow
	2012	2031		2012	2051	
RC_01	6.0	5.3	12%	6.0	5.2	14%
RC_02	3.3	3.2	1%	3.3	3.6	-12%
RC_03	6.0	5.3	13%	6.0	5.0	17%
RC_04	3.0	3.0	0%	3.0	2.0	34%
RC_05	1.1	0.4	69%	1.1	0.4	69%
RC_06	2.0	1.1	47%	2.0	0.3	87%
RC_07	3.1	1.4	55%	3.1	0.6	79%
RC_08	2.7	1.3	52%	2.7	0.8	72%
RC_09	7.4	7.4	0%	7.4	7.0	6%
RC_10	8.1	8.1	0%	8.1	7.5	7%
RC_11	0.4	0.3	26%	0.4	0.6	-37%
RC_12	0.4	0.5	-11%	0.4	0.5	-11%
RC_13	2.0	1.0	50%	2.0	1.1	46%
RC_14	6.6	7.1	-8%	6.6	6.8	-3%
RC_14-15	6.9	8.1	-16%	6.9	8.0	-15%
RC_15	1.8	1.3	27%	1.8	1.4	23%
RC_16	5.6	7.3	-31%	5.6	7.2	-30%
RC_17	5.6	7.5	-33%	5.6	7.4	-32%
RC_18	3.4	1.8	45%	3.4	1.8	46%
RC_19	3.3	2.2	32%	3.3	2.2	32%
RC_20	3.5	2.7	23%	3.5	2.7	24%
RC_21	7.9	7.1	11%	7.9	7.0	11%
RC_22	4.3	3.3	24%	4.3	3.1	27%
RC_23	8.4	7.0	17%	8.4	7.0	17%
RC_24	11.7	8.5	28%	11.7	8.3	29%
RC_25	11.9	8.8	26%	11.9	8.5	28%
RC_26	12.1	9.6	20%	12.1	9.4	22%
RC_27	5.6	7.4	-33%	5.6	7.3	-32%
RC_28	5.3	5.5	-4%	5.3	5.5	-4%
RC_29	6.4	6.7	-5%	6.4	6.7	-5%
RC_30	14.7	12.9	13%	14.7	12.5	15%
C_31	15.9	15.5	2%	15.9	15.6	2%

Table 5.2 – Results of the Quantity Control Hydrology Model – 100-year-12hour AES Design Storm

	Maximum Total Inflow (m^3/s)		% Decrease in Flow	Maximum Total Inflow (m^3/s)		% Decrease in Flow
	2012	2031		2012	2051	
RC_01	19.54	16.81	14%	19.54	16.01	18%
RC_02	12.68	12.62	1%	12.68	8.96	29%
RC_03	18.79	16.89	10%	18.79	15.36	18%
RC_04	18.01	17.49	3%	18.01	9.59	47%
RC_05	4.14	0.98	76%	4.14	0.98	76%
RC_06	7.13	3.41	52%	7.13	1.15	84%
RC_07	12.63	4.56	64%	12.63	2.24	82%
RC_08	11.23	4.32	62%	11.23	2.60	77%
RC_09	38.82	36.48	6%	38.82	27.64	29%
RC_10	45.97	40.28	12%	45.97	29.84	35%
RC_11	5.31	2.13	60%	5.31	2.04	62%
RC_12	5.86	1.69	71%	5.86	1.69	71%
RC_13	9.08	5.10	44%	9.08	4.34	52%
RC_14	43.84	40.51	8%	43.84	30.46	31%
RC_14-15	46.57	43.69	6%	46.57	33.64	28%
RC_15	10.19	5.63	45%	10.19	4.98	51%
RC_16	44.86	47.86	-7%	44.86	35.88	20%
RC_17	42.63	44.49	-4%	42.63	34.62	19%
RC_18	12.62	6.39	49%	12.62	6.38	49%
RC_19	14.04	7.72	45%	14.04	7.76	45%
RC_20	16.23	9.79	40%	16.23	9.80	40%
RC_21	25.96	19.39	25%	25.96	19.34	25%
RC_22	18.56	11.98	35%	18.56	11.99	35%
RC_23	27.67	18.85	32%	27.67	18.59	33%
RC_24	46.52	29.04	38%	46.52	28.73	38%
RC_25	47.26	30.46	36%	47.26	30.02	36%
RC_26	51.35	36.34	29%	51.35	35.92	30%
RC_27	39.58	40.65	-3%	39.58	32.58	18%
RC_28	14.75	15.00	-2%	14.75	15.00	-2%
RC_29	27.44	25.73	6%	27.44	26.24	4%
RC_30	66.17	64.00	3%	66.17	54.26	18%
RC_31	69.62	62.89	10%	69.62	58.25	16%

There is an increase in flow south of Block 61 for smaller storm events and this increase is due to the development of Bock 61. The pond design used for Block 61 is preliminary. It is recommended that the Block 61 ponds be updated once the pond design is finalized. In all other areas pond designed to unit flow rates result in flows which are no more than 5% greater then pre-development levels and in most cases lower than pre-development. For larger storms the unit flow rates control flows to pre-development levels and there is no increase in runoff south of Block 61.

5.2. Regional Storm Model

The results of the hydrology analysis for the regional storm are presented in **Table 5.3** and **Table 5.4**. The locations of the nodes are shown on the attached drainage area plans. These results of the hydrology update indicate that the post development flows are largely consistent with the baseline condition for both the 2031 and 2051 development scenarios. Some local changes in peak flows were observed; however these are generally within 10% of the baseline flows for the portion of the Rainbow Creek sub-watershed located in the City of Vaughan.

Table 5.3 – Results of the Regional storm Hydrology model – 2031 Development conditions

Node ID	Peak Flows		Increase %	Location
	Approved and Existing Conditions (m^3/s)	2031 Development (m^3/s)		
RC_01	42.9	42.9	-0.01	West Robinson Creek
RC_02	25.9	25.9	0.03	West Robinson Creek
RC_03	44.7	45.0	0.57	West Robinson Creek
RC_04	51.5	49.5	-3.88	West Robinson Creek
RC_05	6.1	10.5	70.84	West Robinson Creek – Brampton
RC_06	10.6	9.7	-7.77	West Robinson Creek
RC_07	18.5	21.7	17.55	West Robinson Creek – Brampton
RC_08	20.8	23.2	11.38	West Robinson Creek
RC_09	124.0	120.3	-2.99	West Robinson Creek
RC_10	150.4	144.7	-3.77	West Robinson Creek
RC_11	14.2	27.4	92.26	East Robinson Creek [1]
RC_12	15.3	7.8	-48.80	East Robinson Creek [1]
RC_13	31.5	38.6	22.39	East Robinson Creek [1]
RC_14	152.2	148.4	-2.51	West Robinson Creek
RC_14-15	180.2	174.2	-3.34	Robinson Creek
RC_15	35.1	42.0	19.68	East Robinson Creek
RC_16	172.8	173.8	0.56	Robinson Creek
RC_17	173.9	174.8	0.50	Robinson Creek
RC_18	31.2	34.1	9.44	Brampton – West Rainbow Creek
RC_19	38.3	46.1	20.27	Brampton – West Rainbow Creek
RC_20	48.8	54.4	11.46	Brampton – West Rainbow Creek
RC_21	50.3	48.9	-2.82	East Rainbow Creek
RC_22	52.6	58.2	10.60	Brampton – West Rainbow Creek
RC_23	63.0	59.2	-6.00	East Rainbow Creek
RC_24	130.3	141.3	8.46	Rainbow Creek
RC_25	141.4	152.1	7.53	Rainbow Creek
RC_26	179.3	187.2	4.40	Rainbow Creek
RC_27	169.3	171.5	1.32	Robinson Creek
RC_28	20.6	20.6	0.06	Unnamed Tributary
RC_29	55.3	55.4	0.03	Plunkett Creek
RC_30	305.6	321.1	5.07	Plunkett Creek
RC_31	346.3	361.5	4.40	Plunkett Creek

Note 1: Downstream of Block 61

Table 5.4 – Results of the Regional storm Hydrology model – 2051 Development conditions

Node ID	Peak Flows		Increase %	Location
	Approved and Existing Conditions (m^3/s)	2031 Development (m^3/s)		
RC_01	42.9	43.8	1.91	West Robinson Creek
RC_02	25.9	28.2	8.62	West Robinson Creek
RC_03	44.7	44.0	-1.62	West Robinson Creek
RC_04	51.5	54.1	5.01	West Robinson Creek
RC_05	6.1	10.5	70.84	West Robinson Creek – Brampton
RC_06	10.6	9.8	-7.60	West Robinson Creek
RC_07	18.5	21.6	16.99	West Robinson Creek – Brampton
RC_08	20.8	23.2	11.47	West Robinson Creek
RC_09	124.0	128.4	3.62	West Robinson Creek
RC_10	150.4	155.3	3.29	West Robinson Creek
RC_11	14.2	31.3	119.48	East Robinson Creek [1]
RC_12	15.3	7.8	-48.81	East Robinson Creek [1]
RC_13	31.5	42.2	34.04	East Robinson Creek [1]
RC_14	152.2	159.9	5.09	West Robinson Creek
RC_14-15	180.2	192.5	6.77	Robinson Creek
RC_15	35.1	45.2	28.53	East Robinson Creek
RC_16	172.8	188.8	9.22	Robinson Creek
RC_17	173.9	191.6	10.16	Robinson Creek
RC_18	31.2	34.2	9.60	Brampton – West Rainbow Creek
RC_19	38.3	46.2	20.49	Brampton – West Rainbow Creek
RC_20	48.8	54.5	11.72	Brampton – West Rainbow Creek
RC_21	50.3	48.9	-2.75	East Rainbow Creek
RC_22	52.6	58.4	10.94	Brampton – West Rainbow Creek
RC_23	63.0	59.2	-5.96	East Rainbow Creek
RC_24	130.3	141.9	8.89	Rainbow Creek
RC_25	141.4	152.7	7.96	Rainbow Creek
RC_26	179.3	184.3	2.76	Rainbow Creek
RC_27	169.3	186.3	10.09	Robinson Creek
RC_28	20.6	20.6	0.06	Unnamed Tributary
RC_29	55.3	55.4	0.03	Plunkett Creek
RC_30	305.6	329.2	7.72	Plunkett Creek
RC_31	346.3	369.3	6.66	Plunkett Creek

Note 1: Downstream of Block 61

The future development areas of the City of Brampton within the Rainbow Creek Subwatershed are primarily agricultural land. The assumption made for the 2031 model had converted the proposed land use for employment purposes. This is a conservative assumption and more detailed analysis as part of future study for this area is recommended to consider development density and net developable areas prior to prescribing flood controls.

The west branch of Rainbow Creek, located primarily in the City of Brampton, indicates the potential for some localized increases in flow for both the 2031 and 2051 scenarios. This increase is localized to the headwater reaches and becomes less apparent downstream, becoming consistent with existing flood flows shortly after crossing the Brampton City Limits (Highway 50). As an example, the percent change in flows at node RC_05 appears large, however the baseline flows are low (6.1 m^3/s), which means even a small increase in flow (three (3) – four (4) m^3/s) will represent a sizeable increase in terms of percentage.

