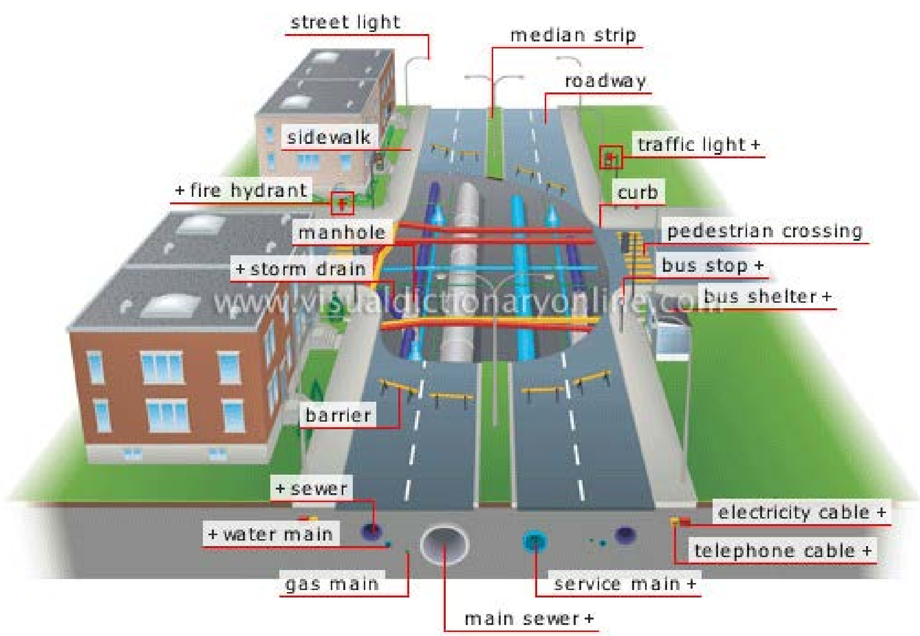
City of St. Catharines

Engineering Standards Manual

Transportation & Environmental Services



Issued June 2015

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1.0 **Overview**

The following sections outline the City of St. Catharines requirements for all engineering submissions forwarded to the City for approval of both private and public developments.

Information about the process and requirements for Site Plan Control applications are included in the Site Plan Manual available from Planning and Building Services.

To ensure submissions to the City are complete, the Engineering Standards Manual should be read in conjunction with the:

- City of St. Catharines Standard Drawings, which include additional technical requirements
- Niagara Peninsula Standard Contract Document (NPSCD)
- Ontario Provincial Standards for Roads and Public Works (OPSS)
- Ontario Provincial Standard Documents (OPSD)
- Transportation Association of Canada Manual (TAC)
- Niagara Region Facility Accessibility Design Standards (FADS)
- Accessibility Act-Design of Public Spaces specifications, standards and guidelines

The City of St. Catharines reserves the right to alter any of these requirements as deemed necessary.

All drawings and documents submitted to the City are to be in a standard metric scale, signed, stamped and sealed by a professional engineer and for municipal projects must be submitted on standard City of St. Catharines sheets a template of which can be provided through the Transportation and Environmental Services department.

Before beginning the detailed design, consultants should consider meeting with staff from Transportation and Environmental Services and/or Planning and Building Services to clarify the City's requirements.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

http://www.niagararegion.ca/business/tenders/npscd/

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/wv?openview&RestrictToCategory=Volume%203&count=1000

http://www.stcatharines.ca/en/governin/resources/fads2007niagarafacility-accessibility-design-standards.pdf

http://tac-atc.ca/en

http://www.e-laws.gov.on.ca/html/source/regs/english/2012/elaws_src_regs_r12413_e.htm

2.0 **General Design Requirements**

Unless otherwise stated, all designs for development-related submissions must include:

- Roads, including hot mix, hot laid asphalt pavement
- Curbs and gutters
- Private walkways and public sidewalks
- Storm and Sanitary Sewers and private drains
- Watermains, hydrants and water services
- Underground utilities (Hydro, telephone, gas, Cable TV., etc.)
- Street lighting
- Street names and regulatory signs
- Tree planting
- Existing tree preservation
- Sodding and reinstatement of boulevards and all residential lots
- Grading to ensure adequate surface drainage
- Landscaping
- Fencing

2.0 Functional Report

A Functional Report is a report that addresses the existing and proposed services that will be impacted by the proposed works. City staff will determine if this report is necessary following a review of the development application. The Functional Report (if required) shall include, but not necessarily be limited to, the following information:

- Roadway Network
  - Impact of the development on any roads within or abutting the Development
- Sanitary Sewer System
  - Drainage areas and proposed flows
  - Main sizing, location and outlets
  - Treatment facilities and pumping stations (if required)
- Storm Sewers and Storm Water Management
  - Drainage areas and proposed flows
  - Designation of major and minor drainage systems – direction of flow and outlet
  - Storm water management facilities, main sizing, location and outlets.
- Water System
  - Main sizing, location and looping
  - Pressure boundaries, booster stations and treatment facilities (if required).

2.1 Engagement of Professional Engineer

The development applicant must retain a professional engineer for any and all development projects, who is to be licensed to practice in the Province of Ontario. The engineer must have experience in the design and execution of land development projects and be acceptable to the City of St. Catharines.

The professional engineer retained by the applicant will prepare and execute the following activities in conjunction with the requirements of the City of St. Catharines, Transportation and Environmental Services Department:

- Preliminary investigation and report
- Pre-engineering survey
- Soils investigation
- Final design and report
- Plan, specifications, tender documents and contracts
- Cost estimate
- Applications
- Calling of tenders
- Analysis of bids and recommendations to the applicant and City staff
- Setting out the work
- General administration of construction, (as per Professional Engineers of Ontario Engineering Services to Municipalities Guidelines)
- Resident supervision of construction (as per PEO Engineering Services to Municipalities Guidelines)
- As-constructed drawings, including individual property lateral cards and value sketches,
- Co-ordination of all utilities (gas, telephone, hydro, cable T.V., etc.)

http://www.peo.on.ca/index.php/ci_id/22117/la_id/1.htm

3.0 Engineering Submission Requirements

Engineering drawings and specifications must be prepared according to current City Standards including the Niagara Region CAD Standard and the Niagara Peninsula Standard Contract Document (NPSCD). Additional requirements for development-related submissions are found in Section 4.0 of this manual.

http://www.niagararegion.ca/business/tenders/npscd/

3.1 Engineering Drawings

A list of requirements for each plan is included in this section, as well as a listing of general requirements which apply to all plans, unless otherwise noted.

All drawings shall be neat, legible and completed to the Niagara Peninsula CAD Standards (NPCS), Where plans require more than one drawing, match lines shall be provided, showing a key plan and both reference drawing numbers, preceding and following, plus station.

http://www.niagararegion.ca/business/tenders/ngcs.aspx

All drawings must be on A1 format (600mm x 900mm), with a horizontal metric scale of 1:200 and a vertical metric scale of 1:50. Metric scale for general plans shall be a minimum of 1:1000.

All sewers, watermains, manholes, manhole numbers, pipe diameter, direction of flow, pipe class and bedding, and service connections must be shown on all drawings.

A complete set of drawings includes:

- Title sheet
- General Plan of Services
- General Lot Grading Plan
- Sanitary Drainage Area Plan
- Storm Drainage Area Plan
- Plan and profile drawings
- Construction details (where required)
- Street Lighting Plan (where required)
- Erosion Control Plan (where required)
- Tree Preservation Plan (where required)

3.1.1 Title Sheet

The Title Sheet must include the following:

- Name of the development
- Name of the developer
- City of St. Catharines
- Name of the consulting engineer

- Key plan at a scale of 1:10,000 indicating the location of the proposed
  development and the proposed new street alignment
- Index to each drawing constituting the complete set indicating drawing
  number and title

3.1.2 General Plan of Services

To a scale of 1:1000 showing the following:

- Roads, lots and their numbers
- Sanitary and storm sewers including pipe diameter and direction of flow
- Watermains, hydrants and valves
- Manholes and catchbasins
- Culverts and easements
- Existing streets and services surrounding the development and their relation to the proposed work
- Location and description of all available benchmarks

3.1.3 General Lot Grading Plan

To a scale of 1:500 showing the following:

- Existing and proposed elevations at all lot corners
- Existing contouring at 500 mm elevation intervals for the area under consideration, including sufficient area of the adjacent lands to establish the overall drainage pattern
- Proposed road elevations at 25 m intervals (maximum), at changes in grade, and at all intersections, and the location of catchbasins, proposed top of curb elevation in front of each lot, and at each lot corner.
- Percentage grade along the gutter at the outside edge of road for any cul-de-sac,
- Minimum basement floor elevations of proposed structures susceptible to basement flooding
- Proposed apron elevation of all houses
- Proposed ground elevation at the rear or all rear walkouts, rear back split and front split lots, or where steep grades from the front to the rear of the lot are encountered
- Proposed drainage easement and rear yard swales and invert elevations of rear yard swales
- Direction and percentage grade of surface drainage on individual lots, swales and driveways
- Proposed rear lot catchbasins and top elevations
- Typical sections for all proposed drainage courses and swales
- Existing surface drainage features such as ditches, channels, ponds or swamps,
- For each lot, a proposed drainage type shall be specified

- Typical detail drawings of proposed drainage types as per City of St. Catharines Standard Drawings shall be included
- All proposed embankments with hatched lines and proposed top and toe of embankment elevations and degree of slope, e.g. 3:1. 4:1
- Location of all proposed retaining walls and proposed elevations including cross-sections
- Location of all street catchbasins
- Any additional plans, sections and details that may be required for drainage courses, major overland storm routing and erosion protection, irregular or steep topography, and screening and noise abatement as may be requested by the City Engineer or his/her designate.
- Proposed elevations shall be shown at the lot corners, top of catchbasins, building aprons and ground floor, along the top of curb and centre line of all roads and parking areas and at strategic points along property lines, swales, etc. such that the proposed drainage pattern is clearly indicated by arrows showing direction of flow.
- All swales must be shown in detail, including cross sections, and include the length of the swale with the percentage grade along the swale. The minimum grade along any swale shall be 2%.
- A legend shall be included in every lot grading plan clearly indicating existing elevations, proposed elevations, etc.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

3.1.3.1 Certification by Engineer or Surveyor

- The following note shall be placed on the proposed grading plan and duly signed, sealed and dated by the professional engineer or Ontario land surveyor .:

> I hereby certify that this proposed grading will be compatible with adjacent lands and that all surface drainage originally flowing through, onto or from this site is being accommodated and the proposed development will drain satisfactorily to the present existing grades of adjacent properties.
>
> NAME: ______________________
>
> SIGNATURE: ______________________
>
> FIRM: ___________________________
>
> DATE: __________________

- The following note shall be placed on the As-Constructed grading plan and duly signed, sealed and dated by the professional engineer or Ontario land surveyor:

> I have taken the field elevations shown with respect to the final grading and do hereby certify that the building constructed and grading of the General Grading and Lot Grading plans are in conformity with the approved plans. I further certify that this development will drain satisfactorily and such grading has not adversely affected adjacent properties.

3.1.4 Sanitary Drainage Area Plan

To a scale of 1:1000, unless otherwise approved by the City Engineer showing the following:

- Proposed sanitary sewers, manholes and appurtenances, indicating grade, pipe size, type of pipe, length of each section of pipe and direction of flow
- Drainage areas within the development and the limits of outside areas within the development and the limits of outside areas draining into the proposed system
- Area in hectares, direction of flow and for existing & future (ultimate) development or population density

3.1.5 Storm Drainage Area Plan

3.1.5.1 Major Storm

To a scale of 1:1000, unless otherwise approved by the City Engineer showing the following:

- Major storm system flow route along streets and easements including controlling elevations, grades, direction of flow and sizes of conduits and swales incorporated in the system
- Limits of area outside the plan draining through the proposed major system for temporary & ultimate development
- All existing drainage channels and the method or incorporating these channels into the proposed major system
- Location of catchbasins and size of orifice plates limiting flow in the catchbasins leaders (if required)
- Detention or retention basis
- When split drainage is used, the major system overland routes from the rear lot catchbasins should be shown.

3.1.5.2 Minor System

To a scale of 1:1000, unless otherwise approved by the City Engineer showing the following:

- Proposed storm sewers, manholes, catchbasins indicating grade, pipe size, type of pipe, lengths and direction of flow
- Ditches, culverts and ponds, where required, showing all necessary information as above
- Drainage areas within the subdivision and the limits of areas outside the plan draining into the proposed system for temporary & ultimate development
- Area in hectares, direction of flow and runoff coefficient

3.1.6 Plan and Profiles of Road

Plan and profile drawings must be drawn for all streets and easements within the development as well as for any existing streets easements upon which the development may front.

