CITY OF STRATFORD

STRATFORD WEST
SECONDARY PLAN

ROADHOUSE DRAIN MASTER DRAINAGE PLAN

DRAFT REPORT

MCCORMICK RANKIN CORPORATION
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1.0 INTRODUCTION

1.1 Purpose

McCormick Rankin Corporation (MRC) has prepared this Master Drainage Plan for the Roadhouse Drain in conjunction with the West Secondary Planning Study for the City of Stratford (City). The limits of the study area for the West Secondary Plan are presented on Exhibit 1. The study area of the Master Drainage Plan extends beyond the limits of the West Secondary Plan area to include external areas that are tributary to the Roadhouse Drain as shown on Exhibit 2. The north portion of the Secondary Planning area drains to the McNamara Drain and Court Drain, which are not covered by this Master Drainage Plan (addressed under separate cover). The south portion of the Secondary Planning area lands drain to the Roadhouse Drain, which flows through the City and ultimately to the Avon River.

Previous studies provided selective information pertaining to the Roadhouse Drain, including floodline mapping for a portion of the Drain. The purpose of the Master Drainage Plan is to provide a comprehensive understanding of the hydrologic and hydraulic aspects of the Roadhouse Drain, an understanding of the system as a whole, to establish the flood plain limits, to develop a storm water management strategy for future developments, to evaluate flood plain management alternatives, and to provide implementation recommendations.

As part of the Master Drainage Plan, refinements were made to previous hydrologic modelling which generated additional flow values along the entire reach of the Roadhouse Drain. The existing floodline mapping was extended from the upstream limit of the study area to the downstream limit of the study area, based on the updated and additional flow values.

Based on the updated floodlines, Roadhouse Drain flood plain management alternatives were developed and evaluated based on a number of environmental, socio-economic, and storm water management factors. This Master Drainage Plan also identifies appropriate storm water management criteria for future developments and locations and conceptual designs for future storm water management facilities to protect the Drain and existing developments.

1.2 Background Information

Relevant background information was collected and reviewed to assist in developing a thorough understanding of the Roadhouse Drain and tributary lands. The following information was examined:

- 1:10,000 Ontario Base Maps;
- 1 m contour interval topographic maps from the City;
- Aerial photography;
- City storm sewer layout and storm sewer subcatchment areas;
- Report No. 15 of the Ontario Soil Survey, *The Soils of Perth County* (1952);
- City of Stratford Roadhouse Drain Drainage Report (Proctor & Redfern Limited, 1977);
- Roadhouse Drain Reports, (K. Smart Associates, 1978, Revised 1979 and 1982);

- Douglas Street Subdivision Storm Water Management Report (Johnson Engineering Consultants, 1998, Revised 1999);
- Court Drain Subwatershed Plan Study (Phases 1 to 5) (Aquafor Beech Limited, 2002);
- Jenann Subdivision Stormwater Management Report (Johnson Engineering, 2003); and
- City of Stratford City Wide Storm System Master Plan (Dillon Consulting, 2004).

The 1977 Proctor and Redfern report presented a summary of the existing Roadhouse Drain at that time, and recommended works to improve the drain to convey the 100-year and Regulatory storms. Expanding on the 1977 Proctor and Redfern report, the 1977 and 1978 Roadhouse Drain Reports prepared by K. Smart Associates provided information on the history of the Drain, and presented costs and methods of reconstructing the Roadhouse Drain. Updated hydrologic modelling and floodline mapping for the Roadhouse Municipal Drain was presented in the 1998 and 1999 Douglas Street Subdivision development reports. The floodline mapping was limited to the area between Huron Street and the CN Railway, where the Regulatory floodlines were determined to be contained within the channel.

1.3 History of the Roadhouse Municipal Drain

The following history of the Roadhouse Drain is based on documentation provided by the 1999 Douglas Street Subdivision Report prepared by Johnson Engineering Consultants. The Roadhouse Municipal Drain was constructed in 1928. The 1928 report stated that the Drain was to be maintained by municipalities within their own limits. The Drain was partially reconstructed in 1941, with maintenance in Stratford being completed in 1942, and another portion reconstructed in 1945. In 1975, the Drain was again reconstructed, while approximately 91 m of channel within Stratford was cleaned out as a maintenance project by the City. In 1989, additional reconstruction was carried out upstream of the south crossing of O'Loane Avenue.

Floodlines for the 100-year and Regulatory storms were determined by Proctor and Redfern Ltd. in 1977. The analysis indicated that the Drain would flood adjacent properties during infrequent storms, and it was recommended that the Drain be designed and reconstructed within the City limits to accommodate flows from the 100-year storm, with a minimum freeboard of two feet (0.6 m), with adequate full flow capacity for the Regulatory storm runoff. The proposed changes included reconstruction of the Drain to an open channel with a 10 foot (3 m) bottom, 2:1 side slopes, and an average depth of 4 to 5 feet (1.2 to 1.5 m). Realignment of the Drain was also proposed, along with erosion control measures, and replacement of existing culverts and bridges on the existing Drain to structures with capacity to carry the design flows of the Drain.

The costs and methods of reconstructing the Drain through the City of Stratford (per the Ontario Municipal Drainage Act, R.S.O. of 1975), was examined and reported by K. Smart Associates Ltd. in 1978. In 1979, K. Smart Associates Ltd. prepared a report documenting the proposed work, and established assessment amounts. The report included design drawings based on Drain sizes determined by Proctor and Redfern in their 1977 report. The 1979 report was revised in 1982 as a result of appeals to the Ontario Drainage Tribunal.

Drawings provided in the revised 1982 report provide details for the installation of a gabion drop structure just downstream of Matilda Street and just upstream of the 90 degree bend (see Exhibit 2), to accommodate a difference in elevation resulting from the regrading of the Drain downstream of the 90 degree bend. The drawings also provide details on the gabion structures that were to be installed along the banks of the Drain from Huron Street to upstream of Hibernia Street.

2.0 PUBLIC AND AGENCY CONSULTATION

The Master Drainage Plan was carried out in conjunction with the Municipal Class Environmental Assessment (Class EA) for the McCarthy Road extension and water / wastewater servicing, as part of the overall City of Stratford West Secondary Plan. The Master Drainage Plan was undertaken following the Master Planning Process identified in the Municipal Class Environmental Assessment (Municipal Engineers Association, June 2000). As stated therein, work undertaken in preparation of Master Plans "should recognize the planning and design process of the Class EA, and should incorporate the key principles of successful environmental assessment planning, including consultation with affected parties early in and throughout the process, consideration of a reasonable range of alternatives, and identification and consideration of the effects of each alternative on all aspects of the environment, systematic evaluation of alternatives in terms of their advantages and disadvantages, to determine their net environmental effects, and provision of clear and complete documentation of the planning process followed, to allow "traceability" of decision-making with respect to the project."

The Master Drainage Plan involved consultation with the City of Stratford, the Upper Thames River Conservation Authority (UTRCA), and the public. Consultation with the City and the UTRCA was ongoing throughout the Study process. This included attendance at several Steering Committee meetings which included a representative of the UTRCA, and regular correspondence with City and UTRCA staff. The City also provided background information, and co-ordinated communication between MRC and a number of stakeholders (property owners) and developers.

During development of the Master Drainage Plan, the UTRCA reviewed the technical analyses that formed the basis for the storm water management strategy and recommended flood plain management works. MRC submitted the hydrologic and hydraulic modelling for the Roadhouse Drain to the UTRCA as preliminary findings for their review and comments. MRC staff also attended a technical meeting with UTRCA staff. Comments were received from the UTRCA on February 2, 2007, and were addressed in a response letter dated February 14, 2007. Documentation of the correspondence with the UTRCA is provided in Appendix A. Additional comments were received from the UTRCA and from the City of Stratford subsequent to the submittal of the Draft report. The comments were addressed in a response letter dated December 20, 2007.

Information was prepared by MRC for presentation at the Public Information Centres (PICs) that were held throughout the overall study. MRC provided input for the first two PIC's in May 2006 and November 2006, including work completed to date, a brief history of the Roadhouse Drain, and work yet to be completed. MRC presented a summary of the Master Drainage Plan during a formal presentation at the March 2007 PIC, including the purpose of the Master Drainage Plan, storm water management requirements, flood plain management alternatives and recommendations, and requirements for implementation of the Plan.

3.0 EXISTING CONDITIONS

The area draining to the Roadhouse Drain consists mainly of rural agricultural lands, some areas of gravel extraction, and a few rural residences upstream of the City Limits. Tributary City lands are comprised of mixed residential areas (low and medium density) and a smaller percentage of commercial and industrial developments. The mainly agricultural upstream contributing drainage areas outside of the West Secondary Plan study area include depression areas with imperfect natural drainage. The soils within the study area consist of mainly Perth Silt Loam soils, classified as hydrologic soil group B. The existing conditions are presented on Exhibit 2.