The development plan for Block 61 included a re-alignment of Rainbow Creek which results in a change of tributary drainage areas to the two (2) tributaries which flow through Block 61. This results in an increase in flow to node RC_11 and a decrease of flow at node RC_12. The confluence of the two (2) channels from Block 61 occurs just south of McGillivray Road and the increase in flow becomes less pronounced down stream of this confluence and is less than a 10% increase south of Rutherford Road. It is our understanding, based on discussion with the TRCA, that the Block 61 development will include storage for Regional Controls which were not included in this model.

5.3. Floodline Update

The current flood lines for Robinson and Rainbow Creek were delineated using a HEC RAS model created by Hatch Acres, *Digital Flood Mapping for the Rainbow Creek Watershed Summary Report,* June 2006, and peak flows from the Humber River Watershed Hydrology Update, Aquafor Beech Limited, November 2002. As part of this study the HEC RAS model has been updated using a combination of the DEM surface for Rainbow Creek and surveyed cross sections and Culvert information. The peak flows generated using PCSWMM were input into the HEC RAS model in order to update the flood lines for the Rainbow Creek Sub-watershed. Updated Flood lines are shown on **Drawings FLA-1** and **FLA-2** in **Appendix A**.

5.4. Flood Vulnerable and Historic Flooding Locations

As part of this study, flood vulnerable locations within the Rainbow Creek Watershed were identified based on the updated floodline mapping and a flood risk evaluation was completed for each site. In addition the four (4) locations of historic flooding and 11 flood susceptible sites that were identified in the 1989 Master Drainage Plan (shown on **Figure RC-4** following the report) and flood susceptible sites provided by the TRCA were evaluated. The criteria used for this evaluation were agreed upon with staff at the City of Vaughan. These criteria include:

- Increases in flow;
- Increases in depth of flooding;
- Increases in the area of flooded;
- Increases in flow velocity;
- Increases in the frequency of flooding;
- Changes in accessibility for emergency vehicles; and,
- (Criteria agreed to with the City of Vaughan is 0.3 m maximum depth for emergency vehicle access).

A Flood Risk Evaluation Matrix was created and each of the flood vulnerable sites was evaluated to determine if there is currently a risk to this site and if there is an increase in flood risk to the site with the 2031 and 2051 development conditions. This process was used to rank sites in terms of flood risk and to identify areas where flood mitigation work is recommended. A summary of our analysis of the flood vulnerable sites and historic flooding sites from the 1989 Master Drainage Plan is included in **Table 5.5**. Flood vulnerable sites identified in this study are shown on **Drawing FLA-1** and **FLA-2**, located in **Appendix A**, a detailed evaluation of all flood vulnerable sites is included in **Appendix D**.

Table 5.5 – Historic Flooding and Flood Susceptible Sites identified in the 1989 Master Drainage Plan

Description		Risk	Event When Flooding Begins	Exceeds Emergency Vehicle Threshold	Change in Risk from Development	Notes
Historic Flooding Site						
#1	House and storage yard for shipping containers	Property is located in the floodplain	2-year event	2-year event	Possible increase in flood risk	There is no site plan available for this site
#2	Bridge under Rutherford Road West	Bridge designed for 100-year event	Regional	Regional	No increase in flood risk	Flood analysis does not include Block 61 ponds
#3	Bridge under Rutherford Road West	Bridge designed for 100-year event	Regional	Regional	No increase in flood risk	Flood analysis does not include Block 61 ponds
#4	Building Demolished					
Flood Susceptible Site						
#1	Woodbridge Foam Factory	Building located in floodplain	50-year event	100-year event	No increase in flood risk	There is no site plan available for this site
#2	Small horse barn	Building located in floodplain	25-year event	N/A, no driveway to building	No increase in flood risk	Frequency of flooding is reduced with development
#3	Same property as Historic Flooding Site #1					
#4	Removed from floodplain as part of re-grading for building expansion					
#5	Same as Historic Flooding Site #4					
#6	Small private pond and rear yard of house	Pond and yard are located in the floodplain	25-year event	N/A, no driveway flooding	Small increase in depth and area flooded (± 4% increase)	Increase in flooding does not increase risk to property
#7	Has been demolished as part of the Block 64 Development.					
#8	Buildings have been demolished.					
#9	Barn has been demolished.					
#10	Storage yard and small office building	Property is located in the floodplain	2-year event	50-year event	No increase in flood risk	There is no site plan available for this site
#11	Now the site of Consolidate Fastfrate, this tributary has been re-routed and the site re-graded.					

Based on our evaluation, the majority of the sites identified as flood susceptible sites do not require any flood remediation work. For most sites there is little or no increase in flood risk. For instance road crossings sized for the 100-year event which flood during a regional storm are designated as having an acceptable level of risk. Also sites where there is flooding that does not affect buildings or accessibility to emergency vehicles are deemed to have an acceptable level of risk. Figures 1 through 14 in **Appendix D** show the flood vulnerable sites with a higher level of risk or an increase in flooding; recommendations for these sites are as follows:

Flood Vulnerable Road 7 (FVR #7)

This is a culvert located under Highway 27, north of Langstaff Road. Under existing conditions this culvert, which is designed to pass runoff from a 100-year storm, floods during the regional event. The depth of flooding is under a foot which would allow access for emergency vehicles. Under the 2031 the flooding remains unchanged; however the 2051 development scenario results in a flooding depth of 0.36 m, which may prohibit emergency vehicle access. We recommend that this culvert be re-evaluated as part of the next Rainbow Creek Update Study.

Flood Vulnerable Road 14 (FVR #14), Flood Vulnerable Structure 24 (FVS #24)

This site was identified in the 1989 Master Drainage Plan as Flood Susceptible Site #3 and Historic Flooding Site #1. This site includes a house located south of a storage yard for shipping containers. The creek has been filled in and realigned; the entire property is located within the floodplain. This culvert conveys flows under McGillivray Road to the realigned Creek. This section of McGillivray Road is located in the floodplain and both the road and property begin flooding at the 2-year event. This section of road and the adjacent property becomes inaccessible to emergency vehicles during the 25-year event. Although there is little increase in flooding depth with development there is an increase in flows and velocity. This increase in velocity, along with the high frequency of flooding in this area, warrants further investigation. We recommend that a more detailed investigation, including a detailed survey of the site, road and adjacent section of Rainbow Creek, be completed in order to determine the best solution for the flooding on this site. Recommendations for this site could include:

- Flood proofing buildings on the site;
- Increasing the capacity of the realigned channel;
- Raising the road and increasing the culvert size; and,
- Building landforms to protect the buildings on this site.

It should be noted that this culvert is a few meters downstream of a culvert under raised CP railroad tracks. The raised railroad tracks act as a barrier and water is forced through the smaller culvert and over the road. There is visible damage to the road and to the channel downstream of this culvert and we recommend that this site be a priority for future work.

Flood Vulnerable Road 16 (FVR #16)

This culvert is located under Major Mackenzie Drive, west of the CP railway and south of Block 61. The increase in flow is due to the planned realignment of Rainbow Creek as part of the Block 61 development, which will increase the tributary drainage area to this culvert. Our analysis does not include the proposed SWM facilities for Block 61, which will provide some storage for the regional event. We recommend that this culvert be re-evaluated once the Block 61 design is approved.

Flood Vulnerable Road 24 (FVR #24)

This culvert is located under McGillivray Road, east of Huntington Road and south of Block 61. The increase in flow is due to the Block 61 development, which will increase the flows to this culvert. The flooding at this culvert is minor (4 cm – 6 cm), only occurring under 2031 and 2051 development conditions and does not affect accessibility for emergency vehicles. Our analysis does not include the proposed SWM facilities for Block 61, which will provide some storage for the regional event. We recommend that this culvert be re-evaluated once the Block 61 design is approved.

Flood Vulnerable Structure 1 (FVS #1)

This site, located at 7231 Martin Grove Road, consists of a Private Driveway and some barns and sheds. Our analysis shows that under existing conditions this site begins to flood during a 5-year event and becomes inaccessible to emergency vehicles during the 25-year event. Although there is no increase in flooding with the 2031 and 2051 events, the frequency of flooding under existing conditions should be addressed. We recommend that a more detailed investigation, including a detailed survey of the site, adjacent road and adjacent portion of Rainbow Creek, be completed in order to determine the best solution for the flooding on this site. Recommendations for this site could include:

- Flood proofing buildings on the site;
- Building landforms to protect the buildings on this site; and,
- Increasing the size of the driveway culvert.

Flood Vulnerable Structure 6 (FVS #6)

This site is the Woodbridge Foam factory located on Meeting House Road. This site was identified in the 1989 Master Plan as Flood Susceptible Site #1. Our analysis shows the building as being partially in the floodplain; however the contours from the DEM do not appear to match the site. There is no site plan available for this site. We recommend that a more detailed investigation, including a detailed survey of the site and adjacent section of Rainbow Creek, be completed in order to determine the best solution for the flooding on this site. Recommendations for this site could include:

- Flood proofing buildings on the site; and,
- Building landforms to protect the buildings on this site.

Flood Vulnerable Structure 7 (FVS #7)

This site includes 15 single family homes on the south end of Woodcroft Lane and Blossom Court. Under existing conditions the flooding occurs during the regional event and extends into the rear yards of 12 homes and the front yards of three (3) homes on Woodcroft Lane. Our analysis shows two (2) houses that will be impacted by flooding from rear yards. There is a small increase in flood depth due to development in the 2031 (1 cm) and 2051 (9 cm) scenarios.

It should be noted that the grades used in our analysis were based on design drawings from 1982, which were provided by the City in order to refine the DEM surface. These grades show the lots and homes were built bellow the current (TRCA, 2006) floodplain elevation of 166.51 m. These lots are privately owned and it is probable that some of the grading has been changed by the owners during the past 30 years.

It should also be noted that the floodplain elevation calculated for the 2051 scenario as part of this report is 166.39 m, which is lower than the current TRCA elevation of 166.51 m. Given the age of the topographic data used in this study and the nature of this development, we recommend that a more detailed investigation, including a detailed survey of the site and adjacent section of Rainbow Creek, be completed in order to determine the extent of the flooding and the best solution for the flooding on this site. This investigation should occur prior to the approval of the projected 2051 development. Recommendations for this site could include:

- Flood proofing homes impacted by rear yard flooding;
- Re-grading yards to take them out of the floodplain; and,
- Building landforms.

Flood Vulnerable Structure 8 (FVS #8)

This site includes nine (9) single family homes on the north end of Woodcroft Lane. Under existing conditions the flooding during the regional event extends into the rear yards of these homes, our analysis does not show any houses in this area that may be impacted by flooding from rear yards. There is a small increase in flood depth due to development in the 2031 (1 cm) and 2051 (10 cm) scenarios.