The City will designate chainages for roads forming a continuation of existing streets. All chainages shall be calculated along the street centrelines. There must be at least two ties provided per sheet to determine the relationship of the road centerline to the property bars. All appurtenances and construction details are to refer to applicable City Standard Drawings or Ontario Provincial Standards Drawings (OPSD).

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Any design details not covered by the above requirements, should be put in the form of special design standards and attached with the contract plans with the approval of the City Engineer or his/her designate.

Plan and Profile drawing shall be drawn at a horizontal scale of 1:200 and at a vertical scale of 1:50, and shall show the following:

- Existing and proposed sewer, giving for each section the size, material class, pipe grade, and bedding requirements
- All sewer appurtenances. The manholes must be numbered on both the plan and the profile. Designation between sanitary manhole numbers and storm manhole numbers must be shown.
- Details of manholes such as number, location, standard details and safety grate elevations should be shown.
- All manhole invert elevations, including a description & rear yard catchbasin invert elevations,
- Existing ground profile,
- Proposed centerline of road profile (top of pavement), showing grades, chainage of P.V.I.'s and vertical curve data
- Radius and angle of intersection as well as tangent arc length and chord for all horizontal curves,

- Chainage of beginning of curve (B.C.), end of curve (E.C.) and point of intersection (P.I.), etc. is to be shown on the plan and indicated as such,
- Names of streets given outside and above the road allowance.
- Curb radii for all intersections and on bends, where applicable.
- Location and description of the nearest geodetic benchmark on each drawing.

3.1.7 Construction Details

A details page must be provided for any detail referenced on any of the preceding drawings or any additional necessary detail drawing required by the City Engineer such as a trench section or road cross section

3.1.8 Street Lighting Plan

To a scale of 1:1000 showing the following:

- Roads, lots and their numbers
- The position of all new light standards within the development
- The position of existing light standards surrounding the development and their relation to the proposed work
- Details of and tabulated specifications for the type of luminaire proposed.
- All streetlight designs shall conform to the Illuminating Engineering Society of North America's (IESNA) Manual for Roadway Lighting (RP-8-14)

https://www.ies.org/store/product/roadway-lighting-ansiies-rp814-1350.cfm

3.2 Ministry of the Environment Approval

An Environmental Compliance Approval (ECA) is required for activities that fall under Environmental Protection Act Section 9 & 27 and Ontario Water Resource Act section 53. It is the developer's and his consultant's requirement to obtain the necessary ECA approval.

http://www.ontario.ca/environment-and-energy/environmental-approvals

http://www.ontario.ca/laws/statute/90e19

http://www.ontario.ca/laws/statute/90o40

3.2.1 Approval for Sanitary Sewage and Stormwater Collection System and Stormwater Management Facility

The engineering consultant must submit four (4) copies of the completed Environmental Compliance Approval applications for sanitary sewage and stormwater collection system and stormwater management facility to the City to be signed by the City Engineer.

The following must be provided and found to be acceptable before the City Engineer will sign application:

- Letter or form of transmittal
- Engineer's report
- Supporting documentation – servicing study, charts, graphs, etc.
- Plan and profile drawings
- Contract specifications – detail drawings and standards
- General drainage area plans
- Design sheet and computations

Once the applications are signed by the City Engineer, the consultant must submit the completed application to the Niagara Region or MOECC for approval on behalf of the applicant. One copy of the complete application will be retained by the City.

Niagara Region conducts the necessary policy checks and submits its recommendation with the appropriate information to MOECC.

The MOECC will review the submission and issue an Environmental Compliance Approval (ECA) if the requirements are met.

A copy of the ECA is made available on the MOECC's website and the original is forwarded to the Office of the City Clerk. A copy is then forwarded from the Clerks Department to the City Engineer which is then further forwarded to the applicable staff managing the project.

3.2.2 Approval for Water Distribution System

The City of St. Catharines received its Drinking Water Works Permit from the Ministry of Environment and Climate Control (MOECC) on October 29, 2009 (revised February 14, 2013) and a Municipal Drinking Water License on October 30, 2009.

The Permit authorizes specific alterations to the drinking water system including the addition, modification, replacement or extension of watermains that meet certain conditions set out in the Permit. Any alterations that do not meet conditions will require a Permit amendment.

The consulting engineer is required to complete either:

Form 1 - Record of Watermains Authorized as a Future Alteration or
Form 2 - Record of Minor Modifications or Replacements to the Drinking Water System

These forms are published by the Ministry of the Environment and Climate Control and must be submitted with a copy of the servicing drawing to the City for approval. Once the approval is completed the form will be signed by the City Engineer and a copy provided to the developer.

Consultants and Contractors working on the City's water distribution system shall make themselves aware of their duties and responsibilities under the Safe Drinking Water Act (SDWA).

3.3 Contract Documents

Contract documents are to be prepared as per the Niagara Peninsula Standard Contract Document. The number of copies of the contract to be provided will be specified for each project.

http://www.niagararegion.ca/business/tenders/npscd/

Additional requirements for development related applications are found in Section 4.0 of this manual.

3.4 Cost Estimate and Proposed Construction Schedule

An itemized cost estimate for the construction of the works must be prepared & provided to the City as per the NPSCD and a breakdown of any items designated to be cost-shared must be listed separately.

A proposed construction schedule for all construction activities is to be provided to the Transportation and Environmental Services department. The City must be notified of any changes to the original schedule which may occur.

3.5 As Built Record

3.5.1 As-Built Drawings

As-built drawings constitute the original Engineering Drawings which have been revised to show as-built conditions. The as-built drawings must be submitted to the City for its permanent records. All as-built drawing submissions must include two (2) hard copies and a digital copy in both .dwg and .pdf formats The PDF version must be full size, to scale, stamped, signed and dated.

As-built plans for municipal services are to be completed and submitted prior to acceptance of the primary services. As-built drawings must be submitted for review by the City no later 30 days after completion of primary services.

The as-built lot grading plans must also be submitted prior to acceptance of the development for the City's records. The elevations must be based on a survey to be completed when 80% of the lots have been built. The as-built lot grading plan must indicate elevations at the following locations:

- All lot corners
- At grade brakes/changes
- Building aprons
- Catch basin tops
- At the mid-lot, bottom of swale and any other area necessary for areas that appear to be problematic
- Strategic point along property lines to clearly establish a drainage pattern and show that it will not adversely affect adjacent properties

The as-built revisions shall be based upon an as-built survey of all the development services and must include a field check of the following items:

- Location of manholes for all utilities
- Location of catchbasins
- Location of hydrants
- Location and ties to valve chambers and valve boxes
- Manhole inverts
- Pipe sizes
- Distance between manholes
- Special manhole details
- Catchbasin inverts

The as-built drawings for all the municipal services must incorporate all revisions found in completing the as-built field survey and include a check of the following items and incorporation of the necessary revisions.

- Sewers
    - Percent grade
    - Invert elevations at manholes, catchbasins and at plugs for future extensions
    - Top of sewer pipe at centerline of creek crossing
    - Pipe type, class and bedding
    - House connections – chainage of connections to mainline pipe and tie or chainage at the street line

- Watermains
    - Percent grade for all watermains 400mm and greater
    - Top of pipe and/or invert elevations, where necessary,
        - e.g. where watermain has been varied from normal depth requirements, in field, to avoid conflict with other buried services

- Top of watermain at centerline of creek crossing
  - Pipe type, class and bedding
  - House connections -chainage of connections to mainline pipe and tie or chainage at the street line
  - Locations of watermain valve box and valve chambers are to be dimensioned up or down the road from the nearest manhole and an offset distance from the centerline of the road or back of the curb.
  - Where watermains are not within road allowances or near sewers, ties to SIB's shall be used.

- Original design information (inverts, grades, etc.) is to remain on drawings but crossed out, with as-built information shown adjacent to original information. For example:
  - E. Inv. 97.5 (original design invert)
    - 97.62 (as constructed invert)
- Label As-built Drawings (shown in revision column with date)
- Registered Plan Number is to be shown on plan view of each drawing including general plans.
- Lot and block numbers or municipal numbers must be in conformity with the registered plan.
- Street names must be in conformity with the registered plan or as approved by the municipality.

3.5.2 Lateral Cards

Lateral cards referencing all lateral locations within a development must be submitted to the City. For development-related projects lateral cards, completed by the consulting engineer, must be submitted upon completion of the primary services. For municipal projects submission is required before the watermain is operational.

All lateral cards are to be submitted prior to the release of any primary service securities.

Lateral cards must indicate the following:

- Sanitary Services
  - Locations of service tie connections at the main line sewer are to be dimensioned along the mainline sewer from each manhole.
  - Locations of services at street line are to be dimensioned from the lot corners and the elevation of the service invert at street line is to be recorded.

- Storm Services and Rear-Yard Catchbasin Leads
  - Location of service and catchbasin lead tie connections at the main line sewer are to be dimensioned along the main line sewer from each manhole.
  - Locations of services at street line are to be dimensioned from the lot corners and the elevation of the service invert at street line is to be recorded.
  - Catchbasin locations are to be dimensioned as a distance along the storm sewer from the nearest manhole and the elevation of the catchbasin rim and lead invert recorded.

- Water Services
  - Water service main stops, tapping valve or service branch trees are to be dimensioned along the alignment of the water main stops from the nearest mainline valve. Curb stops and boxes are to be dimensioned from lot corners.

3.6 Valve Sketches

Detailed sketches of each valve location must be completed; for development-related projects submission sketches are required upon completion of the primary services. For municipal projects, sketches must be submitted within 30 days after the watermain is operational.

Sketches are to include dimensions for the location of valves and fittings. The dimensions must be given to existing manholes within close proximity and street line or curb line. Where more than one valve is located within an intersection, one sketch may be prepared for the whole intersection.

4.0 Additional Engineering Submission Requirements for Private Development Applications (to be assumed by the City when work is completed)

Prior to the preparation and execution of a private development application such as a:

- subdivision,
- servicing or
- development agreement,

The City of St. Catharines requires the works to be designed and constructed by the developer's engineer and contractor. Once the works are completed to the City's satisfaction the works will be assumed by the City. The required drawings and specifications, provided by the consulting engineer are as detailed below.

4.1 Letter of Transmittal

A formal letter indicating the submission date and number, contents of the submission package, and the name of the appropriate contact personnel must be submitted.

4.2 Engineering Design Brief

The engineering design brief is a technical report summarizing the intent of the project, and outlines the design assumptions, calculations, supporting documentation and references to previous studies, for each component of the development.

These include:

- Sanitary sewer design calculations,
- Storm sewer design sheets utilizing standard City form,
- A soils consultant report if deemed necessary by the City,
- Calculations for pipe strength and bedding requirements,
- Engineering drawings
- MOECC applications

4.3 Contract Documents

Upon final Engineering submission for approval of the Engineering Drawings, two (2) copies of the Contract Documents for the project are required to be provided to the City of St. Catharines for their review.

Prior to commencement of construction of services, two copies of the Contract Documents, one with prices and one without plus two (2) sets of contract drawings are required to be provided.

All development related construction shall be as per the Niagara Peninsula Standard Contract Document for Special Provision & General Contact provisions.

http://www.niagararegion.ca/business/tenders/npscd/

4.4 Additional Documentation

Other general requirements include:

- Construction cost estimate and proposed construction schedule
- Proposed final plan for registration (M-plan)
- Reference plan for easements being conveyed to the City

4.5 Preparation of Agreement

The draft of the development agreement will be prepared by the City of St. Catharines Planning and Building Services Department and forwarded to the City Solicitor. The solicitor will then prepare the final agreement and obtain Council approval where necessary for execution of the agreement by the City.

4.6 Security and Cash Payment Requirements

4.6.1 Engineering Securities

The required securities for a Site Plan Agreement are specified in the Site Plan Agreement Manual.

For all other agreements that require servicing within the municipal road allowance, the developer must provide adequate securities to ensure construction and reinstatements are completed to the City's satisfaction. The required security is calculated based on 10 per cent of all primary services, 120 per cent of all secondary services and 120 per cent of street lighting.

Securities and/or cash deposits will be required to cover the cost of the required boulevard plantings.

The City reserves the right to plant any boulevard trees and require a cash deposit in order to complete this work.