External drainage areas located to the west of the West Secondary Plan study area discharge easterly where flows combine with runoff from subcatchments within the City. The northerly subcatchments drain to the upstream end of the Roadhouse Drain which runs perpendicular to O'Loane Avenue. The Drain then crosses O'Loane Avenue (north crossing). A gabion drop structure is located within the drain just downstream of Matilda Street. The Drain then turns sharply to the south just downstream of Matilda Street, resulting in a 90 degree bend. Overland flows continue to discharge to the Drain as it runs southerly to the west of O'Loane Avenue. At Douglas Street, the Drain jogs and runs southwesterly.

A spill point exists just north of Highway 8 West, at which point flows reaching an elevation of approximately 360.8 m would spill and flow southerly towards Highway 8 West and to the Finnegan Drain. The Finnegan Drain is a closed conduit that runs southerly from Highway 8 West through an agricultural field, and discharges to a culvert across O'Loane Avenue and then a ditch that directs flows to the Drain just upstream of the CN Railway. The Drain continues south of the CN Railway receiving runoff from adjacent agricultural areas, then crosses O'Loane Avenue for a second time (south crossing), before continuing through agricultural fields and ultimately discharging to the Avon River south of Lorne Avenue.

3.1 Site Reconnaissance and Survey

A site reconnaissance was carried out in August and November 2005, and April 2006 to establish a better understanding of the existing conditions along the Roadhouse Drain within the overall study area, including areas beyond the West Secondary Plan study area. The Roadhouse Drain and adjacent tributary lands were observed, and are discussed in further detail in the following section. Conditions observed during the site reconnaissance were documented with photographs, which are included in Appendix B of this report.

A detailed field survey was carried out to generate the data necessary to complete the backwater and floodway analyses. The detailed survey included a geodetic survey of numerous points, including cross-sections along the Drain, and all structures along the Drain. Surveyed structures include the twin CSPs across O'Loane Avenue (south crossing), twin box culverts under the CN Railway, the box culvert under Douglas Street, the twin box culverts under Huron Street, the twin culverts under Hibernia Street, the CSP culvert under Matilda Street, and the CSP culvert under O'Loane Avenue (north crossing). Two sections were surveyed at the gabion drop structure, with one section on top of the structure (top of gabion wall), and the other at the bottom of the structure (downstream face of the gabion wall).

All points and sections were surveyed geodetically with horizontal and vertical control in order to tie into existing base mapping.

3.2 Roadhouse Municipal Drain Characteristics

The Roadhouse Municipal Drain currently consists of a 5,277 m long channel, 1,651 m of which is upstream of the City of Stratford in the Township of Perth East. Approximately 2,011 m are within the City of Stratford limits, and 1,615 m are downstream of the City limits within the Township of South Perth.

The portion of the Drain upstream of the north crossing of O'Loane Avenue flows through agricultural lands, and has an irregular trapezoidal cross-section with medium to heavily vegetated banks. Although some bank erosion upstream of the O'Loane Avenue crossing was observed, the channel generally appears to be stable. Little flow was observed in the channel during the site reconnaissance, although standing water was observed along a significant portion of the Drain. Downstream of O'Loane Avenue, the Drain is straight to Matilda Street, and retains a trapezoidal cross-section with vegetated banks. A gabion drop structure with an approximate 0.5 m drop extends across the width of the channel just downstream of Matilda Street. The drop structure poses a barrier to fish movement. Through a portion of the residential area from just upstream of Hibernia Street to Huron Street, the banks consist of 3 m high gabion basket walls containing a low flow grass channel.

The channel again becomes a well-vegetated trapezoidal cross-section south of Huron Street, then through the Douglas Street Subdivision. Beyond the limits of the City's development and downstream of the O'Loane Avenue south crossing, the Drain flows through agricultural lands. The channel cross-section remains trapezoidal and well-vegetated and includes a low flow channel with a more varied morphology, and the gradient steepens as the Drain approaches its confluence with the Avon River.

3.3 Hydrologic Characterization

The SWMHYMO hydrologic model was used to estimate the runoff contribution to the Roadhouse Drain. Storm water management reports including hydrologic modelling summaries were previously prepared for various areas contributing to the Roadhouse Drain, and were obtained from the City of Stratford. These include the Douglas Street Subdivision Storm Water Management Report (Johnson Engineering Consultants, 1998, Revised 1999), the Jenann Subdivision Stormwater Management Report (Johnson Engineering, 2003), and the City of Stratford City Wide Storm System Master Plan. These reports were reviewed prior to the preparation of the existing conditions hydrologic modelling for the Roadhouse Drain.

Existing conditions flows were generated using the hydrologic model SWMHYMO, based on the Chicago 4-hour duration and 24-hour duration storms. The 4-hour duration storms were used in the conceptual design of the storm water management facilities. Existing conditions flows were generated for all return periods from 2 years to 250 years. The 24-hour duration 250-year storm flows were used in the hydraulic modelling to determine the existing floodlines for the Roadhouse Drain. Rainfall parameters were obtained from the City of Stratford City Wide Storm System Master Plan. The existing conditions hydrologic model for the Roadhouse Drain

was developed based on catchment parameters determined by MRC using aerial photography, topographic mapping and survey information.

It should be noted that MRC thoroughly examined the parameters used in the hydrologic modelling to ensure a reasonably accurate model given that calibration was not possible. Measured flow data was not available for calibration purposes, however previous modelling and modelling for the nearby McNamara Drain was utilized for comparison purposes. Parameters examined included time steps used for storm hyetographs, rainfall parameters, soils, curve numbers, initial abstraction, percent impervious values and time to peak. Soil types were confirmed using the Soil Survey of Perth County (Ontario Soil Survey). Hydrologic modelling prepared for the Court Drain Subwatershed Plan Study included an in-depth comparison of the hydrologic modelling with actual flow data. The analysis found that using an N value of 1.3 (where N is the number of linear reservoirs used for the derivation of the Nash unit hydrograph) resulted in a calibrated model. MRC has applied this calibrated parameter to the Roadhouse Drain hydrologic modelling due to the similar nature of the subwatersheds.

Of particular note is the subcatchment boundary between the Roadhouse Drain and the McNamara Drain. The subcatchment drainage divide determined by MRC based on the topographic information, including additional recent survey information, correlates to the drainage divide established by the City of Stratford City-Wide Storm System Master Plan. This includes MRC's subcatchments 111 and 120 as part of the Roadhouse Drain subwatershed as shown on Exhibit 2. The City Wide Plan also presented the subwatershed boundary established by the Court Drain Subwatershed Study, which showed MRC's subcatchment 120 as draining north to the McNamara Drain instead of to the Roadhouse Drain, and MRC's subcatchment 111 draining south to the Roadhouse Drain.

A summary of the peak flows generated by the model for existing conditions for the 2-year to 250-year return periods are included in Table 1. The catchment parameters and modelling input and output files are included in Appendix C. Hydrologic modelling files in electronic format are provided in Appendix F.

Table 1 – Summary of Existing Peak Flows								
Subcatchment	**Chicago 4-hour Storm Flows (m^3/s)**							**Chicago 24-hour Storm Flows (m^3/s)**
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**250-yr**	**250-yr**
101	0.20	0.56	0.88	1.33	1.73	2.15	2.76	3.92
102	0.05	0.11	0.16	0.24	0.30	0.37	0.47	0.63
103	0.02	0.06	0.09	0.14	0.18	0.22	0.28	0.38
104	0.10	0.26	0.39	0.58	0.74	0.90	1.14	1.62
105	0.03	0.08	0.12	0.19	0.25	0.31	0.40	0.56
106	0.01	0.04	0.06	0.09	0.12	0.14	0.18	0.26
107	0.12	0.31	0.48	0.72	0.92	0.14	1.45	1.99
108	0.05	0.12	0.18	0.27	0.34	0.42	0.54	0.73
109	1.75	2.71	3.32	4.08	5.04	5.84	7.12	8.41
110	0.04	0.10	0.16	0.25	0.32	0.40	0.51	0.71
111	0.01	0.02	0.04	0.06	0.08	0.10	0.14	0.20
112	0.83	1.20	1.63	2.16	2.63	3.55	4.42	5.34
113a	0.64	0.88	1.08	1.33	1.51	1.71	2.28	2.58
113b	1.40	1.93	2.38	2.92	3.32	3.76	5.02	5.68
114	2.52	3.86	4.74	5.81	6.60	7.48	8.98	11.14
115	1.00	1.36	1.62	1.96	2.34	2.63	3.16	3.48
116	2.13	2.91	3.46	4.18	4.91	5.50	6.56	7.03
117	0.03	0.09	0.14	0.22	0.28	0.35	0.45	0.63
118	0.53	0.73	0.92	1.14	1.31	1.77	2.19	2.64
119	0.72	0.98	1.17	1.48	1.67	1.88	2.24	2.43
120	0.05	0.17	0.28	0.45	0.60	0.76	0.99	1.43
121	0.13	0.37	0.58	0.88	1.15	1.43	1.84	2.67
122	0.08	0.21	0.33	0.49	0.63	0.79	1.01	1.39

3.4 Hydraulic Analysis and Flood Plain Mapping

The Court Drain Subwatershed Study and the City Wide Storm Sewer Master Plan state that the Chicago 24-hour, 250-year storm is to be used for determining flows for Regulatory Floodplain Mapping. This was implemented by the Upper Thames River Conservation Authority (UTRCA) subsequent to the 1977 Roadhouse Drain Drainage Report. The Roadhouse Drain Drainage Report specifies that a 250-year storm was used in the design of the Roadhouse Drain, however the storm distribution and duration were not noted. The City Wide Storm System Master Plan concluded that the 250-year storm flows are contained within the banks along the Roadhouse Drain. The City Wide Storm System Master Plan and the Roadhouse Drain Drainage Report state that the Roadhouse Drain reconstruction was designed and built to convey the 250-year storm event.