It should be noted that the grades used in our analysis were based on design drawings from 1982, which were provided by the City in order to refine the DEM surface. These grades show the lots and homes were built bellow the current (TRCA, 2006) floodplain elevation of 166.51 m. These lots are privately owned and it is probable that some of the grading has been changed by the Owners during the past 30 years.

It should also be noted that the floodplain elevation calculated for the 2051 scenario as part of this report is 166.57 m, which is lower than the current TRCA elevation of 166.84 m. Given the age of the topographic data used in this study and the nature of this development, we recommend that a more detailed investigation, including a detailed survey of the site and adjacent section of Rainbow Creek, be completed in order to determine the extent of the flooding and the best solution for the flooding on this site. This investigation should occur prior to the approval of the projected 2051 development. Recommendations for this site could include:

- Re-grading yards to take them out of the floodplain; and,
- Building landforms.

Flood Vulnerable Structure 13 (FVS #13)

This site is a small horse barn located at 9290 McGillivray Road and was identified in the 1989 Master Plan as Flood Susceptible Site #2. Under existing conditions the building begins to flood during the 25-year event and reaches a depth of 1.6 m during the regional event. There is a small increase (4 cm) in flood depth due to development in the 2031 and 2051 scenarios. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be Flood proofed to prevent damage from flooding.

Flood Vulnerable Structure 15 (FVS #15)

This site is a storage yard and small office located at 9441 Huntington Road, north of Rutherford Road and was identified in the 1989 Master Plan as Flood Susceptible Site #10. Under existing conditions the building begins to flood during the 2-year event, becomes inaccessible to emergency vehicles during the 25-year event, and reaches a depth of 0.8 m during the regional event. There is a slight decrease (2 cm) in flood depth due to development in the 2031 and 2051 scenarios. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be flood proofed to prevent damage from flooding.

Flood Vulnerable Structure 22 (FVS #22)

This site is 10 duplex lots located on the south side of Albany Drive. Under existing conditions flooding begins during the regional event and extends into the rear yards of these homes, our analysis shows one building that may be impacted by flooding from rear yards. There is a slight increase (3 cm) in flood depth due to development in the 2031 and 2051 scenarios. We recommend that a more detailed investigation, including a detailed survey of the site and adjacent section of Rainbow Creek, be completed in order to determine the best solution for the flooding on this site. Recommendations for this site could include:

- Flood proofing homes impacted by rear yard flooding;
- Re-grading yards to take them out of the floodplain; and,
- Building landforms.

Flood Vulnerable Structure 23 (FVS #23)

This site is a small shed or barn located at 10223 Highway 50, north of Major Mackenzie Drive. Under existing conditions the building begins to flood during the 100-year event and reaches a depth of 0.65 m during the regional event. There is a small increase (5 cm) in flood depth due to development in the 2031 and 2051 scenarios. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be flood proofed to prevent damage from flooding.

Flood Vulnerable Structure 26 (FVS #26)

This site is storage yard for shipping containers with a small office building or storage shed, located at 9751 McGillivray Road, north of Rutherford Road. This site is adjacent to the site identified as Flood Susceptible Site #3 and Historic Flooding Site #1 in the 1989 Master Plan. Under existing conditions the building begins to flood during the 50-year event, is inaccessible to Emergency vehicles during the 100-year event, and reaches a depth of 1.6 m during the regional event. There is a small increase (9 cm) in the regional flood depth due to development in the 2031 and 2051 scenarios but the frequency of flooding is reduced. We recommend that a more detailed investigation, including a detailed survey of the site, road and adjacent section of Rainbow Creek, be completed in order to determine the best solution for the flooding on this site. Recommendations for this site could include:

- Flood proofing building on the site;
- Increasing the capacity of the realigned channel;
- Raising the road and increasing the culvert size; and,
- Building landforms to protect the buildings on this site.

Flood Vulnerable Structure 28 (FVS #28)

This culvert is located under the CP rail tracks south of McGillivray Road, east of Huntington Road and south of Block 61. This site does not flood under existing conditions. The increase in flow is due to the Block 61 Development, which will increase the flows to this culvert. The flooding at this culvert is approximately 10 – 17 cm, only occurring under 2031 and 2051 development conditions and does not affect accessibility for emergency vehicles. Our analysis does not include the proposed SWM facilities for Block 61, which will provide some storage for the regional event. We recommend that this culvert be re-evaluated once the Block 61 design is approved.

5.4.1. Recommendations

Most of the recommendations made for flood vulnerable sites with a higher level of risk or an increase in flooding include a detailed survey to determine the extent of flooding. These studies are required because the DEM does not represent current grading in some areas of Rainbow Creek. We have updated the modeling surface with information provided by the City, but as built survey information was not available for all the sites and grading may have been changed on private properties. We have identified areas that appear to be at risk of flooding; however it is recommended that a study to determine the extent of the flood risk be completed for each of these sites prior to implementing solutions for flooding. **Table 5.6** below contains a summary of the recommendations and estimated costs for studies and flood remediation works, the locations of these recommended works are shown on **Figure-RW1** following the report.

Table 5.6 – Summary of Recommendations for Flood Vulnerable Sites

Site ID	Description	Risk	Recommendation	EA Schedule	Cost
FVR #7	Culvert under Highway 27, north of Langstaff Road	Flood depth for the regional event exceeds 0.30 m under the 2051 development scenario.	Culvert should be re-evaluated as part of the next Rainbow Creek update.	N/A	N/A
FVS #24	House and storage yard for shipping containers	Property is situated in the floodplain, flooding begins at 2-year event and exceeds 0.30 m for the 25 year event. There is little increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000
FVS #26	Storage yard for shipping containers with several small office buildings and storage sheds	Both road and property are situated in the floodplain, flooding begins at the 50-year event and reaches a depth of 1.6 m during the regional event. There is a small (9 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000

Site ID	Description	Risk	Recommendation	EA Schedule	Cost
FVR #14	Section of McGillivray Road	Road is situated in the floodplain, flooding begins at 2-year event and exceeds 0.30 m for the 25 year event. There is little increase in flooding for the 2031 or 2051 scenarios. There is visible damage to the road and channel due to frequent flooding.	Raise road and increase culvert size to match the capacity of the culvert under the railroad, which is a few meters upstream. Increase capacity of the downstream channel.	Schedule B	$480,000
FVS #1	Private Driveways, barns and sheds located at 7231 Martin Grove Road.	Under existing conditions the site begins to flood during a 5-year event and exceeds 0.30 m for the 25-year event. There is no increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000
FVS #6	Woodbridge Foam Factory located on Meeting House Road	Under existing conditions the site begins to flood during a 50 year event and exceeds the threshold for emergency vehicle access at the 100 year event. There is no increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000
FVR #16	Culvert under Major Mackenzie Drive, west of CP Rail and south of Block 61	Modeling shows no flooding in this area under existing conditions and flooding during the regional storm for the 2031 and 2051 scenarios. The flooding appears to be due to increased flows from the development of Block 61. The development plan for Block 61 includes ponds with some additional storage for regional control; these ponds were not included in the model.	Add the ponds with regional storage for Block 61 to the model once they have been approved.	N/A	$23,000
FVR #24	Culvert under McGillivray Road, east of Huntington Road and south of Block 61		Detailed survey of the culverts, road and adjacent sections of Rainbow Creek.		
FVS #28	Culvert under the CP Rail track, east of Huntington Road and downstream of FVR #16 and FVR #24		Update model and flood mapping to determine the frequency and extent of flooding.		

Site ID	Description	Risk	Recommendation	EA Schedule	Cost
FVS #7	This site includes 15 single family homes on the south end of Woodcroft Lane and Blossom Court.	Under existing conditions the lots begins to flood during the regional event and two (2) buildings are impacted by flooding. There is a small (9 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$12,000
FVS #8	This site includes nine (9) single family homes on the north end of Woodcroft Lane	Under existing conditions the lots begins to flood during the regional event. There is a small (10 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000
FVS #13	Small horse barn located at 9290 McGillivray Road	Under existing conditions the buildings begin to flood during the 25-year event and flooding reaches a depth of 1.6 m during the regional event. There is a small (4 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to verify the frequency, depth and extent of flooding. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be Flood proofed to prevent damage from flooding.	N/A	$16,000
FVS #15	Storage Yard and Small office located at 9441 Huntington Road	Under existing conditions the buildings begin to flood during the 2-year event and flooding reaches a depth of 0.8 m during the regional event. There is a small (2 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to verify the frequency, depth and extent of flooding. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be Flood proofed to prevent damage from flooding.	N/A	$16,000

Site ID	Description	Risk	Recommendation	EA Schedule	Cost
FVS #22	This site includes 10 duplex lots on the south side of Albany Drive	Under existing conditions the lots begins to flood during the regional event and one house is impacted by flooding. There is a small (3 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to determine the frequency and extent of flooding.	N/A	$10,000
FVS #23	Small shed or barn located at 10223 Highway 50, north of Major Mackenzie Drive	Under existing conditions the buildings begin to flood during the 100-year event and flooding reaches a depth of 0.65 m during the regional event. There is a small (5 cm) increase in flooding for the 2031 or 2051 scenarios.	Detailed survey of the site, road and adjacent section of Rainbow Creek. Update model and flood mapping to verify the frequency, depth and extent of flooding. With this structure being located well into the floodplain there are no practical solutions for preventing flooding. It is recommended that the building be Flood proofed to prevent damage from flooding.		$16,000

Note: FVR = Flood Vulnerable Road; FVS = Flood Vulnerable Structure

5.5. Erosion Control – Continuous Modeling

The Water's Edge Environmental Solutions Team determined the erosion thresholds for Rainbow Creek downstream of proposed pond locations, as shown of **Figure RC-5** following the report. These thresholds represent the minimum flow at which erosion will begin to occur. As erosion is a gradual process that is associated with the more frequent lower intensity storms continuous modeling is used for this analysis. The Rainbow Creek PCSWMM model was run using 33 years of rainfall data from the Toronto Lester B. Pearson International Airport weather station. For each of these sites we recorded the duration of time that flows in Rainbow Creek exceeded the erosion threshold. This analysis was then repeated for the 2031 scenario with different erosion mitigation strategies, to determine the most effective criteria to use for erosion controls. This analysis included the following controls:

- Baseline condition;
- 24-hour drawdown of runoff from a 25 mm storm;
- 48-hour drawdown of runoff from a 25 mm storm;
- 72-hour drawdown of runoff from a 25 mm storm;
- Onsite retention of the first 5 mm of rainfall for each event;
- Onsite retention of the first 10 mm of rainfall for each event; and,
- Onsite retention of the first 5 mm of rainfall for each event with 24-hour drawdown of runoff from a 25 mm event.