For sites located on regional roads, boulevard trees are planted by the Region at the cost of the owner. A cash deposit will be required in this regard, the amount of which will be determined by the Region on a case-by-case basis.

A lot grading security is to be provided based on $500 per lot and to be no less than $20,000 for the entire development.

4.6.2 Engineering Inspection Fees

Inspection during construction may be carried out by the City, or a consultant hired by the City and the cost of such undertaking shall be paid by the developer prior to commencement of construction.

The cost of the inspections fees is based on a percentage of the estimated construction costs of all storm sewers, culverts, sanitary sewers, watermains, roads, curbs and sidewalks and all other construction works pertinent to the development under the jurisdiction of the City of St. Catharines.

The amount of money to be paid for inspection will be determined by the following scale of fees:

- 4.5 percent of the total cost of services up to $100,000.00, with a maximum payment of $4,500.00;
- 4 percent of the total cost of services in excess of $100,000.00 up to $400,000.00 with a minimum of $4,500.00
- 3.5 percent of the total cost of services in excess of $400,000.00

These fees shall be payable in cash or certified cheque to the Corporation of the City of St. Catharines.

4.6.3 Sewer and Water Testing Fees

The estimated cost to inspect and test all sewers and watermains within the development after completion of primary services and prior to final assumption must be paid by the developer prior to the registration of the subdivision agreement.

4.6.4 Street Sign Fees

The cost to install all required road signage throughout the development must be paid by the developer prior to the subdivision agreement being registered and shall be based on the number of signs required.

5.0 **Roads**

Road classification is subject to the approval of the City Engineer and is described in the Official Plan (The Garden City Plan).

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

In general, residential roads are classified as arterial, collector or local.

Arterial roads are intended to carry large volumes of traffic, moving at medium to high speeds. Arterial roads serve the major traffic flows between the principal traffic generators and connect with collectors and freeways. Designs of arterial roadways are to meet the requirements of the controlling authority.

Collector roads provide for both traffic service and land access. The primary traffic service function is to carry traffic between local streets and arterial roadways and may act as transit corridors.

The function of a local road is to provide access to those properties which directly front on it and enable movement of low volumes of traffic to collector roads.

5.1 Clearing and Grubbing

The road allowance must be cleared of all trees shrubs and other obstructions for the width required for the proper installation of all roads, services, and other works. The only exception is for trees and shrubs which will be used in the final landscaping, or subject to a tree preservation plan.

Rough grading must be completed to bring the travelled portion of the road to the necessary grade and in conformity with the cross-section shown on the City's Standard Drawings. The sub-grade for all roads shall be properly shaped and thoroughly compacted prior to any application of granular base course materials. In all cases, topsoil shall be stripped for the complete width of the right-of-way and stockpiled at locations approved by the City Engineer.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

For existing roads, the area of clearing will be determined after the road is cut to the sub base and the site depth is determined.

5.1.1 Geometric Design Standards

Geometric design standards must be in accordance with the Transportation Association of Canada Manual (TAC), the Geometric Design Standards for Ontario Highways from the Ministry of Transportation Ontario (MTO), Roadside Safety Manual , also from MTO.

http://tac-atc.ca/en

http://www.mto.gov.on.ca/

Roadway Design Criteria			
	Local Road	Collector Road	Arterial Road
Minimum Boulevard Grade (Sidewalk to curb)	2.0%	2.0%	2.0%
Minimum Grade	0.3%	0.3%	0.5%
Maximum Grade	8.0%	8.0%	5%
Maximum Grade for Through roads at intersection	3.5%	3.0%	3.0%
Maximum Grade for Stop Road at Intersection	2.5%	2.0% at Local 1.5% at Collect	1-2.0% back fall at Local 1.5% at Collect/Arterial
Minimum curb grade at radius of intersection	0.7%	0.7%	0.7%
Minimum Curb Radius at Intersection with Arterial Road:	9 m	13 m	15
Minimum Curb Radius at Intersection with Collector Road:	9 m	13 m	13
Cul-de-Sac Minimum Outside Curb Radius	15 m	N.A.	N.A.
Cul-de-Sac Minimum Island Curb Radius	7.5 m	N.A.	N.A.
R.O.W.	18m/20m**	20 m	26.2 m
Pavement Width	8.5 ***	10 m***	Varies
Minimum Centerline Radius Proposed	90*	130	130-250
Design Speed	50 kph	60 kph	60 - 80 kph
Vertical Curve Minimum sight stopping distance LVC=KA (MTO Manual) K. for Sag K. for Crest	65 m 12 8	85 m 20 15	85 -140 m 20-32 15-36
Superelevation	None	None	None
Intersection Angle	70-110 degrees at local, 80-100 degrees at collector****	80-100 degrees*****	90 degrees

*   Except at 90 degree corners for crescents and courts
**   At discretion of City Engineer
*** Measured curb face to curb face
**** All streets are to intersect at 90 degrees unless existing road alignments or property restrictions require otherwise

5.1.2 Alignment

Horizontal and vertical alignment is to conform to the requirements as outlined in Section 5.1.2, Geometric Design of this manual and the Ontario Provincial Standard Drawings (OPSS).

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

All curves must meet the geometric design standards. Vertical curves are required for changes in grade greater than 1% for collector and 1.5% for locals.

The minimum length of each grade is 6 metres. Cul-de-sacs are to have a minimum grade of 0.5% around the longest curb, to ensure adequate surface drainage.

5.1.3 Road Pavement Design

The pavement design for all roads will be considered on an individual basis but at a minimum must be based on the design provided in the chart below. A geotechnical consultant with experience in pavement design must provide the required design for all proposed roads. The composition and construction thickness of the road pavement shall be designed based upon the following factors:

- Mechanical analysis of the subgrade soil
- Drainage
- Frost susceptibility
- The future volume and class of traffic expected to use the pavement
- Bus/ public transit routes

Pavement shall be designed for a minimum Average Daily Traffic (ADT) of 1000 vehicles and an anticipated life for 20 years.

5.1.4 Minimum Pavement Structure

The following table outlines the minimum pavement structures required by the City. Where the geotechnical report and proposed pavement design exceed the minimum requirements the designer shall specify the higher strength pavement structure.

Minimum Pavement Structure

Road Classification	Granular ‘A’ Base (mm Depth)	HL8 HS Asphalt Base Course	HL3 HS Asphalt Surface Course
Local	325	50	50
Local – Bus Route	380	75	50
Collector	380	75	50
Arterial	450	100 (2 Lifts)	50

5.1.5 Road Allowance Cross-Section

The typical road allowance cross-section shall be as per the City's Standard Drawings. Details shall be provided for any approved special provisions required due to unique physical conditions on the site or for existing or future design conditions such as retaining walls, slope protection, culverts, bridges or special cross fall conditions.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

5.1.6 Intersections

At the intersection of two roads, any transition of the minor classification road shall not interfere with the normal cross fall of the major road. A 1 per cent to 2 per cent back fall grade shall be provided on all road profiles where local streets intercept with arterial roads. The backfill grade shall be from the crown of the major road to the end of radius or first catchbasin on the local road.

5.1.7 Road Sub-Drains

In general, sub-drains will be required to run continuous along both sides of all roads, as per the City's Standard Drawings. However, reducing sub-drain requirements for a particular development may be considered where a recognized soils consultant indicates that there will be no adverse effects to the road either during or after construction.

In all cases, sub-drains will be required for a minimum length of 6 m on the upstream side of all catchbasins.

Sub-drain may not be required if the existing soil provides acceptable drainage. Boreholes and a soils report must be provided to confirm the soil is acceptable.

5.2 Curb

Barrier curb and gutter as shown on Ontario Provincial Standard Drawing shall generally be used on local streets.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Capping of curb depressions will not be permitted however saw cutting of curb depressions may be allowed.

Mountable curbs as per Ontario Provincial Standard Drawing may be used on the approval of the City Engineer.

Two-stage poured curb construction in accordance with City Standard Drawing may be used with the approval of the City Engineer.

5.3 Sidewalks

Concrete sidewalks as per the City's Standard Drawings shall be constructed on both sides of all roads and at such other locations as may be determined by the Planning and Building Services Department of the City of St. Catharines. Sidewalks must extend through driveway entrances unless otherwise directed. (E.g. signalized intersections).

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

The minimum width of sidewalks based on the road type is outlines below.

Local Road (non-curb face)	1.5m
Collector and Arterial Road (non-curb face)	1.5m
Curb Face (all roads)	1.8m
Bridge or Tunnel (structures) with a wall/railing	2.4m

Requirements for the materials and the production of concrete sidewalks are:

- Minimum 28 day compressive strength 32 MPa
- Class of exposure C-2
- Maximum nominal size of coarse aggregate 19 mm
- Slump at point of discharge 80 ± 30 mm
- Air content 6.5 ± 1.5%
- Maximum water/cementing materials ratio 0.45

5.4 Boulevards

Boulevards must be graded to ensure a minimum 2 per cent grade from the sidewalk to the roadway and be sodded on a minimum of 100 mm of topsoil from curb line to property line.

During development boulevards must be kept free of rubbish and other materials.

All sod that fails to grow, or dies within one year of placement, must be replaced at the developer's expense.

5.5 Boulevard Trees

A minimum of one 60 mm caliper tree shall be planted on the fronting road allowance/boulevard of each property. Where space permits along the fronting road allowance, and along any flanking boulevards, additional trees are required at 6 to 9 metre centers.

Only tree species approved by the City may be planted. The Street Tree List provides a list of acceptable species organized by street address. Species selection may be site specific and must have regard to site characteristics, including the presence of any above and below-ground utilities.

http://www.stcatharines.ca/en/livein/resources/Tree-Planting-List.pdf

Trees cannot be placed within 15 m of an intersection, and cannot impede sightlines at driveways. If, as part of a development proposal, any works are proposed that would be within the root plate of a boulevard tree (distance from trunk to drip line +20% where the drip line is assumed to be the natural longest branch top of the lowest branch) or involve infringement of any kind on that area, the Forestry Foreman must review the proposal to indicate if any type of tree protection will be required. The tree health will be assessed at this time. If deemed necessary, the Forestry Foreman may ask for the applicant to provide a Tree Protection Plan to be approved.

5.6 Driveway Entrances

The contractor is required to provide asphalt, concrete or other acceptable hard surface, in good condition for each driveway from the travelled portion of the road to the lot line or sidewalk.

The maximum widths of curb cuts at the street line are determined by the applicable zoning regulations. Where mutual driveways are constructed between two adjoining properties, the curb cut-out must be continuous for driveways separated by less than 1 metre.

The maximum grade for an access driveway, from the curb line to the garage is 8%. Employed grade of 10% may be permitted only in exceptional cases where physical conditions prohibit the use of lesser grades. The minimum grade from the street line to the curb line where there is a sidewalk shall be 2%. See Section 9.1.3 for reverse driveway requirements.

The radius of curvature from the road into apartment, commercial and industrial driveways will be designed to accommodate the anticipated vehicular traffic without causing undue interference with the traffic flow on the street.

Standard Entrance accesses are as per Ontario Provincial Standard Drawings.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

5.7 Daylighting

When streets intersect with collector or arterial or local streets, the City engineer may request land for daylighting triangles. The amount required is based on the classification of the intersecting roads and shall be determined by the City Engineer.

5.8 Footpaths and Walkways

All footpaths and walkways require a 1.5 m wide concrete sidewalk, built to City Standards and a minimum, 1.5 metre high chain link fence on both sides along property line unless otherwise specified in the City's Fence By-law.

https://stcatharines.civicweb.net/Documents/DocumentList.aspx?ID=18244

5.9 Emergency Accesses

Emergency Accesses are to be a minimum width of 3.9 m (4.5 m in instances where a walkway is incorporated with the access) and be built with 225 m base course stone and 50 mm HL3 surface course asphalt.

5.10 Street Name and Traffic Sign Requirements

The owner must pay for permanent street name and traffic signs, as well as installation of the signs. The City Engineer will determine which traffic control signs are required to ensure the safe and efficient flow of traffic.

5.11 Utility Installation

Location and installation details for utilities must be shown on all road cross sections and streetscape plans. Prior to installation, a municipal consent must be approved by the City Engineer in which the utility plans must match the approved road cross section and streetscape plans.

All utility trenches within the road allowance are to be backfilled and compacted to 95 per cent Standard Proctor Density. Backfill material shall be in accordance with the requirements of the City Engineer.

5.12 Street Lighting

The developer is responsible for the design, installation, inspection and connection of all streetlight plant in accordance with applicable provincial and City standards. This includes but is not limited to, poles, arms, luminaires, wiring, conduit, junction boxes, and supply and distribution panels.