The flows calculated by MRC based on existing conditions were compared to hydrologic modelling flow data summarized in the 1977 Proctor & Redfern Roadhouse Drain Drainage Report, and the Douglas Street Subdivision Storm Water Management Report as shown in Table 2. The 1977 Roadhouse Drainage Report findings at Hibernia Street are somewhat higher than the MRC flows, and the flows at the CNR crossing are similar but somewhat lower than the MRC 24-hour duration flows. The Douglas Street Report flows at the CNR crossing are similar to the MRC 4-hour duration flows. It should be noted that the Proctor & Redfern report does not specify which storm duration was used to determine the 250-year flows, and that this report was prepared prior to the implementation of the 24-hour duration storm for Regulatory Flood estimation.

Table 2 – Comparison of 250-Year Peak Flows

Source of Peak Flows	250-Year Peak Flow (m^3/s)				
	O'Loane Ave	Hibernia St.	CNR	O'Loane Ave	600m u/s of Avon River
Roadhouse Drain Drainage Report (Proctor & Redfern, 1977)	-	27.0	35.9	-	-
Douglas Street Subdivision (12hr SCS storm) (Johnson Engineering,1998)	-	-	31.5	-	-
MRC -4hr Chicago	4.4	17.6	29.5	29.5	32.2
MRC -24hr Chicago	6.0	22.5	36.5	36.7	40.5

The existing floodplain along the Roadhouse Drain is presented on Exhibit 4. Hydraulic modelling carried out by MRC shows that the Chicago 4-hour duration 250-year storm is contained within the banks of the existing Roadhouse Drain downstream of the north crossing of O'Loane Avenue (culvert S7). However, the modelling shows that the Chicago 24-hour duration 250-year storm is not contained within the banks of the existing Drain downstream of Douglas

Street (culvert S3) to the south crossing of O'Loane Avenue (culvert S1) and upstream (west) of Matilda Street. The flood plain expands significantly upstream of Matilda Street, and expands further upstream (west of) O'Loane Avenue. The expansion of the floodplain in this area is due to limited capacity of the existing culvert at O'Loane Avenue and the culvert at Matilda Avenue, as well as the low ground elevations along the Drain upstream of O'Loane Avenue. The ground elevations upstream of O'Loane are similar to those along the Drain downstream of Matilda Street.

Table 3 summarizes the hydraulic performance (capacity) of all of the structures across the Drain. As shown, the 1400 mm diameter CSP across the farm lane at the City Limits (upstream of O'Loane Avenue, culvert S8), the north crossing of O'Loane Avenue, and the 2200 mm diameter CSP crossing Matilda Street (culvert S6) have the least freeboard with respect to the 250-year storm. Excess flows would overtop the farm lane at the City Limits during this storm.

Table 3 – Performance of Existing Structures

Structure ID (HECRAS section)	Location/ Street Name	Dimensions (mm) / Type	250-Year Storm (24 hour)	
			Freeboard from Top of Road (m)	Headwater Depth (m)
435 (culvert S8)	Farm lane at City Limits (u/s of O'Loane Ave.)	1400 CSP	-0.26	2.19
375 (culvert S7)	O'Loane Ave. - North Crossing	1700 CSP	0.32	2.28
325 (culvert S6)	Matilda Street	2200 CSP	0.06	2.01
275 (culvert S5)	Hibernia Street	Twin 3000 x 2400 Box	0.80	2.15
245 (culvert S4)	Huron Street	Twin 3000 x 2400 Box	1.11	2.11
205 (culvert S3)	Douglas Street	6200 x 3450 Box	1.42	2.60
165 (culvert S2)	CN Railway	Twin 3100 x 2380 Box	2.78	2.77
125 (culvert S1)	O'Loane Ave. - South Crossing	Twin 3000 CSPs	0.45	3.01

4.0 FUTURE CONDITIONS HYDROLOGY AND STORM WATER MANAGEMENT STRATEGY

4.1 Future Conditions Hydrology and Potential Impacts

The SWMHYMO hydrologic model for existing conditions was modified to reflect future development within the West Secondary Planning Area and estimate the runoff contribution to the Roadhouse Drain. The future conditions hydrology was developed based on the proposed future land use scenario. Various community plans were developed by GSP Group, comprised of various residential and medium density developments, school blocks, and industrial/commercial development areas.

The recommended community plan was utilized to develop the future conditions modelling parameters. It should be noted that undeveloped lands outside of the existing City Limits were modelled as undeveloped under future conditions. Based on our analysis of these areas, it was concluded that flow control and water quality treatment could be provided for these areas in conjunction with their future development such that the current SWM targets could be met with additional facilities located on these lands. In other words, any development beyond the current City Limits would not require SWM facilities within the current City Limits. The future conditions drainage mosaic is presented on Exhibit 3. Future conditions catchment parameters and modelling input and output files are included in Appendix D.

4.2 Storm Water Management Objectives and Criteria

The storm water management objectives for future developments within the Roadhouse Drain subwatershed are:

- to maintain or reduce peak flows along the Roadhouse Drain up to and including the 250-year storm;
- to maintain or reduce erosion potential along the Roadhouse Drain;
- to maintain or improve water quality; and
- to ensure no adverse impacts to existing developments and their storm drainage systems.

The following specific criteria were identified in order to meet these objectives:

- Maintain or reduce peak flows on a catchment-by-catchment basis for the 4 hour 2-year to 250 year Chicago design storms and the 24 hour 250 year Chicago design storm;
- Apply the “Simplified Approach” to erosion control as outlined in the Ministry of the Environment’s (MOE) Stormwater Management Planning and Design Manual and the Court Drain Subwatershed Study;
- Provide MOE “Normal” level of protection with respect to water quality (formerly Level 2);

- Control the 4-hour duration post development flows up to and including the 250-year storm event, to the 4-hour duration 5-year existing flow rates (i.e. overcontrol) where developments will drain to existing storm sewers.

Through the hydrologic modelling, it was found that if peak flows are maintained on a catchment-by-catchment basis, peak flows along the Roadhouse Drain will also be maintained. The need for overcontrol for areas draining to existing sewers was identified in the City of Stratford City Wide Storm System Master Plan and was based on a review of the capacity of the sewer system.

4.3 Storm Water Management Strategy

The overall strategy that was developed to meet the storm water management criteria includes the provision of a number of storm water management (SWM) facilities. SWM facility locations were initially based on 'proposed' and 'alternate' SWM basin locations as presented in the 2004 City of Stratford City Wide Storm System Master Plan. Locations were refined based on topography, existing features, and consolidation of previously proposed SWM facilities to reduce the overall number of facilities required. The feasibility of each of the proposed SWM facility locations was analyzed based on the need for sufficient fall to achieve surface drainage from the contributing drainage areas to the SWM facilities, while at the same time accounting for sufficient gradient to allow for discharge to the receiving watercourse/storm sewer.

The SWM facilities were designed to be wet ponds, and were sized to provide a Normal (Level 2) level of protection, as required by the MOE's Stormwater Management Planning and Design Manual. For a wet pond with a 55 percent impervious contributing area, 70 m^3/ha of permanent pool volume, and 40 m^3/ha of extended detention volume are required for a Normal level of protection. The percent impervious value for future developments was estimated based on the recommended West Stratford Community Plan.

The Distributed Runoff Control (DRC) Simplified Approach for erosion control was applied to the SWM facility design, as per the procedure as outlined in the CDSWS. Application of the DRC Simplified Approach to erosion control resulted in the need for 225 m^3/ha of extended detention volume. Thus the extended detention zones of the SWM facilities must include this volume; the 40 m^3/ha of extended detention volume required for water quality control is included in the 225 m^3/ha volume). In addition to the volume calculation procedure as demonstrated in Section 7.2.2 of the CDSWS (Figure 7.2), the detailed design of the outlet rating curves for the facilities must follow the proposed rating curve development procedure as outlined in Section 7.2.2 of the CDSWS (Figure 7.3). Excerpts of the procedures from the CDSWS are included in Appendix E.