The results of this analysis are presented graphically for each erosion site as shown in **Figure 5-1** through **Figure 5-11.**

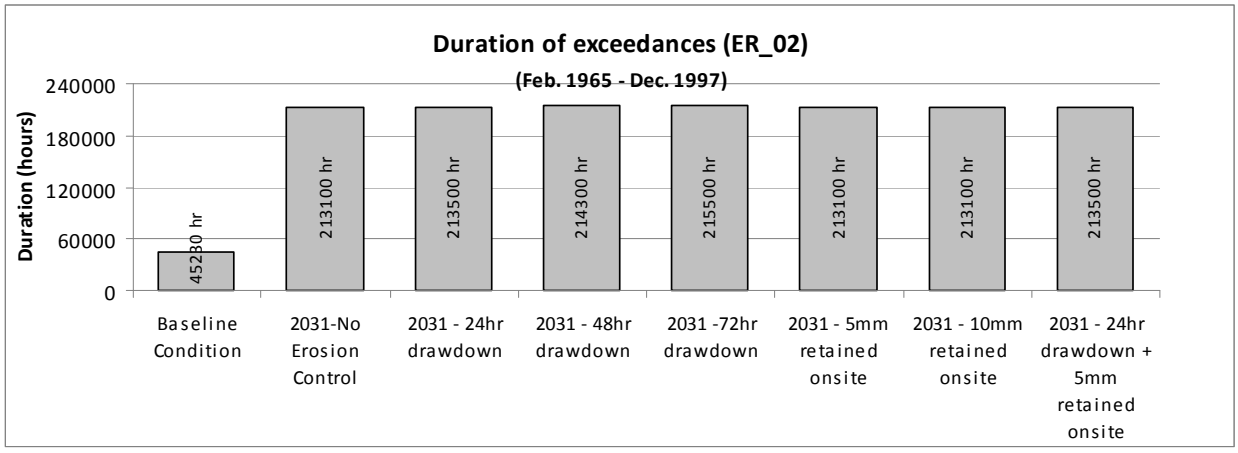


Figure 5-1 Erosion Threshold Site 02

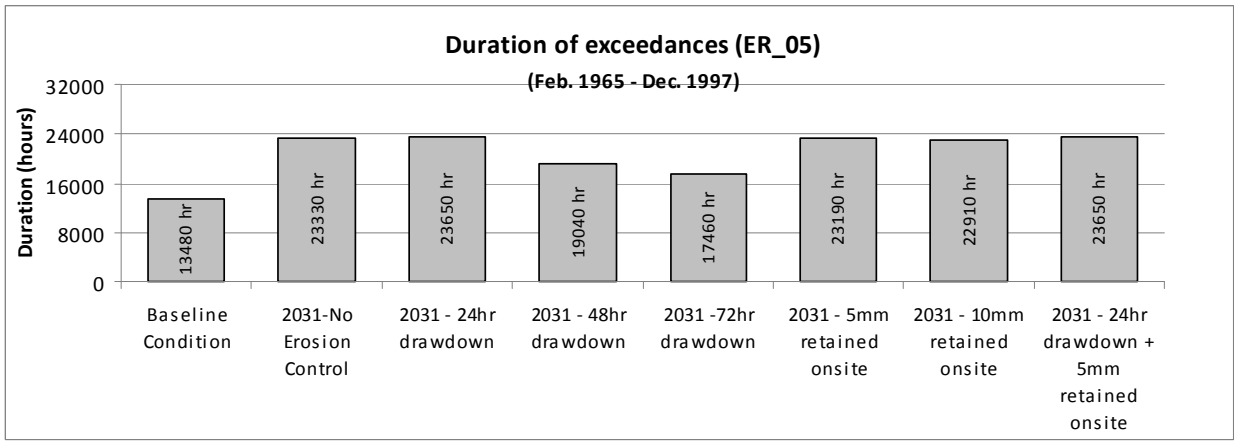


Figure 5-2 Erosion Threshold Site 05

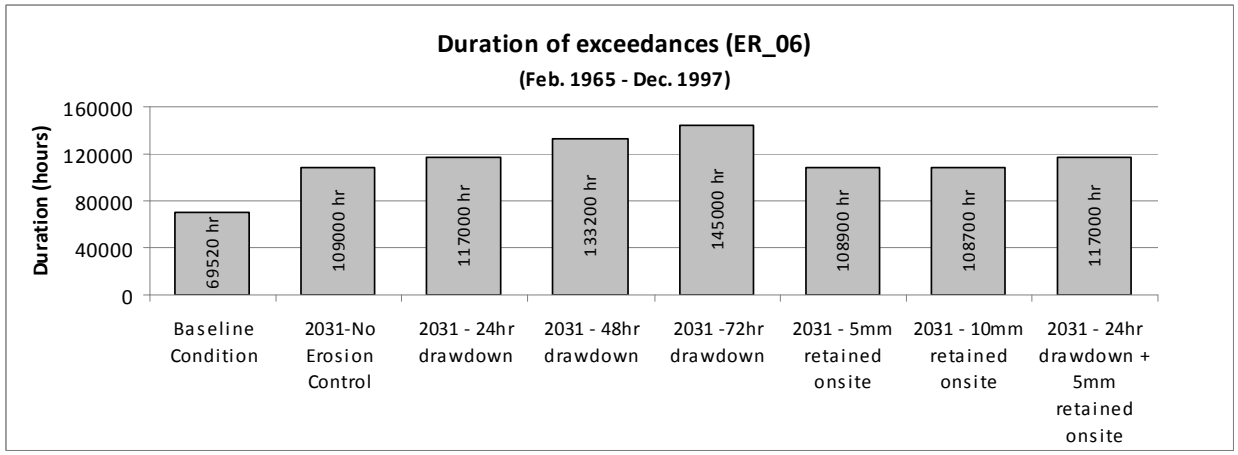


Figure 5-3 Erosion Threshold Site 06

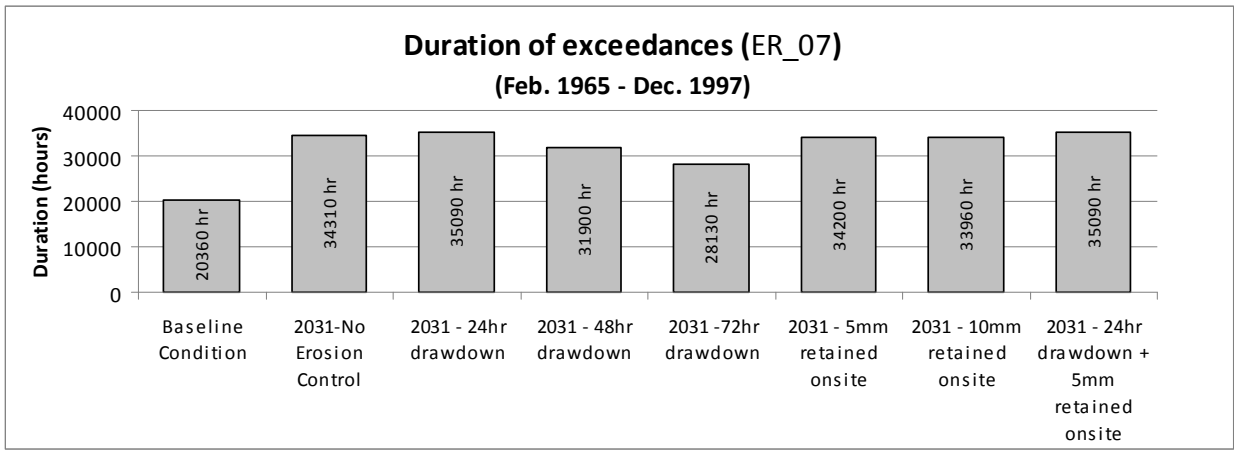


Figure 5-4 Erosion Threshold Site 07

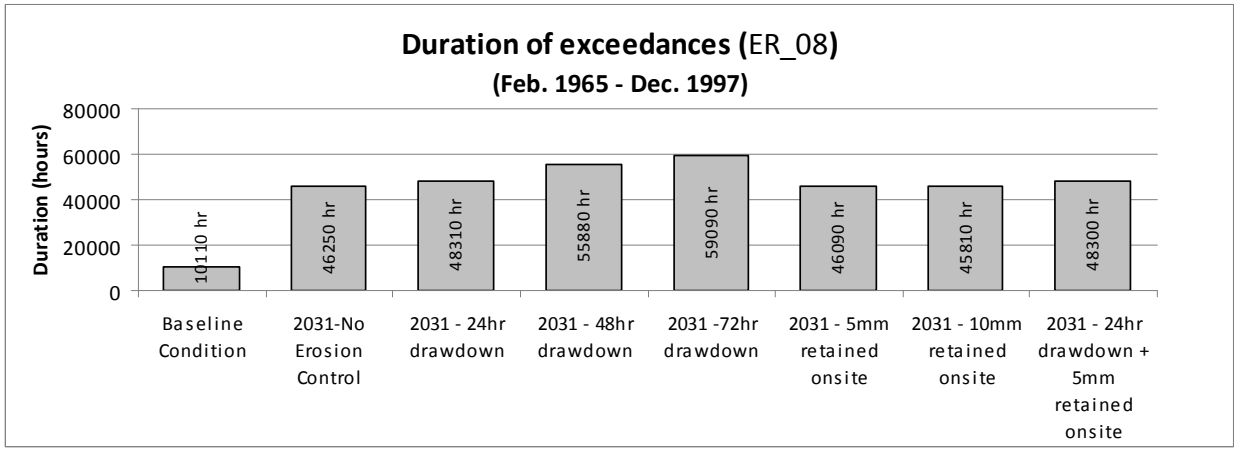


Figure 5-5 Erosion Threshold Site 08

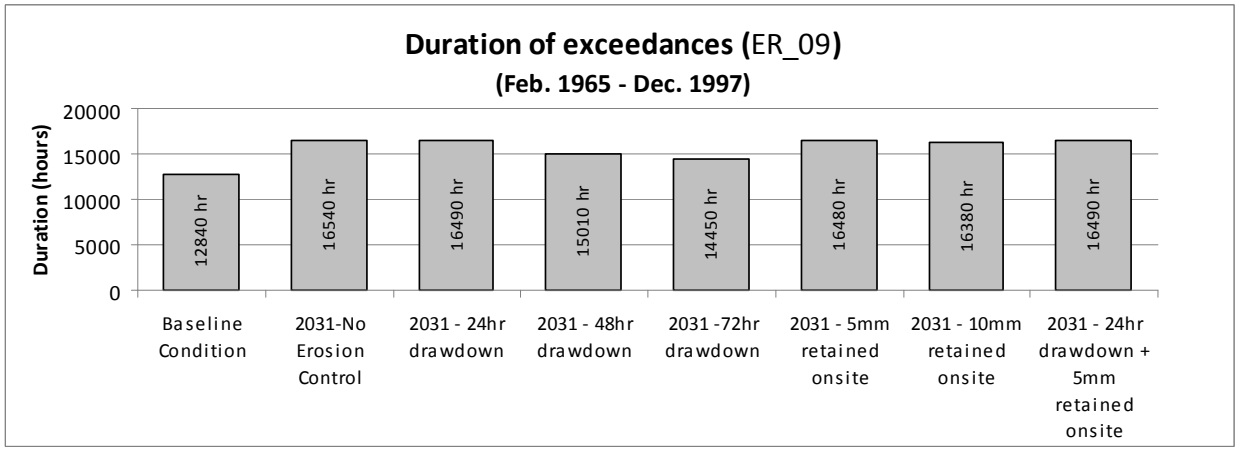


Figure 5-6 Erosion Threshold Site 09

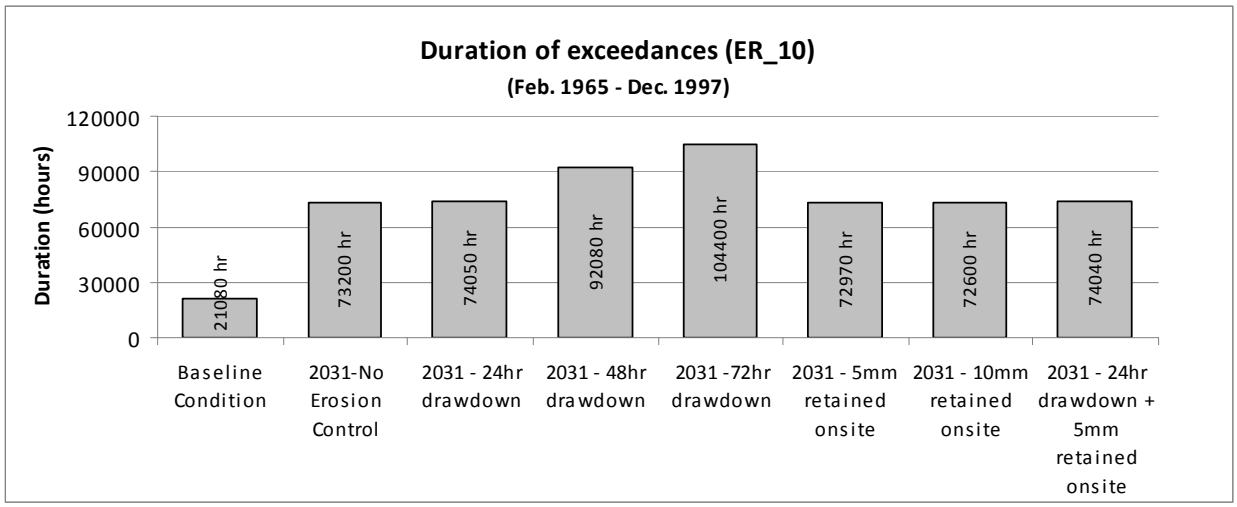


Figure 5-7 Erosion Threshold Site 10

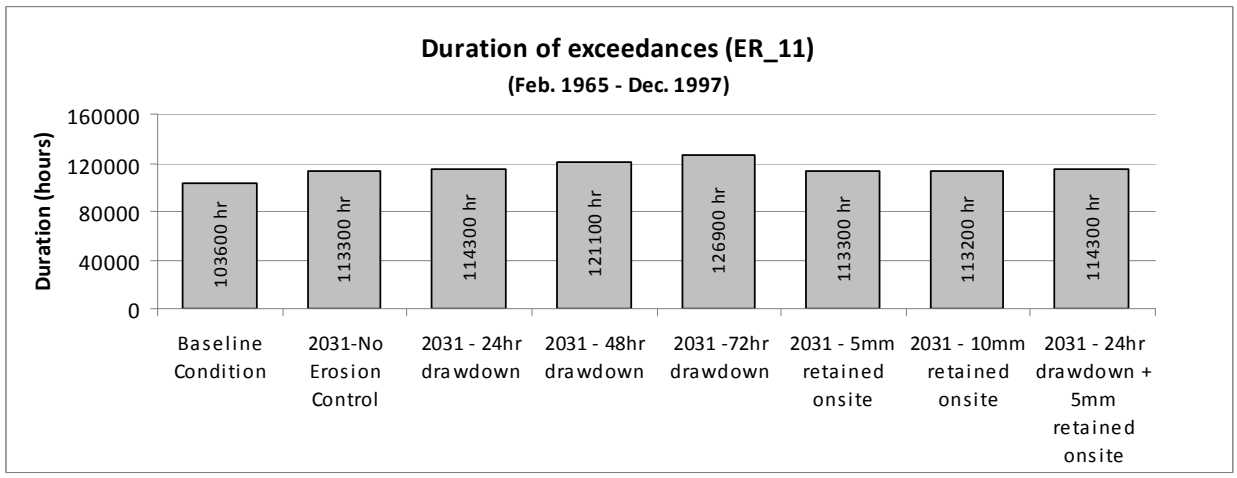


Figure 5-8 Erosion Threshold Site 11

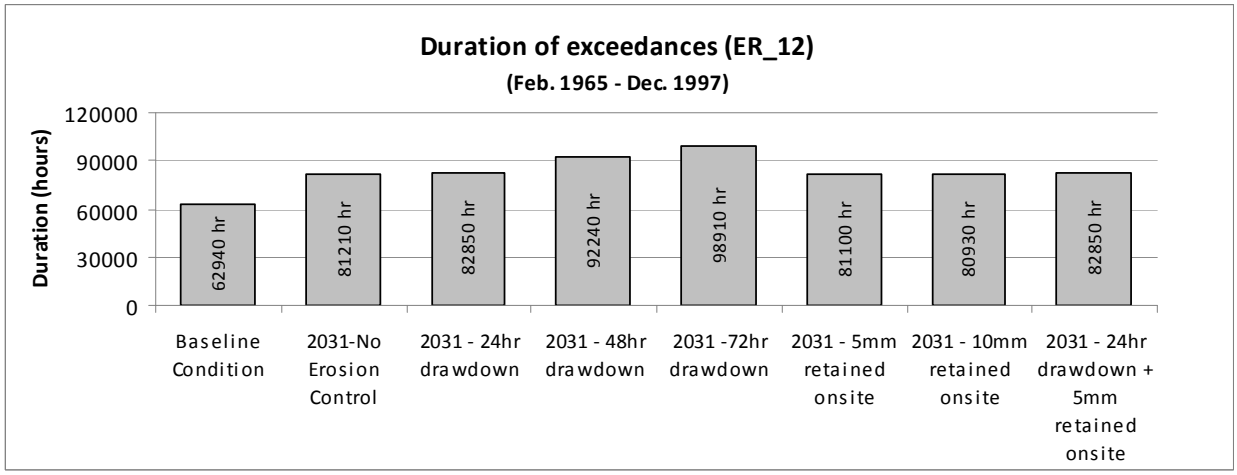


Figure 5-9 Erosion Threshold Site 12

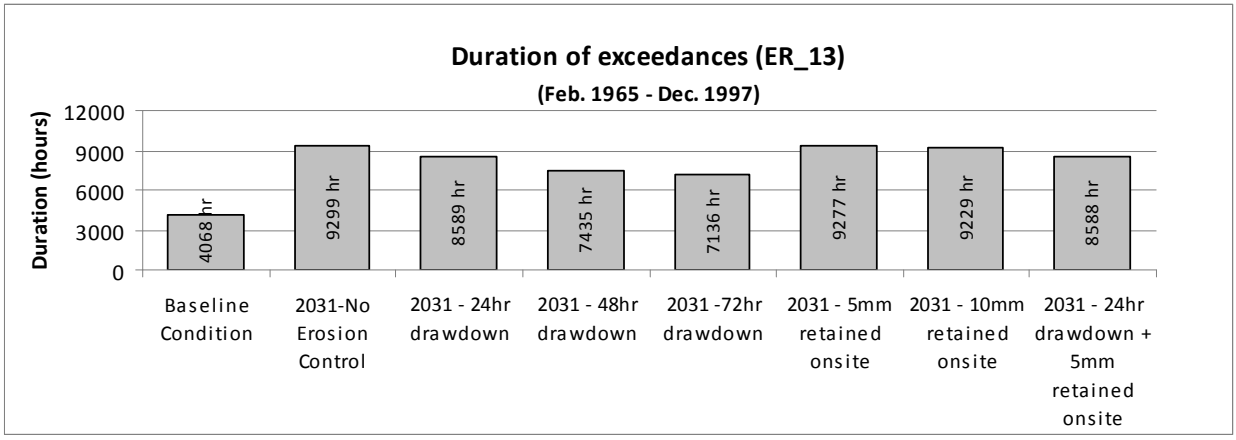


Figure 5-10 Erosion Threshold Site 13

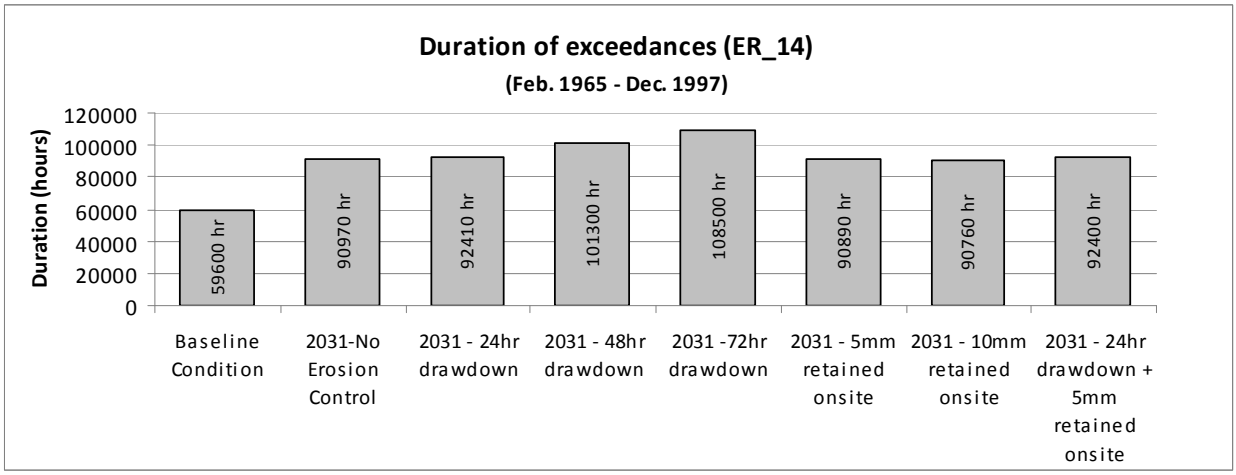


Figure 5-11 Erosion Threshold Site 14

These results show that in general the most beneficial erosion control criteria is the on-site retention of the first 10 mm of rainfall. Although this does not reduce the duration of erosive flows to pre-development levels it does provide the greatest overall reduction in the duration of erosive flows. Given the low erosion thresholds in much of the Creek, it is not possible to reduce duration of post-development erosive flows to pre-development levels. It was also found that in many areas that using a 24, 48 or 72-hour drawdown time for the first 25 mm of rainfall would lengthen the time that erosive flows were present in the Creek. This occurs when the erosion threshold in the Creek is low, so the release rate required to achieve a longer drawdown time is still greater then the erosion threshold. In these cases the longer draw down time results in a longer period with erosive flows. The on-site retention of 5 mm of rainfall provides a reduction of erosive flows that is almost equal to that achieved through the on-site retention of 10 mm. Given the difference in cost and the minimal benefit in terms of reducing hours of erosive flows it is recommended that 5 mm onsite retention be the criteria for erosion control in Rainbow Creek.