All streetlight designs shall conform to the Illuminating Engineering Society of North America's (IESNA) manual for Roadway Lighting (RP-8-14). The City Engineer must approve any lighting assembly that differs from the approved City standard.

http://www.ies.org/

https://www.ies.org/store/product/roadway-lighting-ansiies-rp814-1350.cfm/

5.13 Electrical Distribution

Design and installation of the electrical distribution system for the proposed development is to meet the requirements of the local hydro authority.

Underground street wiring and wiring to the lots and houses are mandatory. In circumstances where underground wiring is not practical, an alternative may be agreed upon.

The location of all overhead wires must be indicated and must not interfere with the proposed development. Verification must be provided that all proposed structures meet the clearance from all overhead conductors.

Wherever possible, the developer will supply the City and/or the local electrical supply authority with easements.

6.0 **Sanitary Sewers**

This section outlines the criteria to be used for sanitary sewer design. Reference is made throughout this section to Ontario Provincial Standard Drawings (OPSD) when dealing with standards for sewers, manholes, catchbasins, etc. These OPSD's shall be used whenever possible.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

6.1 Design Flows

Calculation of sewage design flows shall conform to the latest edition of the Ontario Ministry of the Environment and Climate Control's Design Guidelines for Sewage Works.

Peak domestic flows shall be calculated using the following formula:

$$Q\ (d) = \frac{PqM}{86.4} + IA$$

Where:

Q (d)= Peak domestic sewage flow (including extraneous flows) in L/s
P = Design Population, in thousands
q = Average daily per capita domestic flow in L/cap·d (Exclusive of extraneous flows)
I = Unit of peak extraneous flow, in L/(ha·s), consult applicable references for values
A = Gross tributary area in hectares
M = Peaking factor (minimum M = 2.0), determined using the Harmon formula:

$$M = 1 + \frac{14}{4 + P^{0.5}}$$

6.2 Sewer Design

Sanitary sewer capacities shall be computed by using Manning’s Equation on the basis of sewer pipe flowing full.

Manning's Equation

$$Q = VA = \frac{k}{n} A\, R^{2/3} S^{1/2}$$

Where:

Q	= Flow (l/s or cfs)
V	= Velocity (m/s^2 or ft/s^2)
A	= Cross-sectional area (m or ft)
R*	= Hydraulic radius (m or ft)
	= A/P
P	= Wetted perimeter (m or ft)
S	= Slope (%)
n	= Manning's roughness coefficient
k	= 1.0 (Metric) or 1.486 (Imperial)

*for pipes flowing full (used for design)

$$R = {}^{D}/_{4}$$ Where D = diameter (m or ft)

6.2.1 Roughness Coefficients

For all types of pipe, a roughness coefficient of n = 0.013 shall be used.

6.2.2 Velocity and Grade

The minimum velocity for all City sewers is 0.6 m/s (2ft/s). The minimum grade (slope) shall be as per the chart below except the minimum grade of the first upstream leg is 0.6%. The maximum velocity is 3m/s (10ft/s).

Sewer Size (mm)	**Minimum Slope in m / 100m (%)**
200	0.40
250	0.28
300	0.22
350	0.17
375	0.15
400	0.14
450	0.12
525	0.10
600	0.08
675	0.067
750	0.058
825	0.052
900	0.046
975	0.041
1050	0.037

6.2.3 Minimum Size and Depth

The minimum size for sewer mains is 200mm (8”) diameter and 100mm (4”) diameter for service connections.

For residential, commercial and institutional areas, the minimum depth is 2.5 metres. Depths of cover less than this may be approved by the City Engineer where this minimum is not feasible.

For industrial areas, the minimum depth is 2.15 metres.

Depth is measured from the final centerline finished road elevation to the top of the sanitary sewer. In all cases, the proposed sanitary sewers shall be installed at sufficient depth to service lands external to the site as determined by the City.

6.2.4 Location

Sanitary sewers will be located in the centre of the road allowance, as shown on the City's Standard Drawings. If common trenching is required for the storm and sanitary sewer, the consulting engineer must prepare special design standards and provide to the City the specification for such requirements.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

Any non-standard design for locations will required the approval of the City Engineer.

6.2.4.1 Easements

The minimum width of easements for pipes shall be determined by the consulting engineer to account for the number of pipes, pipe size, depth and excavation of open-cut method. The easement width must never be less than 6.0 metres. The developer must grant to the City permanent easements for any drainage works which are not within the road allowance.

6.2.5 Manholes

Manholes are required at each change in alignment, size, and grade, pipe material, at all junctions and at the end of each line. They are also required at the points of connection over 200 mm in diameter as per Section 6.4.

Manholes must be poured or precast concrete as detailed on the Ontario Provincial Standards Drawings (OPSD).

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

The maximum change in the direction of flow in any sanitary sewer manhole shall be 90 degrees for sewers with diameter less than 450mm and 45 degrees for sewers with diameter greater than or equal to 450mm. A change of flow direction at acute interior angles shall not be permitted.

The maximum drop allowed across a manhole is 0.6 m. If the design of the sewer system is such that the difference in elevation between the manhole inlet and outlet will exceed 0.6 m, then an external drop structure will be required.

The minimum drop across the manhole for all straight runs shall be sufficient to maintain the design head.

When pipe size does not change through a manhole and the upstream flow velocity does not exceed 1.5 m/s, the following allowances shall be made to compensate for hydraulic losses:

Alignment Change	Drop Required
Straight run	grade of sewer
15 – 45 degrees	0.03 m
45 – 90 degrees	0.06 m

When the upstream flow velocity exceeds 1.5 m/s, the drop required through a manhole shall be calculated.

For all junction and transition manholes, the drop required shall be calculated.

The obvert(s) on the upstream side of a manhole must never be lower than those on the downstream side.

The Ontario Provincial Standard Drawings (OPSD) provide details for manholes up to certain maximum depths; the consulting engineer will analyze individually, each application of the standards, related to soil conditions, loading and other pertinent factors, to determine structure suitability.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

In all cases where the standards are not applicable or the dimensions of a manhole exceed those on Standard Drawings manholes must be individually designed and detailed.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

Safety grating shall be provided in accordance with current Provincial Regulations made under the Occupational Health and Safety Act. Safety gratings are required in all manholes greater than 5.0 metres in depth. Safety gratings shall not be more than 5.0 metres apart and constructed in accordance with the current OPSD.

http://www.ontario.ca/laws/statute/90o01

6.2.5.1 Size

All manholes shall be sized as follows:

Maximum Sewer Diameter (Straight Through)	Maximum Sewer Diameter (Right Angle)	Required Manhole Diameter
≤ 600mm (24")	≤ 450mm (18")	1200mm (48")
675-825mm (27-33")	525-600mm (21-24")	1500mm (60")
900-1050mm (36-42")	675-825mm (27-33")	1800mm (72")
1200-l500mm (48-60")	900-1050mm (36-42")	2400mm (96")

6.2.5.2 Spacing

Generally manholes shall be spaced at:

- A maximum of 100m for pipe sizes 250mm diameter to 750mm diameter
- A maximum of 120m for pipe sizes 825mm diameter to 1200mm diameter
- A maximum of 150m for pipe sizes greater than 1200mm diameter

6.2.5.3 Benching

A bench is required in all manholes (except catchbasin manholes) on both sides of the channel whenever the pipe diameter is less than the manhole diameter. The benching in the manhole shall be a minimum of 225 mm in width in accordance with the current OPSD and shall be sloped no greater than 1:4 nor less than 1:8.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

The type and size of manhole shall be specified on the profile and a detail of the benching shall be shown on the plan portion of the drawing for cases when the benching differs from the normal.

All manhole chamber openings must be located on the upstream side of the manholes.

6.2.6 Mainline Sanitary Sewer Pipe

6.2.6.1 Location

All sanitary sewers must be located as shown on the appropriate road cross section standard. The class, type of pipe, type of pipe bedding and type of backfill must be shown on the profile for each section of sewer.

6.2.6.2 Radius Pipe

The use of radius pipe for deflected pipe will be permitted to achieve changes in horizontal alignment for sewer sizes 1050 mm diameter and larger. The minimum radius allowed for various pipe diameters will be as detailed in the manufacturer's specifications. When pipes are deflected at the joints, the angle of joint displacement shall not exceed 3 degrees.

6.2.6.3 Size

No decrease of pipe size from a larger size upstream to a small size downstream will be allowed regardless of increase in grade.

Pipe bedding and class of pipe shall be designed to suit ultimate loading conditions.

Service connections will not be permitted to sanitary sewers exceeding 7.60 metres in depth. Depth is measured from the final centerline finished road elevation to the top of the sanitary sewer.

A minimum clearance of 225 mm is required between the outside of the pipe barrels at the point of pipe crossing for sanitary sewers and other utilities. In the event that the minimum clearance of 225 mm cannot be obtained, then the pipes at the crossing shall be concrete encased to insure that the pipes are properly bedded.

6.2.6.4 Crossings

Under normal conditions, watermains shall cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.
When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected by providing:

a) A vertical separation of at least 0.5 meters between the invert of the sewer and the crown of the watermain.
b) Adequate structural support for the sewers to prevent excessive deflection of joints and settling.
c) That the length of water pipe shall be centered at the point of crossing so that the joints will be equidistance and as far as possible from the sewer.

Watermain crossings, adhere to the latest MOECC Design Guidelines.

http://www.ontario.ca/ministry-environment-and-climate-change

6.3 Pipe Materials

Unless otherwise approved by the City Engineer sanitary sewers shall be constructed of concrete pipe, polyvinyl chloride (PVC) pipe or polyethylene pipe (PE). Pipe sections shall be joined by means of approved rubber gaskets. The classification of pipe to be used shall be clearly indicated on the plans. The following are materials which shall be used for sanitary sewer construction. Where a standard or specification is provided it is expected that the most current version of that standard / specification is used.

6.3.1 Concrete Pipe (Circular)

- Non-reinforced : 100 mm (4") - 900 mm (36") - CSA A257 .1
- Reinforced : 300 mm (12") - 3600 mm (144") - CSA A257.2
- Pipe joints (rubber gasket type): - CSA A257.3
- Reinforced Concrete Sewer Pipe (300 mm in diameter and larger): steel reinforced, Class II, III, IV or V, as required.

6.3.2 Polyvinyl Chloride (PVC) Pipe

- DR 35
  100 mm (4") - 150 mm (6") – CSA B182.2 and CSA B182.11
  200 mm (8") - 375 mm (15") – CSA B182.2 and CSA B182.11
- DR 28
  100 (4") - 150 mm (6") - CSA B182.1 and CSA B182.11
- Pipe joints - 'Ring-Tite', or approved equal

The design of sanitary sewer systems using PVC pipe shall be based on the modified Spangler Equation for flexible pipe.

$$X = \frac{D_e K W_e + K W_1}{2\,E/3\,(R-1)^3 + 0.061E'}$$

Where

X = Vertical deflection of pipe (cm)
D_e = Deflection lag factor (1.5 for plastic pipe)
K = Bedding factor
DR = Dimension ratio
W_e = Earth load on pipe (N/L in metre)
W_l = Live load on pipe (N/L in metre)
E = Modulus of elasticity of pipe material (for PVC 1120, E=2.76x10^9 pa)
E` = Modulus of soil reaction

For main sewers, the Standard Dimension Ration (S.D.R.) of the PVC Pipe shall not exceed S.D.R.35. For service connections the Standard Dimension Ratio of the PVC Pipe shall not exceed S.D.R.28.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

The bedding required for P.V.C. main sewer and service connections shall be as detailed on the Standard Drawings.

6.3.3 Polyethylene (PE) Pipe

Polyethylene Pipe (PE) shall be manufactured in accordance with the latest revision of ASTM F714 and CSA B182.6 “Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications”. This standard applied to trenchless technology and shall be HDPE 3408 SRD 17 pipe or harder.

6.4 Sanitary Services (Sanitary Building Sewers and Sanitary Drainage Pipe)

Only one sanitary private drain (sanitary sewer lateral) shall be provided for each property unless otherwise approved by the City Engineer. All freehold townhouses, semi detached and single dwellings shall have individual sanitary private drains.

All 100mm to 200mm diameter sanitary private drains shall be installed in accordance with OPSD 1006.01 (rigid main sewer) or OPSD 1006.02 (flexible main sewer) and their connection to existing or proposed mainline sewers conform to the requirements listed here.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

All sanitary private drains with diameters greater than 200mm shall be install as per mainline sanitary sewer specifications.