An additional peak flow attenuation volume of 200 m^3/ha was determined to be required to control discharge rates to existing discharge rates for storm events up to and including the 250-year storm. It should be noted that the SWM facilities are also required to be designed to operate acceptably up to the 24-hour duration 250-year Chicago design storm.

4.3.1 SWM Facility Design Criteria

Criteria for the conceptual design of the SWM facilities are as follows:

- Permanent pool depth of 1.0 m;
- Maximum total pond depth of 3.0 m (3.3 m to top of freeboard); and
- Pond side slopes of 5:1.

With the exception of Pond 1, the SWM facilities were sized such that the design discharges not exceed the existing conditions peak flow rates. A freeboard of 0.3 m must also be provided above the required storage volume. MRC also calculated the SWM pond size required to meet the discharge criteria. As shown on Exhibit 3, the pond block sizes include SWM basin active storage volumes determined based on modelling results, and permanent pool volumes calculated based on requirements for water quality control. SWM pond sizes included a 15 percent additional area to allow for grading and pond access for maintenance purposes. Actual SWM block sizes will be established during detailed design. It should be noted that if during detailed design it is found that existing condition flows overtop the roadway, then flows must be overcontrolled in the SWM pond to prevent roadway overtopping during future conditions. A summary of the conceptual SWM facility requirements including target flow rates and SWM block areas is presented in Table 4.

The following information regarding SWM facility locations is outlined in the UTRCA's Policy manual:

Stormwater Management Facilities - Consistent with Policy 4.2.1, stormwater management facilities shall be directed to areas located outside of the defined limits of the natural hazard. Additionally, SWM facilities and associated measures may only be permitted in the flood plain if it can be demonstrated that there is a net public benefit in selecting the flood plain location and if all other potentially viable locations have been dismissed (on technical/environmental basis). The following principles will be considered when assessing such proposals:

a) The location of the SWM facilities in the flood plain will have no impact on natural hazard management or fluvial processes;

b)

b) The location of SWM facilities in the flood plain will result in a net ecological benefit for the planning and catchment area;

c)

c) Cultural benefits from the location of SWM facilities in the flood plain are accrued but encroachment in the flood plain cannot be justified solely on the merit of cultural benefits;

d)

d) The SWM facilities must meet design and maintenance performance requirements for the receiving watercourse;

e)

e) SWM facilities must satisfy the approval requirements of the local municipality, Ministry of the Environment and other affected environmental approval agencies; and

f)

f) On-line SWM facilities will only be considered in the context of a current subwatershed plan and where the facility is within a not-apparent valley, where no fish habitat exists and no adverse environmental impacts will result from the works.

4.3.2 Proposed SWM Facilities

Pond 1 located in subcatchment 120 was sized based on the revised subcatchment boundary as discussed previously in Section 3.3. As such, the requirements for SWM Pond 1 are based on the revised drainage area discharging to the south, to the Roadhouse Drain. Due to the existing topography in this area, a fill depth of approximately 0.5 m to 1.0 m will be required in the central portion of the subcatchment to provide adequate gradient for drainage to Pond 1.

Pond 1 is proposed to discharge to the existing 1500 mm diameter storm sewer located just west of Forman Avenue near the Stratford Education Recreation Centre (SERC), which has limited capacity according to the City Wide Storm System Master Plan. Due to the limited capacity of the sewer, Pond 1 must be oversized to control outflows from the 24-hour duration 250-year storm to 5-year existing flows of 0.196 m^3/s for subcatchment 120. Based on MRC's calculations, the 1500 mm storm sewer may have capacity in excess of the 5-year existing flows from catchment 120. As such, only limited overcontrol of Pond 1 may be required, and will need to be confirmed during subsequent design stages. The peak flow comparison location for this facility was downstream of subcatchment 120/ subcatchment 111.

The proposed Pond 2 located in subcatchment 107 will outlet to the Roadhouse Drain immediately upstream (west) of O'Loane Avenue. The peak flow comparison location for this facility was downstream of subcatchment 107.

The proposed Pond 3 located in subcatchment 108 is proposed to discharge to the North to the Roadhouse Drain immediately upstream (west) of O'Loane Avenue. The peak flow comparison location for this facility was downstream of subcatchment 108.

The proposed Pond 4 location is shown in subcatchment 109. It should be noted that the hatched (2.7 ha) portion of catchment 109 is currently developed and has SWM controls. As such, this area does not need to be accounted for the in the SWM facility for subcatchment 109. Due to the proposed reconstruction of O'Loane Avenue in this area, two SWM facilities are proposed to service the areas to the west and to the east of O'Loane Avenue. The facilities will discharge to the Roadside Drain immediately upstream (north) of the CN Railway. The peak flow comparison location for these facilities was downstream of subcatchment 109. The modelling and calculations are based on a total volume requirement and one target flow rate. Additional discussion regarding these ponds is provided in Section 4.4.1.

The proposed Pond 5 is located in subcatchment 110, and will discharge to the Roadhouse Drain downstream (west) of O'Loane Avenue. The peak flow comparison location for this facility was downstream of subcatchment 110.

Exhibit 3 presents the proposed SWM facility locations and block sizes, and Table 4 presents the proposed SWM basin sizes, as well as the target peak flow rates and the designed peak flow rates. The location of the proposed SWM facilities were based on proposed future land use, proposed drainage, and in some cases discharge restrictions, as mentioned previously. The proposed SWM facility locations and sizes are preliminary and conceptual only, and are somewhat flexible. Further refinements on a site-by-site basis are anticipated during subsequent design stages. The SWM facilities are to be located outside of the floodplain.

Table 4 – Conceptual SWM Facility Characteristics

SWM Basin I.D.	Catchment I.D.	Catchment Area (ha)[2]	SWM Basin Volume (m^3)				SWM Block Area (ha)		4hr Target Flows (m^3/s)[6]					24hr	Modelled Flows (m^3/s)				
			Permanent Pool [1]	Extended Detention	Flow Attenuation Storage	Total Volume	Estimated Area[4]	Modelled Area[5]	Ext. Det.	2 yr	5 yr	100 yr	250 yr	250 yr	2 yr	5 yr	100 yr	4hr - 250	24hr - 250
1	111&120	34.20	2,394	7,695	41,350	43,744	2.4	2.9	0.09	0.06	0.20[3]	-	-	-	0.06	0.20	0.20	0.20	0.20
2	107	23.3	1,631	5,243	19,100	20,731	1.6	1.5	0.06	0.06	0.16	0.59	0.75	1.02	0.01	0.01	0.27	0.53	1.02
3	108	14.20	994	3,195	11,560	12,554	1.0	0.9	0.04	0.05	0.12	0.42	0.54	0.73	0.03	0.12	0.42	0.49	0.68
4	109	39.10	2,737	8,798	18,990	21,727	2.7	1.5	0.10	1.75	2.71	5.84	7.12	8.41	0.30	1.82	5.45	7.15	8.40
5	110	20.20	1,414	4,545	17,075	18,489	1.4	1.3	0.05	0.04	0.10	0.40	0.51	0.71	0.05	0.11	0.41	0.49	0.71

Notes:

1) Protection level *Normal (formerly Level 2)*.
2) Based on the proposed land use plan, an impervious level of 55% was used for the conceptual pond designs
3) Basin 1 oversized to control 250-year peak flow to at or below the 5-yr existing peak flow due to limited capacity of receiving storm sewer (existing 1500 mm diameter storm sewer west of Forman Avenue).
4) Estimated SWM Block area calculated assuming a SWM Block size of 7 percent of the contributing drainage area.
5) Modelled SWM Block area based on 15 percent contingency added to SWM facility size modelled to achieve target flow rates.
6) Target flow rates based on existing conditions peak flows.

4.3.3 Effectiveness of Quantity Control Criterion

In order to demonstrate that the control of peak flows on a catchment-by-catchment basis will control peak flows along the Roadhouse Drain, the proposed conditions model was set up with the conceptual SWM facilities and run for the full range of design storms. Comparisons of the existing and future controlled peak flows along the Roadhouse Drain are provided in Table 5. As shown, the future controlled peak flows are very close to the existing flows. Although a slight increase in peak flows is presented at Huron Street and Hibernia Street, the increase in flow is very minimal, and as presented on Exhibit 4, does not result in any adverse effects on the proposed floodlines as there is sufficient capacity to convey the small increase in peak flows.