5.6. Evaluation of Erosion Sites

As part of the 1989 Rainbow Creek Master Plan (Cosburn Patterson Wardman Limited, December 1989) areas with existing erosion and erosion scars were identified. Although it was shown at that time that there was erosion in Rainbow Creek, the consultants felt that with the available modeling software they could not define criteria that would protect Rainbow Creek from increased erosion due to development. The report states "the technology to determine impacts of urban drainage on watercourse erosion is currently being developed and therefore remains untested". The report recommended establishing an erosion levee on future development to address future and existing erosion problems.

For the erosion analysis in Rainbow Creek Water's Edge Environmental Solutions Team (Water's Edge) was hired to evaluate risk from erosion at the 40 sites identified in the previous master Plan. As part of their study Water's Edge examined each reach of Rainbow Creek using current and historical aerial photographs. Various reaches were then walked during site inspections which took place in the winter and spring of 2012, with the intent of identifying critical zones. A more detailed analysis was completed for reaches where storm water management facilities are being considered.

In general Rainbow Creek and its Tributaries have stable and well vegetated banks which are not prone to erosion. However erosion scars were noted in some areas and Water's Edge has identified nine (9) locations where it is recommended that existing erosion problems be monitored or addressed. These locations are as follows:

Main 1: This reach of Rainbow Creek is located between the confluence of the East Humber River and Highway 407. Erosion is occurring under the Highway 407 bridge (**Photograph B1** in **Appendix E**), immediately downstream of the Highway 407 bridge (**Photograph B2** in **Appendix E**) and adjacent to the Highway 407 embankment (**Photograph B3** in **Appendix E**). The erosion under the bridge appears to be caused in part by some geotextile material that is no longer held in place. As erosion in this area has the potential of impacting Highway 407 we recommend that the existing erosion protection installation be repaired. We also recommend that a more detailed hydraulic analysis be conducted at this site to determine the extent of erosion protection required downstream of the bridge and along the Highway embankment.

Main 2: This reach of Rainbow Creek is located upstream of Highway 407 and downstream of regional Road 7. There is ongoing erosion at many of the outside bends (**Photograph B4** in **Appendix E** illustrates a typical outside bend erosion location) however the floodplain for this reach is broad so the impact of this type of erosion is minimal. There is existing toe protection behind some residential units along this reach which should be monitored (**Photograph B5** in **Appendix E**). Downstream of this toe protection is a sanitary crossing with terrafix bank protection (**Photograph B6** in **Appendix E**). The terrafix protection appears to have failed at the sanitary crossing and we recommend that it be repaired or replaced.

West 1: This is a relatively long reach between Langstaff Road and the upper reach of Main 3. Most of this reach is relatively stable and well vegetated. There is a high eroding bank that contributes excess sediment to the stream (**Photograph B7** in **Appendix E**). We recommend that the eroding bank be re-vegetated and monitored until the vegetation is established and the bank is no longer showing signs of eroding.

West 2: This reach is located between Langstaff Road and the forested area located to the north of Langstaff Road. There is erosion at the upper end of this reach where the channel is actively migrating and causing bank erosion (**Photograph B8** in **Appendix E**). There is an old beaver dam in this area which is also contributing to local bank erosion (**Photograph B9** in **Appendix E**). As this area is currently undeveloped the erosion is not causing any problems, however once this site is developed we recommend that the Beaver dam should be removed and the banks should be stabilised.

West 3: This reach is located north of Reach West 2, and is bordered by undeveloped land. Erosion is accruing at various locations within this reach, primarily at the outside bends (**Photograph B10** in **Appendix E**). As this reach is located on undeveloped land the erosion does not need to be addressed at this time. We recommend that a more detailed analysis of this site be carried out when the surrounding properties are developed.

East 1: East 1 is located between Langstaff Road and Reach Main 3. The lands surrounding this reach are a combination of residential and industrial sites. This reach is eroding in many locations, primarily at outside bends (**Photographs B11** and **B12** in **Appendix E**) and at the old weir located downstream of Woodbridge Avenue. We recommend toe protection be installed at outside bends and bank stabilization at the old weir. Water's Edge noted that a contributing factor to erosion along this reach is pedestrian traffic. We recommend that a pedestrian path be installed to allow for foot traffic without further damaging the stream banks. We also recommend that signs be posted in areas where foot traffic is causing erosion in order to educate the public on the effect of pedestrian traffic on stream bank erosion.

East 4: This reach is located in farm fields to south of Rutherford Road, west of Highway 27. This section of channel is predominantly covered with gravel, cobles and some sand. This reach has erosion locations primarily at outside bends (**Photograph B13** in **Appendix E**). We are not recommending any remediation work at his time as the adjacent lands are agricultural and the impact of the erosion will be minimal. We recommend that once this area is developed the banks should be re-vegetated and stabilised where required.

East 5: This tributary starts at Reach East 4 and continues under Rutherford Road to just west of McGillivray Road. This reach is relatively stable and the banks are well vegetated with large trees and grasses. There are a few minor erosion locations in this reach, primarily at outside bends (**Photograph B14** in **Appendix E**). As with Reach East 4 we are not recommending any remediation work at his time as the adjacent lands are agricultural and the impact of the erosion will be minimal. We recommend that once this area is developed the banks should be re-vegetated and stabilised where required.

East 8: This reach begins east of Huntington Road and continues downstream to the forest area of Reach East 7. This reach is located on agricultural land and is used for watering cattle. The presence of cattle has along the banks of this reach has caused bank instability (**Photograph in B15** in **Appendix E**). There is a large online pond in this reach (**Photograph B17** in **Appendix E**) and the outlet of this pond is also creating some erosion issues. We recommend that the banks of this reach be stabilised when the surrounding lands are developed. We also recommend that an analysis of the online pond and its outlet be completed at that time to determine the extent of erosion protection that would be required to mitigate the damage to the banks from the pond outlet.

5.6.1. Recommendations

Most of the recommendations made for sites with existing erosion problems include a detailed hydraulic analysis to determine the extent of the erosion works required. This level of analysis is outside the scope of this study and is required in order to determine the scope of erosion works required at each site. The areas discussed were identified by Water's Edge as being most likely to cause problems for existing infrastructure and future development and areas contributing excess sediment to Rainbow Creek. **Table 5.7** contains a summary of the recommendations and estimated costs for studies and erosion remediation works, the locations of these recommended works are shown on **Figure-RW2** following the report.

Table 5.7 – Summary of Recommendations for Sites with Erosion Problems

Reach ID	Location	Risk	Recommendation	EA Schedule	Cost
Main 1	Between the confluence of the East Humber River and Highway 407.	Erosion occurring under Highway 407 bridge and adjacent to the Highway 407 embankment.	Repair existing erosion protection installation.	Schedule B	$205,000
Main 2	Upstream of Highway 407 and downstream of Regional Road 7.	Terrafix protection has failed at a sanitary crossing downstream of the existing toe protection.	Monitor toe protection behind residential units.	N/A	$10,0000
			Repair existing terrafix installation.	Schedule B	$176,600
West 1	Between Langstaff Road and the upper reach of Main 3.	High eroding bank upstream of Highway 27 is contributing excess sediment to the stream.	Cut bank back to a more gentle slope and install toe protection.	Schedule B	$88,500
			Re-vegetate eroding bank and monitor site until vegetation is well established.		
West 2	Between Langstaff Road and the forested area to the north of Langstaff Road.	Old beaver dam is causing local erosion issues. Downstream of the dam the channel is actively migrating and causing bank erosion.	The old beaver dam should be removed if it has been abandoned and the surrounding area should be cleaned up.	Schedule B	Work to be undertaken as part of the Block 59 development
			Erosion along this reach should be addressed as part of the Block 59 development.		

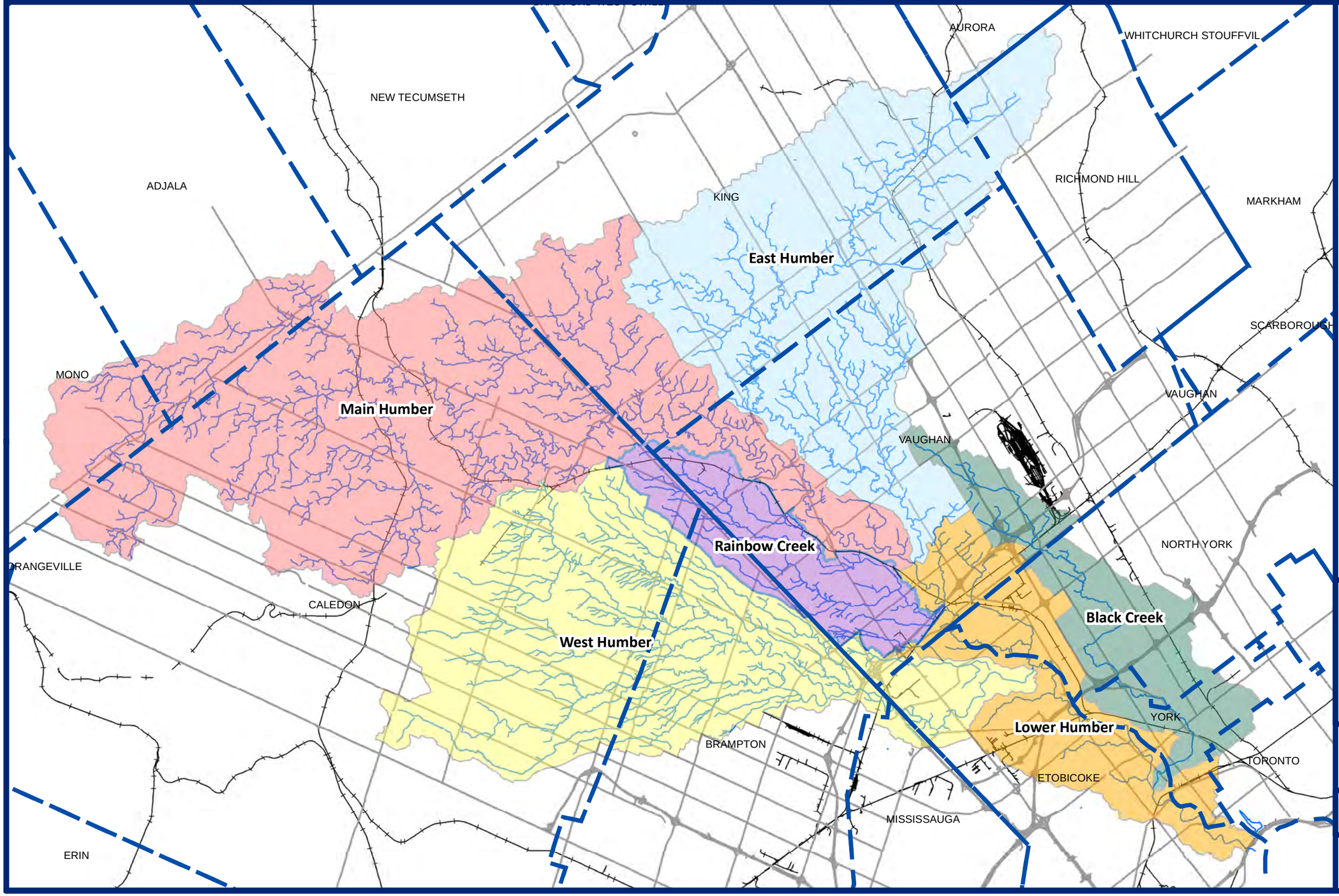
Reach ID	Location	Risk	Recommendation	EA Schedule	Cost
West 3	Between the confluence of the East Humber River and Highway 407.	Erosion is occurring at various locations within the reach, primarily at outside bends	Erosion along this reach should be addressed as part of the Block 59 development.	Schedule B	Work to be undertaken as part of the Block 59 development
East 1	Between Langstaff Road and reach M3, upstream of the confluence with the west branch.	Erosion at several locations due to a narrow corridor, moderate channel entrenchment and pedestrian traffic. Bank erosion is also occurring at the old weir downstream of Woodbridge Avenue.	Toe protection at outside bends. Bank stabilization around the weir. Install a pedestrian path and signs to educated the public on foot traffic causing erosion.	Schedule B	$1,605,000