6.4.1 Connection to Proposed Sewer Main

Where the diameter of the sanitary private drain is greater than 200mm, connections to the proposed main sewer shall be made using a manhole.

Where the sanitary private drain has a diameter less than or equal 200mm, connections to the proposed mainline sewer shall be made using a manufactured wye.

6.4.2 Connection to Existing Sewer Main

Where the diameter of the sanitary private drain is greater than 200mm connections to the existing main sewer shall be made using a manhole.

Where the diameter of the sanitary private drain is less than or equal 200mm connections to the existing main sewer shall be the following.

6.4.2.1 A manufactured wye can be used if:

a) The main sewer diameter is less than or equal to 450mm (18").

6.4.2.2 A strap-on-saddle can be used if:

a) The main sewer diameter is less than or equal to 450mm (18") AND
b) 2/3 of the main sewer diameter is greater than the diameter of the private drain

6.4.2.3 A core and insert-a-tee method can be used if:

a) the main sewer is greater than 450mm (18")

6.4.2.4 A manufactured tee can be used if:

a) the sanitary private drain requires a vertical riser as per OPSD 1106.01 or City Standard Drawings.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

6.4.3 Clean Outs

A clean out must be provided at the property line for all new sanitary laterals as the Standard Drawing.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

6.4.4 Pipe Size

Service connections for single family and semi-detached units shall be 100 mm diameter. Service connections for multiple family and other blocks, commercial, institutional Areas are to be sized individually according to the intended use.

6.4.5 Depth

The depth of the service connections for single family units and semi-detached units, at the street line, measured from the final centreline road elevation will be:

- Minimum – 2.50 metres
- Maximum – 3.00 metres

Risers must be used when the invert depth of the sewer main exceeds 4.0 metres. The riser connection must not exceed 3.0 metres in depth.

6.4.6 Slope

The service shall be graded as such:

Minimum: 100 mm diameter connection - 2%
150 mm diameter connection - 1%

6.4.7 Velocity

The velocity in the service shall conform to the following:
Minimum low flow velocity - 0.60 m/s

6.4.8 Commercial, Industrial and Other Blocks

For a sanitary sewer connection to commercial or industrial blocks a manhole shall be required. The manhole is to be located on private property as per Region's Sewer Use By-law.

6.4.9 Materials

Sanitary sewer service connections may be constructed using any of the materials outlined in Section 6.3 except for polyethylene, which is not listed as an acceptable material under the Ontario Building Code.

6.4.10 Location

Sanitary connections must be located in accordance with the applicable Standard Drawing. For subdivision developments, the service connections shall terminate 0.9m inside the property line.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

7.0 Storm Sewers

Determination of stormwater design flows for both the major and minor drainage system for development must conform to the contents of the following sections of this manual.

These subsequent sections describe the policies to be adhered to, as well as the rainfall data, design storms, design and analysis procedures and storm sewer design standards to be used within St. Catharines. Throughout these sections reference is made to various Ontario Provincial Standard Drawings (OPSD). When dealing with standards for sewers, manholes, catchbasins, and etc. the OPSD. shall be used whenever possible.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

In addition, there are two appendices which provide a more detailed discussion of the various types of design storms and hydrological analysis procedures currently available.

The Design Guidelines for Sewage Works (2008), was used to update this manual and can be referenced if additional information is required.

http://www.ontario.ca/ministry-environment-and-climate-change

The consulting engineer shall meet with staff from the City's Transportation and Environmental Services department prior to beginning detailed design to establish the acceptable methodology to determine stormwater design flows.

Any variance from the policies, procedures or other criteria described in this manual requires the specific written approval of the City Engineer

7.1 Objectives

The main objectives of the City of St. Catharines stormwater management practices are consistent with the Ministry of the Environment and Climate Control and are as follows:

- Protect groundwater systems and base flow characteristics
- Protect water quality
- Ensure the watercourse will not undergo undesirable and costly geomorphic change
- Ensure there will not be an increase in flood damage potential, to prevent loss of life and to minimize property damage and health hazards
- Minimize impairment of aquatic life and habitat and that an appropriate diversity of aquatic life and opportunities for human uses be maintained

The City of St. Catharines supports the concept of urban drainage having two separate and distinct components - the minor drainage system and the major drainage system.

The minor drainage system, also called "convenience" system or the "incipient” system

7.1.1 Minor Systems

Minor drainage systems Includes:

- roof gutters
- rainwater leaders
- foundation drains
- service connections
- lot grades
- ditches
- swales
- street gutters
- catchbasins
- storm sewers

The system accommodates runoff from the more frequent storms up to the design frequency of the system (e.g. up to once in five years). Properly designed and maintained, flows are directed away from intersections and pedestrians crossings where ponding would create a nuisance in the summer and a hazard in the winter.

7.1.1.1 Design Storm

The system of street gutters, catchbasins and storm sewers shall be designed for the 1:5 year storm. Refer to Section 7.2 Hydrological Design and Analysis, for further information regarding the details for storm sewer design.

7.1.1.2 Rainwater Leaders

Rainwater leaders from all single family, semi-detached and townhouse residential units shall be discharged onto grassed or garden areas by splash pads, or at a distance of at least 1.2 metres (4 feet) from the foundation wall.

Rainwater leaders from other types of residential buildings and from commercial, industrial and institutional buildings should be discharged onto grassed or garden areas. Due to intensification and the lack of grassed areas, it may be necessary to find alternative means of providing storm water management. This could include a combination of onsite storage, over sizing pipes and controlled release devices to allow connection to the City storm sewer system which is to be reviewed on a case by case basis and must be to the satisfaction of the City Engineer. See Sections 7.1.4 & 7.2.1.2 for further information. If acceptable to the City of St. Catharines, rainwater leaders from these buildings may be connected to the storm sewer system if controlled release devices are installed on the roof to provide temporary detention of stormwater or the system has been design to accommodate those flows

7.1.1.3 Foundation Drains

Foundation drains shall not be connected to the sanitary sewer.
Foundation drains may be connected to:

- A sump pump which discharges above ground using a check valve in the discharge line; or
- The storm sewer system subject to the following conditions:
  - Basement floor elevations shall be set above the maximum hydraulic grade line in the storm sewer as well as the backwater level in the minor system that would be produced by the 1:100 year storm runoff in the major system, and
  - If rainwater leaders are connected to the storm sewer, the connection shall be made separately from the foundation drain.

7.1.1.4 Streets and Gutters

The depths of flooding permitted on streets while acting as part of the minor drainage for the 1:5 year storm are as follows:

- No curb overtopping;
- On local roads, the flow may spread to the crown;
- On collector roads, the flow spread should leave one lane free of water;
- On arterial roads, the flow spread should leave one lane in each direction free of water.

Flow across road intersections shall not be permitted for the 1:5 year storm.

7.1.1.5 Outfalls to Major System

All outfall pipes, regardless of size, shall be built with a headwall or end wall structure. The structures shall be protected against entry by children or other unauthorized personnel using grating as per OPSD.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

7.1.2 Major Systems

The major drainage system includes:

- natural streams and valleys
- man-made streets
- swales
- stream road crossings
- artificial channels and ponds.

This system is the keystone to good urban drainage, since it should accommodate the runoff from less frequent storms such as the 1:100 year storm. Properly designed and constructed, the major system will significantly reduce the risk of loss of life and property damage due to flooding.

A major system will exist in a community whether or not is has been planned or designed and whether or not development has been wisely situated with respect to it. Water will obey the law of gravity and flow downhill to seek its lowest level whether buildings or people are in its way or not.

Regulations made under the provisions of the Conservation Authorities Act are aimed at reducing the probability of flood damage to buildings caused by flooding in the watercourses. The specified level of protection for St. Catharines is the flood resulting from the 1:100 year storm. The essence of the dual drainage principle (major and minor drainage systems) is that this same level of protection to structures should also be provided within the minor system. Ideally, no new structure should be flooded from the surface or from the foundation drains by runoff from the 1:100 year storm.

7.1.2.1 Design Storm

The components of the major drainage system shall be designed to convey the runoff from the 1:100 year storm. Refer to Section 7.2 Hydrological Design and Analysis Procedures for further information regarding the use of design storms.

7.1.2.2 Streets and Gutters

The depths of flooding permitted on streets and at intersections during the 1:100 year storm are as follows:

- no building should be inundated at the ground line, unless the building has been flood proofed;
- For all classes of roads, the product of depth of water at the gutter times the velocity of flow should not exceed 0.65 sq m/s (7 sqft/s) except in special cases;
- for arterial roads, the depth of water at the crown should not exceed 150mm (6”).

To meet the criteria for major storm runoff, low points in roads are permitted only if adequate provision is made for the safe discharge of overland flow from the low points.

7.1.2.3 Outlet Structures from Ponds

Where a detention (dry) or retention (wet) pond is proposed for quantity control on a major system watercourse, the outlet structures must be designed as much for ease of operation as for hydraulic efficiency. All operational outlet structures shall be of the free-flow, ungated type. Under no circumstances will gate or valve or stoplog structures be acceptable except that a valve will be permitted in the emergency drain for a retention pond. The inlets and outlets must be protected to prevent access by children and major debris. The area at the downstream end must be protected against erosion by channel lining and/or an energy dissipater.

While such ponds will normally be designed not to be overtopped, the dam creating the pond must be designed to pass safely the flows resulting from the 1:100 year storm.

7.1.2.4 Culvert and Bridge Hydraulic Capacity

Road crossings of major system watercourses in urban areas shall be designed for the following flood frequencies:

	Design Flood Frequency	
Road Classification	Culverts up to 6 m Span	Bridges, Culverts Over 6m Span
Arterial	1:50 year	1:100 year
Collector	1:25 year	1:50 year
Local	1:25 year	1:50 year
Temp. Detour	1:5 year	1:5 year
Driveway	1:2 - 1:5 year	1:5 - 1:10 year

Given the need to protect foundation drains from undesirable backwater effects, only arterials and collectors should be permitted to cross the major system watercourses. It is also recommended that designers consider the need to design culverts and bridges on such arterials and collectors for the 1:100 year storm flow. If smaller culverts or bridges are provided, the backwater effects for the 1:100 year storm flows must be determined.

7.1.2.5 Watercourse Erosion and Bank Instability

Major system watercourses and their valleys will be left as much as possible in their natural state. Consulting engineer will be required to eliminate, within the limits of the development, any erosion or bank instability problems in receiving watercourses, either existing or resulting from the proposed development.

Where erosion or bank instability is already evident in an area to be developed or re-developed, the situation shall be stabilized by appropriate remedial measures. Where an upstream development will cause significantly increased downstream erosion, the consulting engineer shall prevent further damage by appropriate remedial measures.

In-stream and bank works are subject to NPCA and MNR approval under the Lakes and Rivers Improvements Act.

When designing remedial erosion or bank instability works, preservation of the natural valley aesthetics must be secondary only to achieving a sound technical solution. A normal low water channel has a capacity of about the 1:5 year flood. Protection to this level will be adequate provided care is taken to prevent undermining by higher floods and provided that the channel bank is not coincident with a higher valley bank. In this latter case, it may be necessary to protect the bank to a level as high as the 1:100 year flood.

7.1.3 Master Drainage Plans

The preparation of a Master Drainage Plan (MDP) is required to establish pre- and post-development flood flows, critical culvert and channel capacities and storage volume requirements. Although it has been generally accepted as a requirement for undeveloped areas of the city, older areas of the city which are already largely urbanized, such as East St. Catharines, would also benefit from some type of MDP in order to determine an overall strategy for redevelopment within these areas.

In general, MDP's delineate watersheds, indicate the routes of the major and minor drainage systems, define floodplain and hazard land, indicate constraints associated with water quantity and quality, indicate existing erosion or bank instability problems and their solutions and indicate specific flood control and environmental problems in the watershed.

The specific requirements for MDP reports will vary depending upon the area involved, degree of existing development, etc. and will be stipulated in the terms of reference for that report. In general, the following items should be discussed in the text of the report, as well as being presented in the form of plans, figures and/or tables:

- watershed topography, location and extent of existing watercourses, etc.
- existing and proposed land uses
- assumed pre- and post-development watershed characteristics
- hydrological model used, along with a discussion of its assumptions
- and limitations

- areas of existing erosion , flooding or water quality problems and proposed relief measures
- existing and proposed major and minor drainage systems , including internal and external drainage areas
- existing and proposed storm drainage facilities (sewers, channels ,
- culverts, detention ponds, etc.)
- benefit-cost matrices of alternative solutions
- pre- and post-development 1:100 year flood lines
- pre- and post-development flood flows (uncontrolled and proposed controlled) at key locations for 1:5, 1:10, 1:25, 1:50 and 1:100 year storms
- plot of peak flow vs. areas for the above range of storms cost estimates and staging of proposed works

Over the past several years, numerous storm drainage studies, which fulfill some of the requirements of MDPs, have been carried out in different areas of St. Catharines. These studies can be referenced when considering a MDP.