4.4 Storm Water Management Implementation

All storm water management facilities should be constructed prior to any development within their future tributary area. Construction phasing plans and cost-sharing agreements will be required for ponds that will service more than one development (different landowners). As part of the Draft Plan and Final Approval process, a storm water management report and detailed design drawings for the storm water management facilities will be required. The hydrologic model developed for this Master Plan should be utilized in development of the storm water management report. Model refinements should be made to reflect any catchment area refinements and catchment parameters should be refined to reflect more detailed development plans. Each update to the model should be returned to the City / UTRCA so that it may be provided to the next proposed development. The report should include the following:

- Demonstration that the storm water management criteria (water quality and quantity) identified in this Master Plan will be met. This should include a comparison of existing and future controlled peak flows along the Roadhouse Drain. Where there are downstream flow constraints, such as those associated with the existing sewers downstream of Pond 1, the report should demonstrate that there will be no adverse impacts to the receiving drainage system and tributary developments.
- Detailed stage-storage-discharge curve for the proposed storm water management pond and details regarding grading, maintenance access and emergency overflow spillways.
- Assessment of the proposed drainage system for the development to demonstrate that both major and minor flows will be directed to the SWM pond(s). A SWM pond may need to overcontrol tributary flows to compensate for any areas that cannot be drained to the pond.
- Results of geotechnical investigations to confirm the suitability of the pond site in terms of soils, bedrock and groundwater elevations. The pond may need to be lined to prevent interaction with groundwater if the soils are not sufficiently impermeable to retain water or the groundwater table is high.
- Landscaping design / thermal mitigation. The storm water management ponds should be designed as aesthetically appealing features that enhance its surroundings. Shade plantings should be utilized to help reduce temperature increases of the ponded water. Where feasible, consideration should be given to thermal mitigation measures such as cooling trenches at the outlet and/or bottom-draw outlets.

- Erosion and sediment control plan detailing the proposed staging of works and proposed erosion and sediment controls measures to protect the receiving waters during construction.

4.4.1 Infill / Redevelopment Areas

The conceptual storm water management ponds identified in this Master Plan were sized based on the pond catchment areas identified on Exhibit 3, which include lands within the West Secondary Planning Area. It is recognized that there may be infill developments or redevelopments within the Roadhouse Drain subwatershed outside of the West Secondary Planning Area. Generally, on-site controls will be required and should be designed to meet the water quality and quantity control criteria identified in this Master Plan.

All of the available storm water management measures should be reviewed with respect to feasibility on a site-by-site basis given that the size of the developments may place additional constraints on the use of certain measures. A combination of measures may be required where a storm water management pond is not feasible. Where land is severely limited, for example, the measures could include hydrodynamic separators in combination with underground or rooftop storage and/or parking lot storage. Some redundancy in the design should be incorporated to account for any uncertainty that the on-site measures will meet the criteria and be properly maintained over the long-term.

Development within the area east of O'Loane Avenue between Huron Street and the CN Railway was accounted for in the conceptual design of Ponds 4a and 4b in anticipation of eventual development. Two ponds are proposed to be located east and west of O'Loane Avenue outside of the West Secondary Planning area, to service these lands. As development proceeds on the west lands, Pond 4a will serve the lands west of O'Loane Avenue, and Pond 4b will serve the lands to the east.

Table 5 - Summary of Flows at Key Points of Interest along Roadhouse Drain

Point of Interest	Location Description	Area (ha)	Drainage Catchment Number[1]	Hec-Ras Section Locations		Peak Flows (m^3/s)															
						2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		250-Year		250-Year	
				From	To	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 4-hour	Future 4-hour	Existing 24-hour	Future 24-hour
1	City Limit	203	101	430	450	0.2	0.2	0.6	0.6	0.9	0.9	1.3	1.3	1.7	1.7	2.2	2.2	2.8	2.8	3.9	3.9
2	O'Loane Avenue	256	108	370	420	0.3	0.3	0.9	0.8	1.4	1.2	2.2	1.9	2.8	2.5	3.4	3.2	4.4	4.2	6.0	5.9
3	Downstream of 113a	319	113a	305	360	1.0	-	1.7	-	2.6	-	3.6	-	4.5	-	5.6	-	7.1	-	9.9	-
4	Hibernia Street	376	114	270	300	4.0	4.0	5.9	5.9	7.7	7.7	9.9	9.8	11.6	11.5	14.0	13.7	17.6	17.2	22.5	22.6
5	Huron Street	387	115	230	260	4.7	4.7	7.0	7.0	9.1	9.1	11.6	11.5	13.8	13.7	16.1	16.0	20.3	20.0	25.8	26.2
6	CNR	532	116	180	220	6.1	4.6	9.9	8.1	12.6	11.6	16.3	15.6	20.1	19.2	23.7	22.8	29.5	28.8	36.5	36.4
7	O'Loane Avenue	555	117	140	170	5.6	4.4	9.3	8.2	12.4	11.5	16.3	15.7	20.0	19.3	23.8	23.0	29.5	29.2	36.7	36.4
8	Downstream of 110	588	110	110	130	5.6	4.4	9.4	8.3	12.6	11.6	16.6	16.0	20.3	19.7	24.2	23.4	30.1	29.7	37.5	37.3
9	Downstream of 106	601	106	90	100	6.0	4.7	10.0	8.6	13.3	12.2	17.4	16.6	21.4	20.5	25.4	24.6	31.6	31.1	39.5	39.1
10	600m upstream of Avon River	756	121	60	80	6.0	4.0	10.1	8.0	13.5	11.3	17.7	15.5	21.7	19.1	25.9	22.9	32.2	28.9	40.5	36.6

Note:

1) Flow downstream of catchment number.

5.0 FLOODPLAIN MANAGEMENT ALTERNATIVES

5.1 Description of Upstream Alternatives

Various flood plain management alternatives were investigated in conjunction with development of the storm water management strategy to improve the function of the existing Drain while at the same time free up existing flood plain areas for development. Opportunities were identified to increase conveyance, to increase the efficiency of storage within the adjacent floodplain, and to better connect the channel with its flood plain. The alternatives included various combinations of improvements including culvert upgrades, removal of the existing gabion weir downstream of Matilda Street, channel regrading, and creation of flood plain corridors through cut/fill works.

The following alternatives were investigated to improve the function of the existing Drain upstream of the existing gabion drop structure. Alternatives were also investigated further downstream in the vicinity of the CN Railway and these are discussed separately in Section 5.3. The various alternatives are shown schematically on Exhibit 4. Hydraulic modelling is provided on CD in Appendix F.

5.1.1 Alternative 1 – Do Nothing

As part of the Class EA or Master Planning process, the Do Nothing alternative must be considered as a bench mark comparison for all alternatives. The Do Nothing alternative maintains the existing flood plain and conveyance system characteristics.

5.1.2 Alternative 2 – Enlarge O'Loane Avenue Culvert

Alternative 2 consists of increasing the size of the culvert located at the north crossing of O'Loane Avenue.

5.1.3 Alternative 3 – Enlarge O'Loane Avenue Culvert and Matilda Street Culvert

Alternative 3 consists of increasing the size of the culvert located at O'Loane Avenue, as in Alternative 1, in conjunction with increasing the size of the existing culvert at Matilda Street.

5.1.4 Alternative 4 – Enlarge Culverts and Implement Channel and Corridor Improvements

The final alternative consists of increasing both of the existing culverts at O'Loane Avenue and Matilda Street in conjunction with channel and corridor improvements including the removal of the gabion drop structure, regrading of the channel to the City Limit, cutting and filling within the flood plain between O'Loane Avenue and the City Limit to create an 80 m enhanced flood plain corridor, and cutting along the south side of the Drain between Matilda Street and the gabion drop structure. Creation of the 80 m corridor involves cutting within the 80 m width along the Drain and filling where required beyond the corridor.

The following sections discuss the analyses and evaluation of the alternatives leading to the recommended flood plain management works and the implementation requirements. A summary of the analysis and evaluation of the alternatives is presented in Table 6.

5.2 Analysis of Upstream Alternatives

The impacts of each of the upstream alternatives were analysed based on the following factors:

- Aquatic habitat impacts including direct loss of habitat, habitat quality, and barriers to fish passage;
- Impacts to vegetation/terrestrial habitat and wildlife movement such as direct loss of vegetation, habitat quality, and impacts to wildlife movement;
- Impacts to flood plain storage/flood risk, such as change in flood plain storage/risk of increased peak flows downstream;
- Impacts to flood elevations/flood risk, including changes in Regulatory flood elevations and changes in flood risk of existing developments;
- Impacts to erosion potential;
- Increases in developable lands within the City;
- Requirements for implementation including Municipal Drain implications, Municipal Class EA requirements, agency approvals, and phasing requirements/considerations; and
- Comparative construction costs.

The analysis involved hydraulic modelling of each alternative in order to determine the impacts with respect to flood elevations, flow velocities and flood plain storage. The need to maintain flood plain storage was a key factor in establishing the cut/fill works along the Drain and corridor width upstream of O'Loane Avenue for Alternative 4.