6.0 Conclusions and Recommendations

Based on the hydrologic analysis of the rainbow creek sub-watershed and observations of the updated hydrologic modelling, it is suggested that:

- **Quantity Control**: SWM facilities designed to control flows to unit flow rates will result in post development flows which are less than or equal to pre-development levels within Rainbow Creek for storm events ranging from the 2-year to the 100-year event;
- Block 61 ponds should be updated in the model once the design has been finalized to verify that they are not causing an increase in flows downstream of the site;
- **Regional Controls**: It is recommended that no regional controls be required for developments within the Vaughan portion of the Rainbow Creek Subwatershed;
- More detailed analysis of the Brampton portion of the Rainbow Creek Subwatershed prior to making recommendations regarding regional controls for Brampton;
- Once Complete the recommendations of the TRCA's Humber River Watershed Update may have to be incorporated along with the recommendations of this study;
- **Erosion Control**: Due to the low erosion thresholds for Rainbow Creek, the recommended erosion criteria for future developments is to retain the first 5 mm of runoff on-site. This criteria results in a reduction of the duration of the low flow events which contribute to erosion in Rainbow Creek. No extended detention is required to mitigate erosion as our analysis shows that extended detention within the Rainbow Creek Subwatershed will increase the duration of erosive flows in the creek.
- **Flood Susceptible Sites**: The recommended studies and mitigation work listed in **Section 5.4** should be completed as funds become available.
- **Erosion Sites**: The recommended studies and mitigation work listed in **Section 5.6** should be completed as funds become available.

Humber Location Plan



Legend

Humber River Watershed

Subwatersheds

- Main Humber
- Lower Humber
- West Humber
- Black Creek
- East Humber
- Rainbow Creek
- Watercourse
- Railraod
- Roads
- Municipal Boundary

Humber River watershed information was taken from:

- Hydrologic Study of Impacts on Flood Flows and Mitigation of Future Development in the Humber River – AMEC Environment and Infrastructure, June 2012 (Draft)

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Location Map

SCALE 1:175,000
0 625 1,250 2,500 3,750 5,000 Meters

FIGURE
RC-1

Existing Conditions

Legend

- Rainbow Creek Drainage Boundary
- Municipal Boundary

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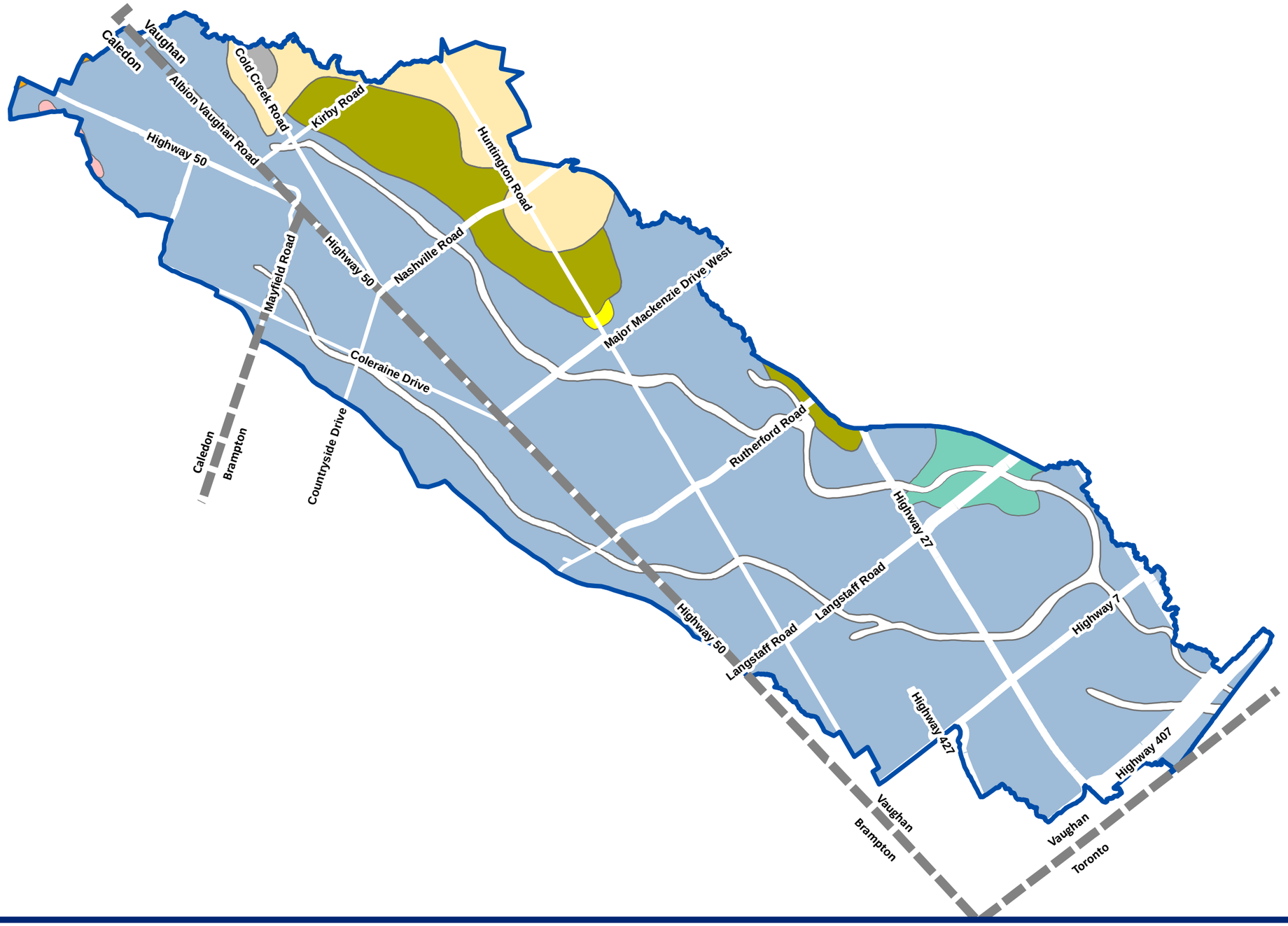
Existing Conditions Map

SCALE 1:50,000
0 170 340 680 1,020 1,360 Meters

FIGURE
RC-2

Soil Classification



Legend

Rainbow Creek Drainage Boundary

Municipal Boundary

Soil Classification

- Berrien Sandy Loam
- Brighton Sandy Loam
- Cashel Clay
- Fox Sandy Loam
- Muck
- Malton
- Monoghan Clay Loam
- Peel Clay

Soils information was taken from:

- The Soil Survey of York County, Report No. 19 of the Ontario soil Survey, Agriculture Canada – Research Branch in conjunction with the Ontario Ministry of Agriculture and Food, 1955
- The Soil Survey of Peel County, Report No. 18 of the Ontario soil Survey, Agriculture Canada – Research Branch in conjunction with the Ontario Ministry of Agriculture and Food, 1953

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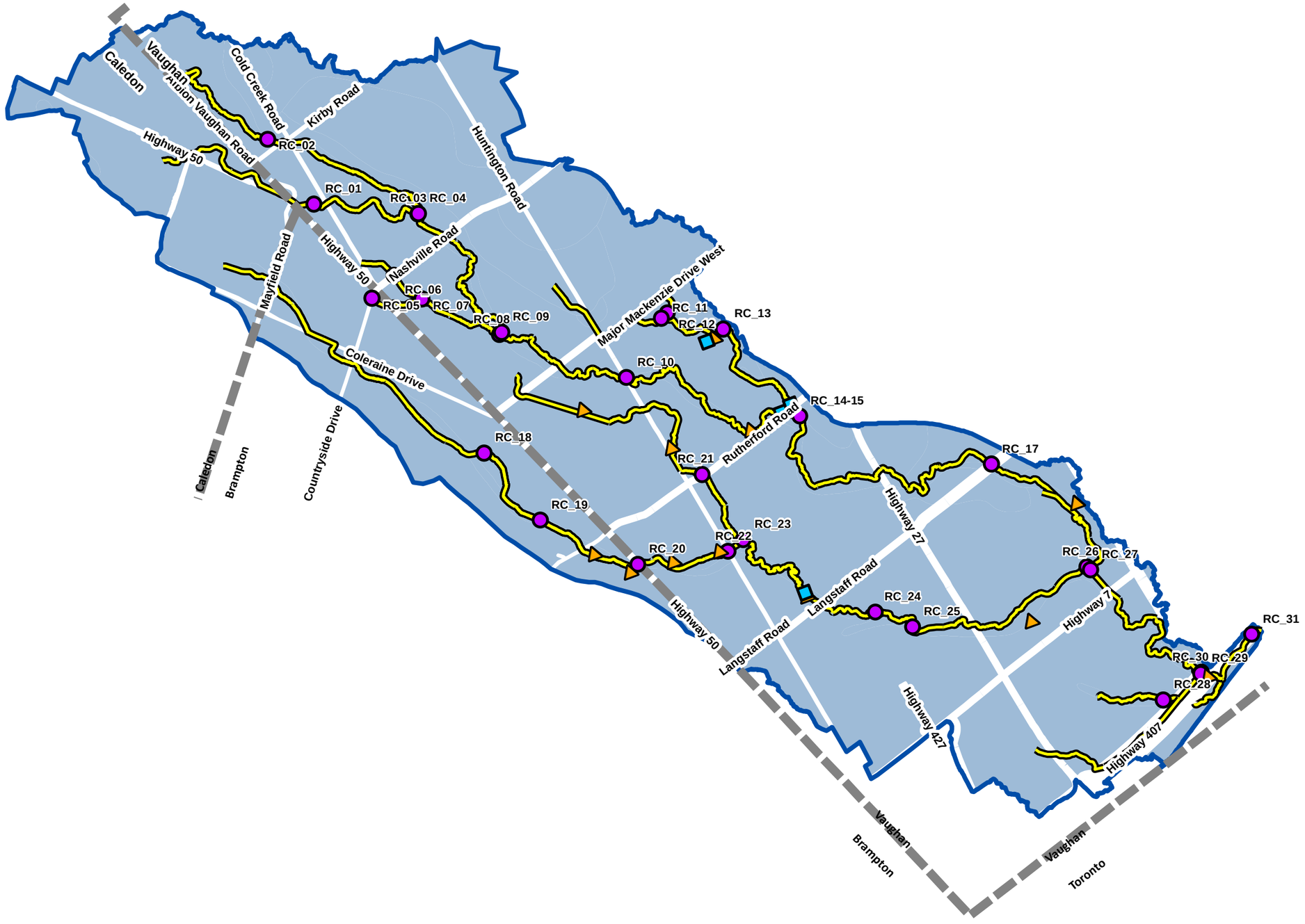
Soil Classification Map