7.1.4 Detention Facilities

The design of detention facilities, whether they are detention ponds, roof-tops, parking lots, underground tanks or oversized pipes, is essentially the same. The degree of detention required for a particular site or subdivision will be indicated in the MDP for that area (where no MDP exists for the area in question, refer to Section 7.1.1.2 for policy guidelines in this regard).

Where detention facilities are required, the Stormwater Management Plan or Report for the subdivision or site should include the following items:

- Detailed design drawings of the detention facility, including landscaping, if applicable
- Depth-storage and depth-discharge relationships for the facility
- Provision for a safe overflow route if the storage capacity is exceeded
- Hydrologic model used, along with a discussion of its assumptions and limitations
- Controlled flows from the facility compared to pre-development flows for the 1:5, 1:25 and 1:100 year design storms
- Anticipated loadings and pollutant removal rates, if the facility is to be used for quality control

When storm water detention is required, a detailed design must be submitted indicating that the site can be developed while, at the same time, providing the necessary detention areas.

The design shall include the method of detention together with the volumes of storm water to be detained, drainage area plans, design flow calculations and the method of restricting the flow from the site calculations showing volume of area on site to be used, as well as the path of flow where detention is exceeded. In addition, release calculations and velocities for these flows should be included.

	*** EAST ST. CATHARINES**	**WEST ST. CATHARINES**
Major System	N/A	Detention of flows in excess of 1:5 year storm but less than 1:100 year storm
Minor System	Detention of excess flow from 1:5 year storm to level determined by City Engineer	N/A

* In general terms, the boundary between East and West is the Twelve Mile Creek

7.1.4.1 Existing Facilities

The requirements for the analysis of existing storm drainage facilities within developed areas differ from those outlined above for new subdivisions. There are usually fewer alternatives available since the area is likely already largely developed. In addition, there may not be a well-defined MDP (master drainage plan) for the area and overland flow routes for the major drainage system were probably never considered when the area was developed.

The specific requirements for a report dealing with an existing storm drainage system will vary depending on the area involved and the extent of the existing drainage problems. These requirements will be stipulated in the terms of reference of the report.

The following items should be discussed in the text of the report as well as being presented in the form of plans, figures and/or tables, as applicable:

- Road and lot layout, with land use
- Road and basement elevations
- Inventory of the existing storm drainage system
- Extent of major and minor drainage areas
- Extent of existing flooding, erosion and water quality problems
- Hydrologic model used, along with a discussion of its assumptions and limitations
- Assumed sub-drainage area characteristics (i.e. per cent imperviousness, slope, etc.)
- Model calibration with real rainfall and flow measurements
- Cost-benefit matrices of alternative relief measures
- Flow and HGL elevations at all manholes, with proposed relief measures, for the 1:2, 1:5, 1:10, 1:25, 1:50 and 1:100 year design storms
- Overland flows, velocities and depths at key points throughout the major drainage system, for the major design storm
- Staging and cost estimates for the proposed relief measures

7.1.5 Protection from Surface Flooding

No new building shall be damaged by the floodwater levels generated by the 1:100 year storm. This applies to both the major and minor drainage systems. This requires proper care in the design and construction of streets, gutters, catchbasins, inlet controls, lot grading, culverts, and in the setting of elevations of basement floors and openings.

Where a natural watercourse or man-made channel is used as a component of the major drainage system, no part of any lot for development may intrude upon the 1:100 year floodplain.

7.1.6 Protection from Basement Flooding

Basements shall be protected from flooding from surface waters in watercourses as described in Section 7.1.2. Basements shall also be protected from flooding from local surface runoff by proper lot grading and the proper setting of elevations at openings into the building. Basements shall be protected from flooding by ground water or backflow from storm sewers by the proper treatment of foundation drains which shall be discharged via sump pumps and the appropriate setting of basement floor elevations.

Where no other options are feasible, the use of backwater prevention valves to alleviate basement flooding problems in existing areas may be considered. This is done in conjunction with foundation drain diversion into a sump pump with discharge to the surface to eliminate any surcharging of the foundation drains from main sewer back-ups.

7.1.7 Stormwater Management Plans & Report

7.1.7.1 Subdivisions

When a draft plan of subdivision is being prepared for a specific site, the developer must submit a Preliminary Stormwater Management Plan to the City for review. This plan must include the following:

- Plans showing the proposed street and lot layout, including land use
- Plans showing the extent and flow directions of the major and minor drainage systems
- A description of how the proposed stormwater management facilities will meet the requirements of the applicable MDP (if no MDP for the area exists, refer to Section 7.2.1. for policy guidelines in this regard)
- A description of the proposed methods of erosion and sediment control

When detailed design drawings are available for the development, and prior to the registration of the final Plan of Subdivision, the consulting engineer must submit the final stormwater management plan report to the City for review.

In general, the following items should be discussed in the text of the report, as well as being presented as plans, tables and/or figures, as applicable:

- How the requirements of the applicable MDP are met (if no MDP for the area exists, refer to Section 7.2.1 for policy guidelines in this regard)
- Hydrologic model used, along with a discussion of its assumptions and limitations
- Road and lot layout, with land use
- Lot grading, road and basement elevations
- Assumed post-development sub-drainage area characteristics (i.e. percent imperviousness, slope, etc.)
- Minor drainage system details, including drainage areas, road and lot grades, storm sewers, manholes catchbasins (including inlet controls, if applicable), etc.

- Major drainage system details, including drainage areas, road grades, overland flow routes, outfalls, etc.
- Post-development flows and hydraulic grade line (HGL) elevations at all manholes for the minor design storm Flow and HGL elevations within the storm sewer system for the major design storm will also be required if the proponent wishes to connect foundation drains to the storm sewer. Overland flows, velocities and depths at key points throughout the major drainage system for the major design storm
- Pre- and post-development hydrographs at outfalls and outlets from stormwater management facilities
- proposed erosion and sediment control plan

If storage facilities are necessary, refer to Section 7.1.4 for an outline of the requirements

7.1.7.2 Site Plan Developments

Most new development within St. Catharines is subject to site plan control and as such the developers of these sites must enter into a Site Plan Agreement with the City. Site plan developments may be divided into two general categories; those with on-site stormwater drainage collection systems (i.e. with one or more catchbasins and/or manholes) and those without.

Prior to the registration of the Site Plan Agreement, a Stormwater Management Report for the site must be submitted. The requirements for the report (plan) are listed below.

Sites with no on-site collection system:

- site layout, with land use
- proposed lot grading and basement elevations, existing adjacent land and road elevations. Proposed building elevations and lot grading must be compatible with adjacent lands. All surface drainage originally flowing through, onto or over the area of the site must be accommodated and the lot must drain satisfactorily to the present existing grades of the existing lands. The drainage must be controlled within the site and must not adversely affect adjacent properties.

Sites with on-site collection systems:

- Items required for sites with no on-site collection system (see above)
- How the requirements of the applicable MDP are met (if no MDP exists for the area, refer to Section 7.2.1 for policy guidelines in this regard)

- Hydrologic model used, along with a discussion of its assumptions and limitations
- Assumed post-development sub-drainage area characteristics
- Minor drainage system details, including drainage areas, road and lot grades, storm sewers, manholes, catchbasins (including inlet control), etc.
- HGL elevations for the major design storm, if foundation drains are to be connected to the storm sewer
- If the applicable MDP determines that a major overland flow route passes through or adjacent to this site, the post-development flows, velocities and depths at key points throughout the major drainage system shall be determined for the major design storm to show that the proposed lot grading and building elevations are compatible

If storage facilities are necessary, refer to Section 7.1.4 for an outline of the requirements
It is recognized that items may be added to or deleted from the above lists depending upon the size of the proposed development. In these cases, the requirements may be changed at the discretion of the City Engineer.

7.1.7.3 Runoff Quantity Control

Where required by the MDP Master drainage plan (or such other studies deemed appropriate by the City of St. Catharines) a specific development shall incorporate runoff quantity controls to reduce post-development peak flows to a specified level.

As a guideline, the post-development peak flow shall be no greater than the corresponding pre-development peak flow for the 1:10 year, 1:25 year and 1:100 year storms.

The proponent cannot pass post-development peak flows that are greater than the corresponding pre-development peak flows for the 1:5 year storm any excess water must be stored on site.

7.1.7.4 Runoff Quality Control

A significant amount of degradation of water quality from development takes place during construction. Developers, contractors and builders must plan and execute their operations so as to minimize sediment and debris pick-up and transport to water bodies. The degree of control and methods used must meet the regulations and guidelines of the Ministries of the Environment and Climate Control (MOECC), Natural Resources (MNR) and Transportation (MTO), as well as the Niagara Peninsula Conservation Authority (NPCA). In this regard, the "Stormwater Management & Design Manual" (March 2003) and MOECC Guideline B-6 "Guidelines for Evaluating Construction Activities Impacting Water Resources" (January 1995) may be consulted for further information. Quality control is required for all new developments and significant changes to existing storm sewer systems.

http://www.ontario.ca/ministry-environment-and-climate-change

7.1.7.5 Methods of Quantity and Quality Control

Typical methods of quantity and quality control include:

- Discharge of rainwater leaders onto grassed areas
- Temporary storage of water on flat roofs or parking areas
- Grassed swales rather than pipes
- Underground storage tanks or over-sized pipes with restricted outlets
- diversion of overland flow into temporary detention ponds with controlled discharge rates
- Storm water management ponds
- Oil and grit separators (OGS)
- Oil/water separators

The City of St. Catharines endorses the use of any or all of these methods of controlling the rate of runoff from a proposed new development, or for redevelopment within the existing urbanized area. The consulting engineer is required to analyze the site specific constraints and various control alternatives to develop an appropriate drainage system that maximizes the benefits to costs.

If a detention (dry) pond is to be used, this should be incorporated into a road crossing of the waterway. Care must be taken to define the environmental concerns at the site and to design the facility to minimize adverse effects. Care must also be taken to ensure the safety of the residents and the safe passage of all flows without causing undue erosion and maintenance.

Under no circumstances should the contours of the land in such detention ponds be altered after construction unless otherwise approved by the City of St. Catharines.

As a condition of any approval, the proponent must submit an outline of the proposed erosion-sediment control plan. This may contain any or all of the following measures and must also be approved by the Ministry of Natural Resources (MNR) and/or their designate (Niagara Peninsula Conservation Authority):

- Sediment traps or temporary retention ponds
- Seeding of topsoil stock piles
- Isolated stripping of development lands
- Vegetation screens

A more complete description of the erosion and sediment control methods available may be found in the "Erosion & Sediment Control Guideline for Urban Construction" (December 2006) produced by the Golden Horseshoe Conservation Authorities and the "Environmental Guide for Erosion and Sediment Control During Construction of Highway Projects" (February 2007) produced by the M.T.O.

http://www.creditvalleyca.ca/wp-content/uploads/2011/01/010-ESC_Guideline-for-Urban-Construction.pdf

http://www.raqsb.mto.gov.on.ca/techpubs/eps.nsf/8cec129ccb70929b852572950068f16b/7ff7c9fa7def430f852572b300578dec/$FILE/MTO%20Env%20Guide%20for%20ESC%20Final%20Feb%202007.pdf

7.2 Hydrological Design and Analysis Procedures

This section outlines the various hydrological design and analysis methods available, along with the required input parameters. A more detailed description of the various methods and models may be found in Appendix B.

The process by which rainfall becomes runoff forms the basis of stormwater drainage design. The methods by which this process is modeled can range from the simple yet popular Rational Method, to more sophisticated computer simulation models.

Generally all storm sewers shall be designed according to the Rational formula. This design must be calculated on a design sheet acceptable to the Ministry of the Environment and Climate Control (MOECC)

7.2.1 Rational Method

The Rational Method, originally introduced in 1889, is still the simplest and most popular technique used for estimating peak flows in a sewer system. It states the peak rate of runoff at the point of interest is directly proportional to the drainage area tributary to that point and the average rainfall intensity over a time equal to the time of flow from the most hydraulically remote point within the drainage area. The amount of runoff from a drainage area is assumed to be a simple percentage of the amount of rain falling on that area.