5.2.1 Alternative 1 – Do Nothing

The Do Nothing alternative results in no loss or change to aquatic habitat, vegetation, terrestrial habitat and wildlife movement. There is no change in flood plain storage, flood elevations, or flood risk, and no change in erosion potential. There is also no increase in developable lands. The City would either continue to manage the Roadhouse Municipal Drain on City lands in accordance with the Drainage Act, or abandon the Drain under the Drainage Act.

5.2.2 Alternative 2 – Enlarge O'Loane Avenue Culvert

Alternative 2 results in an opportunity to incorporate permanent aquatic habitat enhancements within the new culvert, despite temporary disturbance during culvert construction. No loss of vegetation or impacts to habitat quality would result from the proposed works, and wildlife movement may be enhanced with the larger culvert. No change in erosion potential would result from this alternative. The enlarged culvert would result in reduced flood elevations by 0.31 m to 0.42 m between O'Loane Avenue and the City Limit. The reduced flood elevations would eliminate the existing spill to the Finnegan Drain. Six existing residences would be removed

Table 6– Summary of Analysis and Evaluation of Flood Plain Management Alternatives

Analysis Factors	Factor Indicators	Alternative 1 Do Nothing (Maintain Existing Flood Plain and Conveyance System Characteristics)	Alternative 2 Enlarge O'Loane Avenue Culvert	Alternative 3 Enlarge O'Loane Avenue Culvert and Matilda Street Culvert	Alternative 4 Enlarge Culverts and Implement Channel and Corridor Improvements [RECOMMENDED] (Remove Gabion Drop Structure and Regrade Channel to City Limit, Cut & Fill within Flood Plain between O'Loane Avenue and City Limit to create an 80 m enhanced corridor)
Aquatic Habitat Impacts	Direct loss of habitat Habitat quality Barriers to fish passage	No loss or change	Opportunity to incorporate aquatic habitat enhancements within new culvert. Temporary disturbance during culvert construction	Opportunity to incorporate aquatic habitat enhancements within new culverts. Temporary disturbance during culvert construction	Opportunity to incorporate aquatic habitat enhancements within new culverts and with implementation of natural channel design principles and channel bank plantings Removal of gabion drop structure will remove barrier to fish passage
Vegetation / Terrestrial Habitat and Wildlife Movement	Direct loss of vegetation Habitat quality Impacts to wildlife movement	No loss or change	No loss of vegetation or impacts to habitat quality. Wildlife movement may be enhanced with larger culvert	No loss of vegetation or impacts to habitat quality. Wildlife movement may be enhanced with larger culverts	Loss of habitat in fill areas is associated with cultural meadow and agricultural fields. Opportunity to enhance habitat with diverse corridor plantings. Wildlife movement may be enhanced with larger culverts and removal of gabion drop structure
Flood Plain Storage / Flood Risk	Change in flood plain storage / Risk of increased peak flows downstream	No change	Not applicable	Not applicable	Flood plain storage is maintained
Flood Elevations / Flood Risk	Change in Regulatory flood elevations Change in flood risk of existing developments	No change	Reduces flood elevations by 0.31 to 0.42 metres between O'Loane Avenue and City Limit Eliminates spill to Finnegan Drain Six existing residences removed from flood plain along west side of O'Loane Avenue north of channel Existing buildings south of channel removed from flood plain Reduces risk associated with flows over O'Loane Avenue	Reduces flood elevations by 0.63 to 1.15 metres between O'Loane Avenue and City Limit and by 0.73 to 1.05 metres between Matilda Street and O'Loane Avenue Eliminates spill to Finnegan Drain Six existing residences removed from flood plain along west side of O'Loane Avenue north of channel Existing buildings south of channel removed from flood plain Reduces risk associated with flows over O'Loane Avenue and Matilda Street Oakdale Park removed from flood plain	Reduces flood elevations by 1.00 to 1.43 metres between Matilda Street and City Limit and by 0.10 to 0.18 metres between the gabion weir and Matilda Street Eliminates spill to Finnegan Drain Six existing residences removed from flood plain along west side of O'Loane Avenue north of channel Existing buildings south of channel removed from flood plain Reduces risk associated with flows over O'Loane Avenue and Matilda Street Oakdale Park removed from flood plain
Erosion Potential	Change in erosion potential	No change	No change	No change	Some changes in channel velocities, however design can ensure that the risk of bed and bank erosion is not increased
Future Development	Increase in developable lands within City	No increase in developable lands	Approximately 2.5 hectare increase in developable lands	Approximately 5.5 hectare increase in developable lands	Approximately 14.2 hectare increase in developable lands
Requirements for Implementation	Municipal Drain implications Municipal Class EA requirements Agency approvals Phasing requirements/ considerations	City either continues to manage the Roadhouse Municipal Drain on City lands in accordance with the Drainage Act or abandons the Drain under the Drainage Act	Drainage Engineer's report required in accordance with Drainage Act. If Drain is abandoned under Drainage Act, Municipal EA requirements for Schedule 'B' activity must be fulfilled. Additional approvals required from DFO, UTRCA, MOE	Drainage Engineer's report required in accordance with Drainage Act. If Drain is abandoned under Drainage Act, Municipal EA requirements for Schedule 'B' activity must be fulfilled. Additional approvals required from DFO, UTRCA, MOE	Drainage Engineer's report required in accordance with Drainage Act. If Drain is abandoned under Drainage Act, Municipal EA requirements for Schedule 'B' activity must be fulfilled. Approval required from UTRCA, DFO, MOE. Preferred staging of works is from downstream to upstream, need to maintain sufficient flood plain storage during interim stages
Cost	Estimated construction cost	No cost	$300,000 for culvert and restoration works	$550,000 for culvert and restoration works	$1,100,000 for channel and culvert works

Notes: Costs are approximate and for comparison only

from the flood plain along the west side of O'Loane Avenue north of the channel. Existing buildings south of the channel would also be removed from the flood plain.

There would be an increase in developable lands of approximately 2.5 ha. Requirements for implementation include a Drainage Engineer's report in accordance with the Drainage Act. If the Drain is abandoned under the Drainage Act, Municipal EA requirements for a Schedule 'B' activity must be fulfilled, in addition to approvals required form the DFO, UTRCA, and MOE. The estimated cost for the culvert and restoration works would be approximately $300,000.

5.2.3 Alternative 3 – Enlarge O'Loane Avenue Culvert and Matilda Street Culvert

Alternative 3 results in an opportunity to incorporate permanent aquatic habitat enhancements within the new culverts, despite temporary disturbance during culvert construction. No loss of vegetation or impacts to habitat quality would result from the proposed works, and wildlife movement may be enhanced with the larger culverts. No change in erosion potential would result from this alternative. The enlarged culverts would result in reduced flood elevations by 0.63 m to 1.15 m between O'Loane Avenue and the City Limit, and by 0.73 m to 1.05 m between Matilda Street and O'Loane Avenue. The reduced flood elevations would eliminate the existing spill to the Finnegan Drain. Six existing residences would be removed from the flood plain along the west side of O'Loane Avenue north of the channel. Existing buildings south of the channel would also be removed from the flood plain, along with Oakdale Park. There would be an increase in developable land of approximately 5.5 ha.

Requirements for implementation include a Drainage Engineer's report in accordance with the Drainage Act. If the Drain is abandoned under the Drainage Act, Municipal EA requirements for a Schedule 'B' activity must be fulfilled, in addition to approvals required form the DFO, UTRCA, and MOE. The estimated cost for the culvert and restoration works would be approximately $550,000.

5.2.4 Alternative 4 – Enlarge Culverts and Implement Channel and Corridor Improvements

The final alternative provides an opportunity to incorporate aquatic habitat enhancements within the new culverts with the implementation of natural channel design principles and channel bank plantings. The removal of the gabion drop structure would remove the existing barrier to fish passage. The loss of terrestrial habitat in the fill areas upstream of O'Loane Avenue is associated with cultural meadow and agricultural fields. The alternative provides the opportunity to enhance terrestrial habitat with diverse corridor plantings, and wildlife movement may be enhanced with larger culverts and removal of the gabion drop structure.

Although flood plain storage would be maintained, flood elevations would be reduced by 1.00 m to 1.43 m between Matilda Street and the City Limit, and by 0.10 m to 0.18 m between the gabion drop structure and Matilda Street. The reduced flood elevations would eliminate spill to the Finnegan Drain. Six existing residences would be removed from the flood plain along the west side of O'Loane Avenue north of the channel. Existing buildings south of the channel would be removed from the flood plain. The reduced flood elevations would also reduce the risk associated with flows over O'Loane Avenue and Matilda Street. Oakdale Park would also be removed from the flood plain.