SCALE 1:50,000
0 170 340 680 1,020 1,360 Meters

FIGURE
RC-3

Flood Susceptible and Historic Flooding Areas



Legend

- Rainbow Creek Drainage Boundary
- Municipal Boundary
- Historic Flooding Location
- Susceptible Flooding Location
- Flow Node From Regulatory HEC-RAS Model
- Channel (Creek)

Note: Historic flooding locations and susceptible flooding locations shown were taken from the Rainbow Creek, Master Drainage Plan, Town of Vaughan – Cosburn, Patterson, Wardman Limited Consulting Engineers, December 1989

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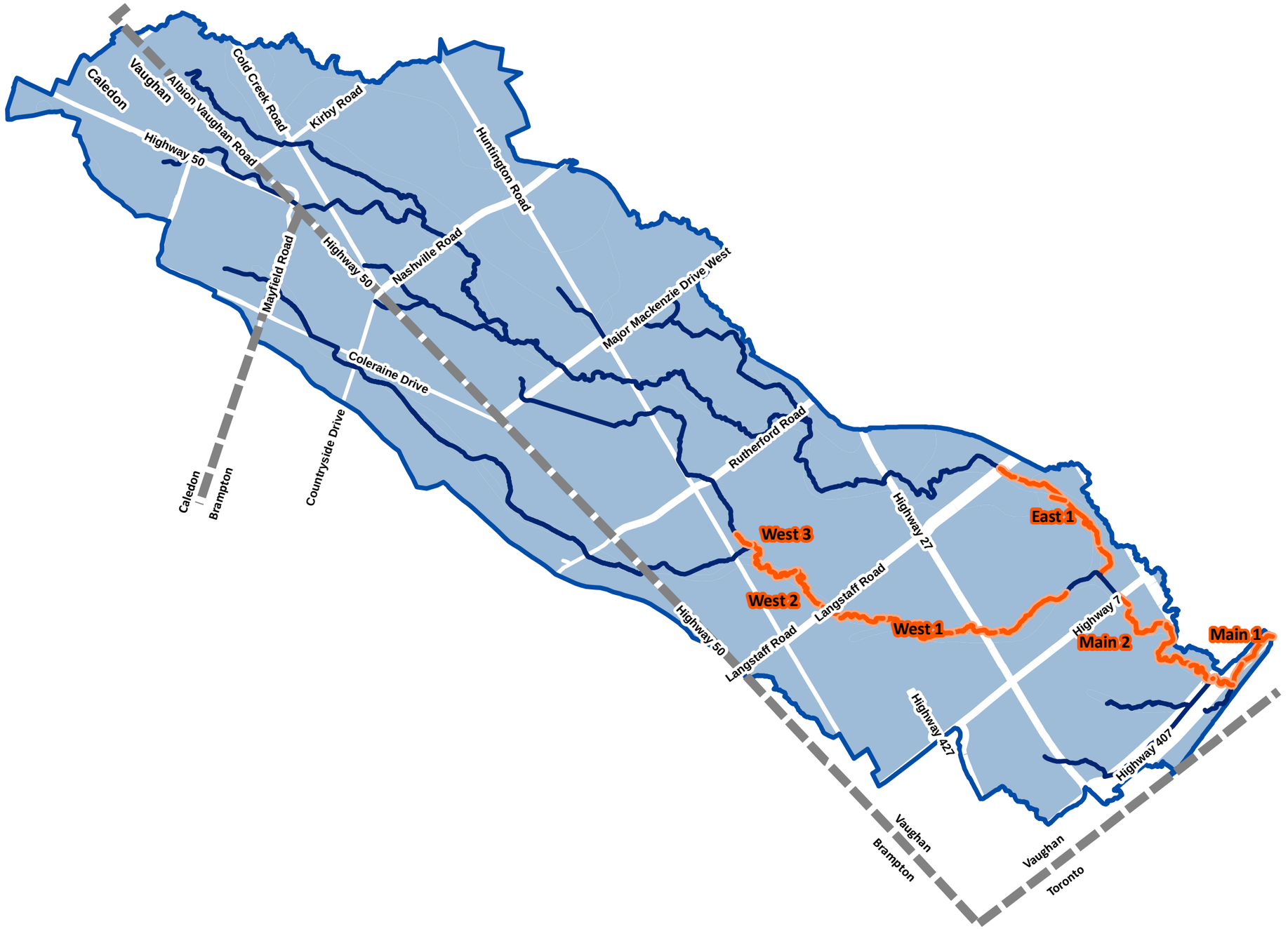
Flood Susceptible and Historic Flooding Areas Map

SCALE 1:50,000
0 175 350 700 1,050 1,400 Meters

FIGURE
RC-4

Recommended Erosion Works



Legend

- Rainbow Creek Drainage Boundary
- Municipal Boundary
- Rainbow Creek
- Recommended Works

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November 2013

Locations of Recommended Erosion Works

SCALE 1:50,000

0 175 350 700 1,050 1,400 Meters

FIGURE
RW-1

Recommended Flood Works

Legend

- Rainbow Creek Drainage Boundary
- Municipal Boundary

Recommended Flood Works

- Flood Vulnerable Roads
- Flood Vulnerable Sites

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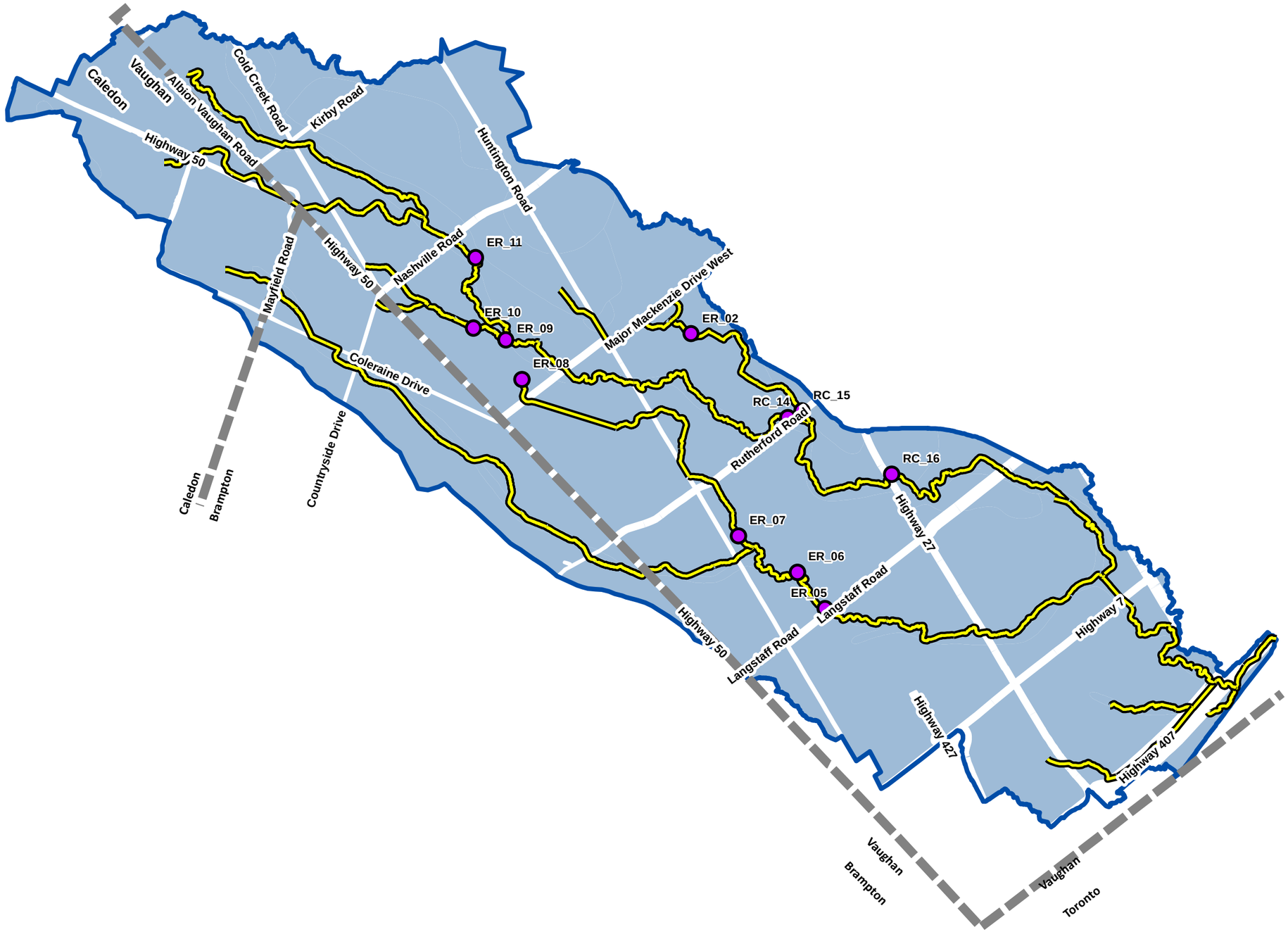
Locations of Recommended Flood Works

SCALE 1:50,000
0 175 350 700 1,050 1,400 Meters

FIGURE
RW-1

Erosion Threshold Locations



Legend

- Rainbow Creek Drainage Boundary
- Municipal Boundary
- Erosion Threshold Locations
- Channel (Creek)

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Erosion Threshold Location

SCALE 1:50,000
0 175 350 700 1,050 1,400 Meters

FIGURE
RC-5