Refer to Appendix B for a more detailed description of the use of the

Rational Method as well as the variables associated with it.

The Rational Method is subject to the following assumptions and limitations:

- The method should only be used for the design of storm sewer systems within urban areas 200 ha (500 acres) in size, or less.
- The rainfall intensity is assumed to be uniform in time and in space.
- The runoff coefficient represents a lumping of all of the physical characteristics of the entire drainage area and is assumed to be constant over time.
- The return frequency of the runoff is assumed to be the same as that of the rainfall
- The method can only be used to estimate the peak runoff and not the actual storm runoff hydrograph, which is one of the requirements for channel routing or designing storage facilities.

Generally all storm sewers shall be designed according to the Rational Formula where:

$$Q = 2.78\,A\,i\,R$$

Where:

$\boldsymbol{A}$ = Area in hectares
$\boldsymbol{i}$ = Average rainfall intensity – mm/hr
$\boldsymbol{R}$ = Runoff coefficient
$\boldsymbol{Q}$ = Runoff quantity in I/s

7.2.1.1 Watershed and Drainage Areas (A)

The watershed area must be determined from contour plans and include all areas that naturally drain into the system and consider all lot grading plans for proposed developments.

A plan of the watershed area must be prepared and include all affected streets, lots and watercourses. The proposed storm sewer system must be shown on this plan including each manhole numbered consecutively for design reference. Manholes are to be located at each and every change of pipe size, grade and alignment.

Manholes must be the tributary points in design. The areas tributary to each manhole will be clearly outlined on the storm drainage area plan with the area in hectares (to the nearest tenth) and runoff coefficient shown in a circle of 15 mm diameter. Thus,

$$\frac{4.6\text{ ha}}{0.5}$$

In cases where areas of different runoff coefficients are tributary to one manhole, the areas tributary to the manhole must be individually outlined. The tributary area and runoff coefficient for each area will be shown as set out above.

In determining tributary areas to manholes, the proposed grading of lots must be considered and taken into account in order to maintain consistency in design.

In the case of large tributary areas under single ownership, such as shopping centres, apartment developments, schools, etc., the design must be prepared on the basis of the whole area being tributary to a manhole in an abutting storm sewer. When more than one sewer connection will be necessary to serve the property in question, the appropriate area tributary to each sewer connection must be clearly shown and taken into account in the design of the storm sewer.

In lieu of precise information on development of the whole or any part of a watershed area, the latest approved zoning by-law and plans must be used to select the correct values of the runoff coefficients to be used in the design and to determine the specific areas where they will apply.

7.2.1.2 Rainfall Intensity

In an effort to maintain uniformity, the following design storms must be adopted for use in storm drainage studies and design throughout St. Catharines. Refer to Appendix A for a more detailed discussion of the various design storms available as well as a history of their use in St. Catharines. As noted previously the 1:5 year storm frequency is used for the minor system and the 1:100 year storm is used for the major system (all watercourses). Generally, inlet time or initiation time of concentration is to be 10 minutes.

7.2.1.3 IDF Curves

The IDF (intensity- duration- frequency) curves to be used for applications within St. Catharines are presented in the table and figure below. The 1:5 year IDF curve may be used in conjunction with the Rational Method, see Section 7.3.1 for the sizing of storm sewers in urban areas.

IDF curves are subject to review and may be altered from time to time to better statistically represent rainfall in this area.

IDF Curves

Return Period	a		b	c
	Metric	Imperial		
2	567	22.3	.746	5.2
5	664	26.1	.744	4.7
10	724	28.5	.739	4.3
25	821	32.3	.735	4.0
50	900	35.4	.734	3.8
100	980	38.6	.732	3.7

$$i = \frac{a}{(t + c)^b}$$

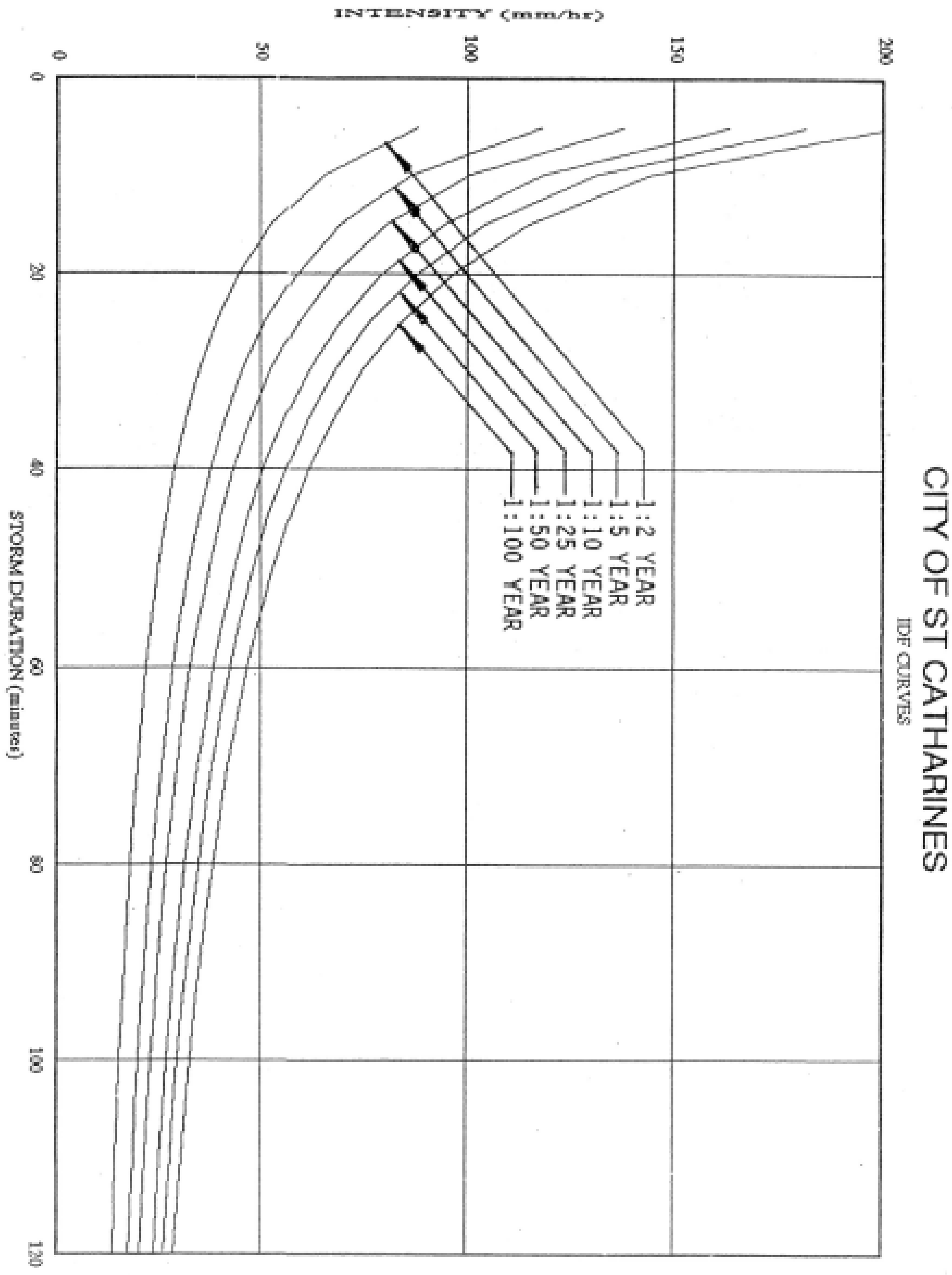
Where:

a, b, c= as above
i = intensity (mm/hr. or in/hr.)
t = storm duration (min)

Rainfall depths for various storm durations and return frequencies, as derived from these IDF curves, are also presented in the table below and may be used in conjunction with the dimensionless rainfall distributions presented below.

Storm Duration	Return Period (Years)					
(hr.)	2	5	10	25	50	100
1	25	30	33	39	43	47
2	31	37	41	48	52	58
3	35	41	46	53	59	65
4	37	44	50	58	64	70
6	42	49	56	65	71	79
12	50	59	67	78	86	95
24	60	71	80	94	104	114

*Storm depths (mm)



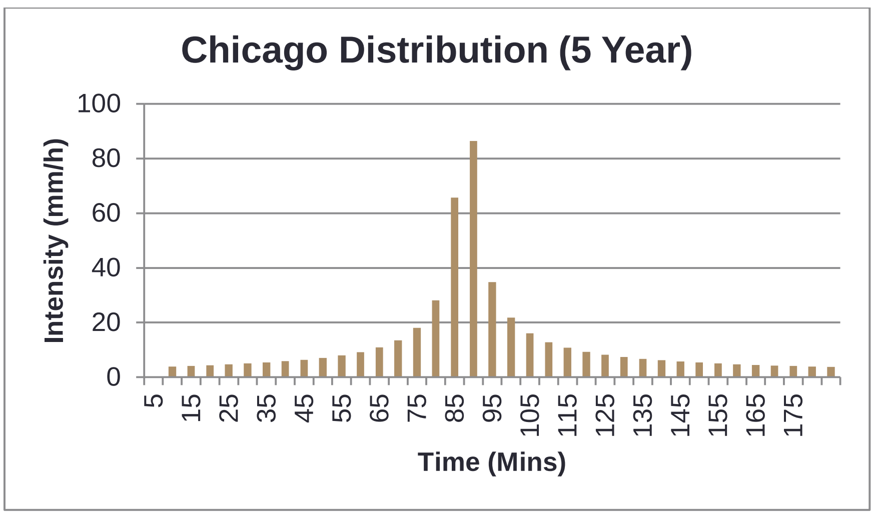
(Derived from: AES Rainfall Intensity Atlas for Canada, 1985)

7.2.2 Synthetic Design Storms

For more detailed analysis and design of storm drainage systems (including the sizing of storage facilities), more advanced hydrologic models are needed. These models require rainfall distributions or hyetographs, either real or synthetic, as input. The following describes the synthetic design storms that may be used for applications within St. Catharines.

7.2.2.1 Chicago Storm Distribution

The Chicago storm profile (below) is one of the more common design storms for use within urban areas and should continue to be used in the design and analysis of storm sewer systems within urban areas. However, it should be noted that some investigators consider the Chicago profiles to yield unrealistically "peaky" hyetographs, especially when a smaller time increment is used.



Chicago Storm Design

Intensity (mm/h)

r=0.46 -3 Hour Duration

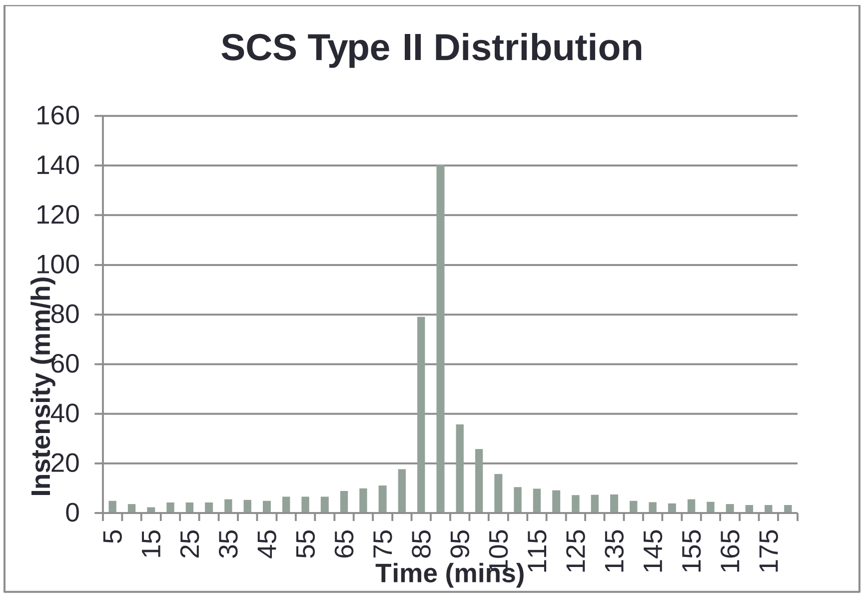
Time	Return Period (Years)					
(mins)	2	5	10	25	50	100
5	3.33	3.95	4.48	5.24	5.79	6.4
10	3.52	4.16	4.72	5.52	6.09	6.74
15	3.72	4.41	4.99	5.83	6.44	7.12
20	3.96	4.69	5.3	6.19	6.83	7.55
25	4.24	5.01	5.66	6.61	7.29	8.06
30	4.56	5.39	6.09	7.1	7.83	8.65
35	4.96	5.85	6.6	7.69	8.47	9.36
40	5.43	6.41	7.21	8.4	9.25	10.21
45	6.03	7.1	7.98	9.28	10.22	11.28
50	6.8	8	8.97	10.42	11.47	12.64
55	7.83	9.2	10.3	11.93	13.13	14.46
60	9.3	10.9	12.17	14.08	15.48	17.03
65	11.56	13.52	15.05	17.35	19.06	20.95
70	15.5	18.1	20.06	23.05	25.29	27.75
75	24.12	28.13	31.05	35.54	38.95	42.65
80	55.57	65.65	72.79	83.55	91.83	100.53
85	72.37	86.37	96.42	111.28	122.72	134.61
90	29.76	34.74	38.31	43.82	48.02	52.54
95	18.68	21.79	24.1	27.65	30.31	33.22
100	13.74	16.05	17.82	20.51	22.51	24.71
105	10.95	12.82	14.29	16.48	18.11	19.91
110	9.17	10.75	12.01	13.89	15.27	16.8
115	7.92	9.3	10.42	12.07	13.28	14.62
120	7	8.23	9.23	10.71	11.8	13
125	6.29	7.4	8.32	9.67	10.65	11.74
130	5.72	6.75	7.59	8.83	9.73	10.73
135	5.26	6.21	6.99	8.14	8.98	9.91
140	4.88	5.76	6.5	7.57	8.35	9.22
145	4.55	5.38	6.07	7.08	7.81	8.63
150	4.27	5.05	5.71	6.66	7.35	8.12
155	4.03	4.77	5.39	6.03	6.95	7.68
160	3.82	4.52	5.11	5.97	6.59	7.29
165	3.63	4.3	4.87	5.69	6.28	6.94
170	3.46	4.1	4.64	5.43	6	6.63
175	3.31	3.92	4.45	5.2	5.74	6.35
180	3.17	3.76	4.27	4.99	5.51	6.1