The works would result in changes in channel velocities, however the design could ensure no increase in the risk of bed and bank erosion. There would be a significant increase in developable lands of approximately 14.2 ha. Requirements for implementation include a Drainage Engineer's report in accordance with the Drainage Act. If the Drain is abandoned under the Drainage Act, the Municipal EA requirements for a Schedule 'B' activity must be fulfilled. Approval would be required from the UTRCA, DFO, and MOE. The preferred staging for the works is from downstream to upstream, with a need to maintain sufficient flood plain storage during the interim stages. The estimated cost for the channel and culvert works would be approximately $1,100,000.

5.3 Analysis of Downstream Alternatives

As noted previously, the 250 year floodlines extend beyond the banks of the Roadhouse Drain between O'Loane Avenue and Douglas Street, whereas the floodlines are contained within the channel banks upstream to Matilda Street, and contained within a narrow corridor along the Drain downstream of O'Loane Avenue. The cause of the more extensive flood plain is primarily due to backwater from the CN Rail and O'Loane Avenue crossings, particularly the O'Loane Avenue crossing. The channel is quite deep (approximately 2.5 m) and its capacity is not significantly different from upstream and downstream reaches.

Through a review of the hydraulic model of this reach of the Roadhouse Drain, the flood plain area was identified as a potential candidate area for a two-zone policy. As shown on Exhibit 4, the floodlines for the 250 year Chicago storm based on a 4 hour duration instead of a 24 hour duration are much closer to the channel banks. Thus, a hydraulic analysis was undertaken to identify the hydraulic impacts of development within the area defined by the two sets of floodlines. The results of the analyses are as follows:

- The difference in the 4 hour and 24 hour 250 year flood elevations ranges between 0.42 m and 0.59 m.
- The maximum depth of overbank flooding during the 24 hour 250 year storm varies between O'Loane Avenue and Douglas Street. The depth is approximately 0.5 m west of the channel between the CN Railway and Douglas Street and 0.1 m east of the channel. The depth is approximately 0.6 m both east and west of the channel between O'Loane and the CN Railway.
- The velocity of flow during the 24 hour 250 year storm in the overbank areas (floodplain) ranges from 0.08 m/s to 0.25 m/s.
- Encroachments up to the 4 hour 250 year storm floodlines between O'Loane Avenue and Douglas Street would increase the 24 hour 250 year flood elevations by 0.01 m to 0.03 m from Douglas Street to Huron Street. Flood elevations would not increase between O'Loane Avenue and Douglas Street.
- These encroachments would increase the peak channel flow velocity by approximately 15%.
- The encroachments would increase the peak overbank flow velocity by between 0.09 m/s and 0.40 m/s between O'Loane Avenue and Douglas Street. There would be no change downstream of O'Loane Avenue.

- The encroachments would result in a maximum reduction in flood plain storage of 9700 m^3. This is assuming that the entire area between the two sets of floodlines would not provide any flood plain storage, which would not be the case; flood plain storage would remain between any future buildings. This amount of reduced storage represents approximately 20% of the storage between O'Loane Avenue and Douglas Street. In reality, the reduction in storage might be closer to 5% if the area were to be fully developed.

Based on these results, development within the area between the 4 hour and 24 hour 250 year floodlines would not have significant impacts with respect to flow velocities and flood levels. Flood-proofing of future buildings would be required up to the 24 hour 250 year flood elevations. Although there would be some loss of flood plain storage, this is not likely to cause adverse impacts downstream in terms of peak flow increases and corresponding increases in flood levels or velocities. To put the amount of lost storage in perspective, based on 5% of the total between O'Loane Avenue and Douglas Street, this storage represents only 0.5 mm over the entire area that is tributary to this reach of the channel.

Flood plain management alternatives similar to those identified further upstream along the Drain were identified for this reach of the Drain. These include: increasing the conveyance capacity at the O'Loane Avenue crossing; increasing the conveyance capacity at the CN Railway crossing; and channel and flood plain corridor improvements. The alternatives were analyzed using the hydraulic model in order to determine the potential benefits and impacts. The results of the analyses are as follows:

- The existing O'Loane Avenue crossing of the Drain causes an approximate 0.95 m increase in the 24 hour 250 year flood elevations (from downstream of the road to upstream of the road). The 250 year flood elevation is only 0.03 m above the road. The twin CSPs project from the road embankment (i.e. there is no headwall) and appear to be in good physical condition.
- The existing CN Railway crossing of the Drain causes a 0.4 m increase in the 24 hour 250 year flood elevations. The 250 year flood elevation is 3.7 m below the Railway. The CN Railway structure appears to be in good physical condition and there is little potential for inlet improvements to increase its capacity. The structure has a headwall and wingwalls.
- Placement of a headwall at the inlet of the twin CSP culverts across O'Loane Avenue would not reduce the upstream 250 flood elevation. The culverts are "outlet" controlled. Another CSP would need to be installed or the entire crossing would need to be reconstructed with a large new structure to have a significant impact on flood elevations. The addition of a third 3.0 m diameter CSP would reduce the 24 hour 250 year flood elevation by 0.5 m immediately upstream of the crossing and 0.4 m immediately upstream of the CN Railway. This would reduce the flood plain such that it would be close to the existing 4 hour 250 year floodlines between O'Loane Avenue and the CN Railway. It would also reduce the flood plain between the CN Railway and Douglas Street. Approximately 1.5 ha of developable land would be gained upstream of the CN Railway and 2 ha would be gained downstream of the Railway. The reduced flood elevations would provide some benefit in terms of reduced flood risk to properties along the east side of the Drain north of the CN Railway.

- Grading (cut/fill) along the Drain to lower the channel banks and reconnect it to its flood plain could lower flood levels somewhat upstream of the CN Railway and maintain flood plain storage while reducing the width of the flood plain. Reduction of the channel depth to 1.5 m and creation of a 60 m wide flood plain corridor would reduce the area of flood plain by approximately 4.5 ha from O'Loane Avenue to Douglas Street. Fill would be required within the existing flood plain beyond the 60 m corridor.

Based on all of this, the viable options are to implement a two zone policy, construct a 60 m wide flood plain corridor, or increase the capacity of the O'Loane Avenue crossing. The advantage of the two zone policy is that there would be minimal costs, whereas the cost of constructing the 60 m flood plain corridor was estimated to be $600,000 and the cost for the culvert upgrade was estimated to be $7,000 based on the CSP pipe cost only. However the 60 m corridor alternative would maintain flood plain storage and would be beneficial to the function of the channel through reconnection with its flood plain. In addition, it would provide the opportunity to enhance riparian habitat. It should be noted that the corridor does not need to be centered on the Drain, but could be shifted to one side if desired to facilitate development.

It is recommended that these options be investigated in more detail using the hydraulic model developed for this Master Plan. Additional work should include the following:

- Hydraulic analysis of additional crossing upgrade options at O'Loane Avenue;
- Further consultation with the UTRCA with respect to requirements to implement a two zone policy;
- Refinement of costs for the corridor works and crossing upgrade alternatives;
- Refinement of the impacts to the flood plain area (increase in developable lands).
- Confirmation of the benefits and potential for adverse impacts, including impacts downstream of O'Loane Avenue.

It should be noted that the modelling encompasses properties located outside of the study area. Specifically, the Stratford owned property (Avon Cemetery) and the MTO (Ontario Realty) sites are included in the modelling, and the existing overall model is sufficient basis for future detailed analysis of these properties. These properties have been identified as candidates for future consideration of local hydraulic floodway analyses.

5.4 Recommended Works and Implementation

5.4.1 Recommended Flood Plain Management Works

The recommended flood plain management works are those associated with upstream Alternative 4, consisting of enlarging the culverts at O'Loane Avenue and Matilda Street, removing the gabion drop structure and regrading the channel to the City limit, cutting and filling within the flood plain between O'Loane Avenue and the City Limit to create an 80 m enhanced corridor, and cutting along the south side of the Drain between Matilda Street and the gabion drop structure. This alternative results in the greatest benefits overall including aquatic habitat enhancements, reduction in flood elevations and flood risk, maintenance of flood plain storage, and the greatest increase in developable lands.

5.4.2 Staging of Corridor Works

The staging of the proposed works must be scheduled and executed to ensure that interim stages do not result in adverse impacts to the Drain and adjacent lands. Sufficient flood plain storage will need to be maintained as the works proceed to ensure no increase in flood risk to adjacent lands.

The upstream and downstream works can be implemented independently. Both works would be required in conjunction with future land development. All of the upstream works are required to facilitate development upstream of the north crossing of O'Loane Avenue in the areas tributary to Ponds 2 and 3 shown on Exhibit 3. Similarly, all of the recommended downstream works are required to facilitate any development between the existing floodlines and the proposed future floodlines shown on Exhibit 4 in the vicinity of the CN railway.

5.4.3 Municipal Drain Process

The Roadhouse Drain is a Municipal Drain, and as such is subject to the Municipal Drain Process outlined in the Drainage Act. Some of the works/improvements to the Drains may require the preparation of a drainage report by a registered engineer. In cases such as improvements in relation to road works (e.g. culvert replacements), or channel regrading, a drainage report is not required. For works such as realignments, drain abandoning, removal of existing drop structures, then a drainage report prepared by a registered engineer is required. Although there are benefits to existing developments that will be removed from the flood plain following the works, the works are only necessary to facilitate future developments and as such, it is recommended that the costs for the works and preparation of the drainage report be shared by the City and land developers.

5.4.4 Approvals

It is anticipated that approvals will be required from a number of agencies including:

- City of Stratford
- Upper Thames River Conservation Authority (UTRCA)
- Department of Fisheries and Oceans (DFO)
- Ministry of the Environment (MOE)

Early consultation with these agencies should be undertaken to confirm approval requirements.

5.4.5 Future Potential Channel Improvements

Based on observations made during the site investigation, there is the potential for future channel improvements within the developed areas of the City. It is recommended that opportunities for improving aquatic and terrestrial habitat and fish passage be explored as part of ongoing maintenance of the Drain. For example, if the existing gabion baskets along the portion of the drain near Hibernia Street require extensive repairs or replacement, green gabions could be

considered to increase vegetation as well as the aesthetics of the channel. The channel morphology could also be improved by better defining the low flow channel and/or incorporating pools for habitat.

6.0 MONITORING PLAN

Monitoring is an important component to the implementation of the storm water management strategy. Monitoring should be undertaken to assess conditions of the Roadhouse Drain over time and to assess the effectiveness of the storm water management strategy. Results of the monitoring should be reviewed in order to determine if changes need to be made to the implementation of the strategy or to the stormwater management criteria.

It is recommended that the Monitoring Plan focus on assessing channel erosion and sedimentation, water temperature and baseflows. The recommended Monitoring Plan consists of the following:

1. Establish baseline conditions prior to any development (minimum one year)
   - Conduct a spring runoff and late summer (dry period) assessment of the Drain along two reaches; one downstream of the south limit of the West Secondary Planning Area and one downstream of the existing gabion drop structure.
   - Collect water temperatures and baseflow measurements
   - Conduct a rapid geomorphic assessment (sediment and erosion)

2. Monitor during construction
   - Continue with above data collection
   - Assess other channel reaches if significant impacts become evident
   - Assess data to determine if any significant changes are problematic and could be related to on-going developments
   - Make recommendations for further action if necessary such as inspection of the operation of storm water management ponds, inspection of temporary erosion and sediment controls, revisiting the storm water management criteria

3. Post-construction monitoring (minimum 2 years)
   - Continue with above data collection
   - Assess other channel reaches if significant impacts become evident
   - Make recommendations for further action if necessary such as inspection of the operation of storm water management ponds or revisiting the designs of storm water management ponds to determine if modification are necessary

It is recommended that a specialist in fluvial geomorphology be retained to implement the Monitoring Plan. It should be noted that this Monitoring Plan does not cover the monitoring of storm water management facilities by developers prior to them being assumed by the City or monitoring that may be required by the UTRCA and/or DFO in conjunction with the flood plain management works.

7.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

McCormick Rankin Corporation (MRC) has prepared this Master Drainage Plan for the Roadhouse Drain in conjunction with the West Secondary Planning Study for the City of Stratford (City). The purpose of the Master Drainage Plan is to provide a comprehensive understanding of the hydrologic and hydraulic aspects of the Roadhouse Drain, an understanding of the system as a whole, to establish the flood plain limits, to develop a storm water management strategy for future developments, to evaluate flood plain management alternatives, and to provide implementation recommendations.

The following summarizes the key findings which are presented in this Master Drainage Plan:

- Under existing conditions, the results of the hydraulic modelling indicated that the 4-hour duration Chicago 250-year storm is contained within the banks of the existing Roadhouse Drain except upstream of the north crossing of O'Loane Avenue;
- Under existing conditions the 24-hour duration Chicago 250-year storm is not contained within the banks of the existing Roadhouse Drain between the south crossing of O'Loane Avenue and Douglas Street and upstream of Matilda Street; and
- Under existing conditions, the flood plain expands significantly upstream (west of) O'Loane Avenue and Matilda Street, in part due to insufficient capacity of the existing culverts across Matilda Street and O'Loane Avenue.

The hydrologic model that was developed to reflect existing conditions was revised to account for future development within the West Secondary Planning Area. Storm water management objectives for future developments are as follows:

- to maintain or reduce peak flows along the Roadhouse Drain up to and including the 250-year storm;
- to maintain or reduce erosion potential along the Roadhouse Drain;
- to maintain or improve water quality; and
- to ensure no adverse impacts to existing developments and their storm drainage systems.

The following specific criteria were identified in order to meet these objectives:

- Maintain or reduce peak flows on a catchment-by-catchment basis for the 4 hour 2-year to 250 year Chicago design storms and the 24 hour 250 year Chicago design storm;
- Apply the "Simplified Approach" to erosion control as outlined in the Ministry of the Environment's (MOE) Stormwater Management Planning and Design Manual and the Court Drain Subwatershed Study;
- Provide MOE "Normal" level of protection with respect to water quality (formerly Level 2);

- Control the 4-hour duration post development flows up to and including the 250-year storm event, to the 4-hour duration 5-year existing flow rates (i.e. overcontrol) where developments will drain to existing storm sewers.

Through the hydrologic modelling, it was found that if peak flows are maintained on a catchment-by-catchment basis, peak flows along the Roadhouse Drain will also be maintained. The need for overcontrol for areas draining to existing sewers was identified in the City of Stratford City Wide Storm System Master Plan and was based on a review of the capacity of the sewer system.

The overall strategy that was developed to meet the storm water management (SWM) criteria included the provision of a number of SWM facilities that were designed to be wet ponds. The location of the proposed SWM facilities were based on proposed future land use, proposed drainage, and in some cases specific discharge restrictions. Conceptual designs were developed based on the above criteria and a number of assumptions. It should be noted that the proposed SWM facility locations and designs are conceptual only, and are somewhat flexible. Changes may be made provided that the SWM objectives and targets are met. Further refinements on a site-by-site basis are anticipated during subsequent design stages.

Numerous Roadhouse Drain flood plain management alternatives were analysed as part of the Master Drain Plan. The recommended alternative includes the following proposed works:

- Enlarging the culverts at O'Loane Avenue and Matilda Street;
- Removing the gabion drop structure and regrading the channel upstream to the City limit; and
- Cutting and filling within the flood plain between O'Loane Avenue and the City Limit to create an 80 m enhanced corridor, and cutting along the south side of the Drain between the gabion drop structure and Matilda Street.

This alternative results in the greatest benefits overall, including aquatic habitat enhancements, reduction in flood elevations and flood risk, maintenance of flood plain storage, and the greatest increase in developable lands. As the Roadhouse Drain is a Municipal Drain, it is subject to the Municipal Drain process as outlined in the Drainage Act. It is anticipated that approvals will be required from The City of Stratford, UTRCA, DFO and MOE. The estimated cost for the channel and culvert works associated with the preferred alternative is approximately $1,100,000.

Additional flood plain management works were investigated for the reach of the Roadhouse Drain between Douglas Street and the south crossing of O'Loane Avenue. Three viable options were identified that increase the amount of developable lands. These consist of: implementation of a two zone policy, construction of a 60 m wide flood plain corridor, or increasing the capacity of the O'Loane Avenue crossing. It is recommended that these options be investigated in more detail, building on the analysis completed as part of this Master Drainage Plan.

The potential for future channel improvements within the developed areas of the City was noted based on observations made during the site investigation. It is recommended that opportunities for improving aquatic and terrestrial habitat and fish passage be explored as part of ongoing maintenance of the Drain.

A Monitoring Plan was developed in order provide a means to assess conditions of the Roadhouse Drain over time and to assess the effectiveness of the storm water management strategy. Results of the monitoring should be reviewed in order to determine if changes need to be made to the implementation of the strategy or to the stormwater management criteria.

Exhibit 1 - Study Area

Exhibit 2 - Existing Conditions Drainage Mosaic

Exhibit 3 - Future Conditions Drainage Mosaic and Conceptual SWM Strategy

Exhibit 4 – Roadhouse Drain 250-year Floodlines and Flood Plain Management Alternatives

APPENDIX A

Agency Correspondence

APPENDIX B

Photographic Inventory

APPENDIX C

Hydrologic Model Input Parameters And Output Files – Existing Conditions

APPENDIX D

Hydrologic Model Input Parameters And Output Files –Future Conditions

APPENDIX E

Distributed Runoff Control – Simplified Approach Procedures (Excerpts from Court Drain Subwatershed Study)

APPENDIX F

Hydraulic Modelling Files
(available on CD)