Synthetic Design Storms
Intensity (mm/h)
1:5 Year Return Period -3 Hour Duration

Time (mins)	Chicago	Huff 4-Quartile 1st	2nd	3rd	4th	SCS Type II	Canadian 1 Hour
5.00	3.95	36.78	4.24	5.47	5.47	4.92	26.55
10.00	4.16	36.78	4.24	5.47	5.47	3.61	53.10
15.00	4.41	36.78	4.24	5.47	5.47	2.30	79.64
20.00	4.69	35.36	7.69	6.56	4.92	4.27	106.19
25.00	5.01	33.23	12.85	8.20	4.10	4.27	54.38
30.00	5.39	33.23	12.85	8.20	4.10	4.27	22.17
35.00	5.85	33.23	12.85	8.20	4.10	5.58	9.04
40.00	6.41	21.96	22.26	6.02	4.10	5.25	3.68
45.00	7.10	19.14	24.61	5.47	4.10	4.92	1.50
50.00	8.00	19.14	24.61	5.47	4.10	6.56	0.61
55.00	9.20	17.59	25.71	5.47	4.24	6.56	0.25
60.00	10.90	11.35	30.08	5.47	4.79	6.56	0.10
65.00	13.52	11.35	30.08	5.47	4.79	8.86	
70.00	18.10	11.35	30.08	5.47	4.79	10.01	
75.00	28.13	9.46	28.44	10.39	6.02	11.16	
80.00	65.65	8.20	27.35	13.67	6.84	17.72	
85.00	86.37	8.20	27.35	13.67	6.84	79.09	
90.00	34.74	8.20	27.35	13.67	6.84	140.47	
95.00	21.79	6.43	18.46	34.87	8.20	35.77	
100.00	16.05	6.43	18.46	34.87	8.20	25.76	
105.00	12.82	6.43	18.46	34.87	8.20	15.75	
110.00	10.75	6.21	14.91	34.87	10.67	10.50	
115.00	9.30	5.88	9.57	34.87	14.36	9.85	
120.00	8.23	5.88	9.57	34.87	14.36	9.19	
125.00	7.40	5.88	9.57	34.87	14.36	7.22	
130.00	6.75	5.55	5.42	22.84	24.20	7.38	
135.00	6.21	5.47	4.38	19.83	26.67	7.55	
140.00	5.76	5.47	4.38	19.83	26.67	4.92	
145.00	5.38	5.42	4.13	17.23	31.59	4.43	
150.00	5.05	5.20	3.15	6.84	51.28	3.94	
155.00	4.77	5.20	3.15	6.84	51.28	5.58	
160.00	4.52	5.20	3.15	6.84	51.28	4.59	
165.00	4.30	5.11	2.49	3.97	27.08	3.61	
170.00	4.10	5.06	2.05	2.05	10.94	3.28	
175.00	39.92	5.06	2.05	2.05	10.94	3.28	
180.00	3.76	5.06	2.05	2.05	10.94	3.28	

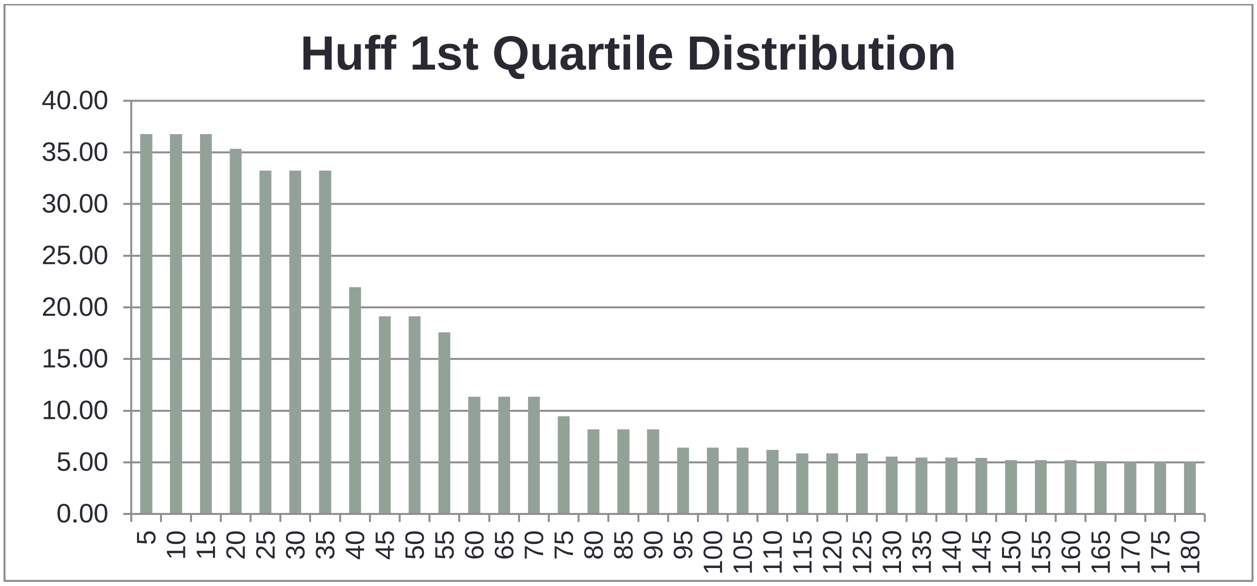
7.2.2.2 SCS Type II Distribution

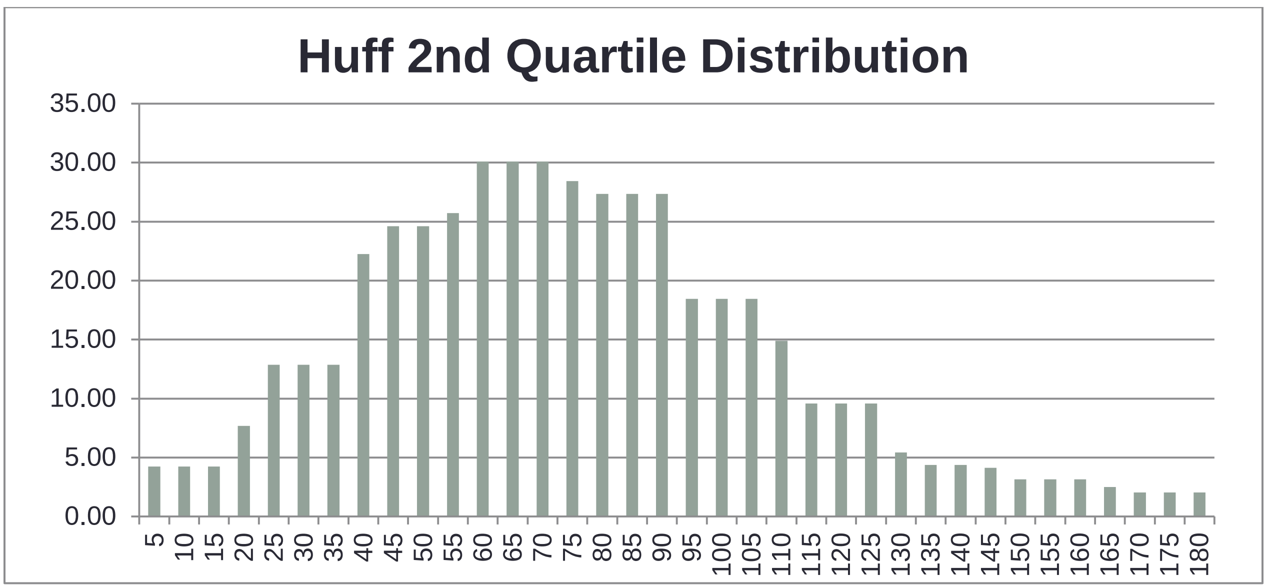
The SCS 24 Hour Type II storm distributions (shown below) generally produce lower peak intensities but greater total volumes than the Chicago profiles. Because of this feature, the SCS Type II distributions should be used when designing storage facilities in urban areas. In addition, the SCS 24 hour Type II distribution should" be used when analyzing rural watersheds, or the pre-development conditions of areas scheduled for future urbanization.

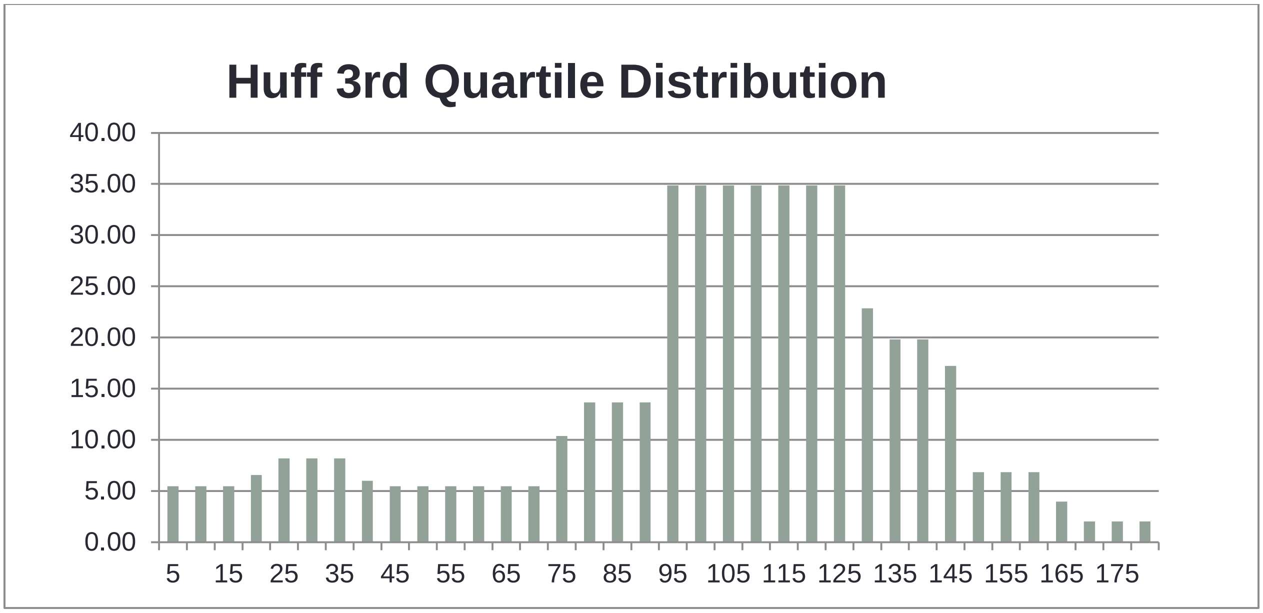


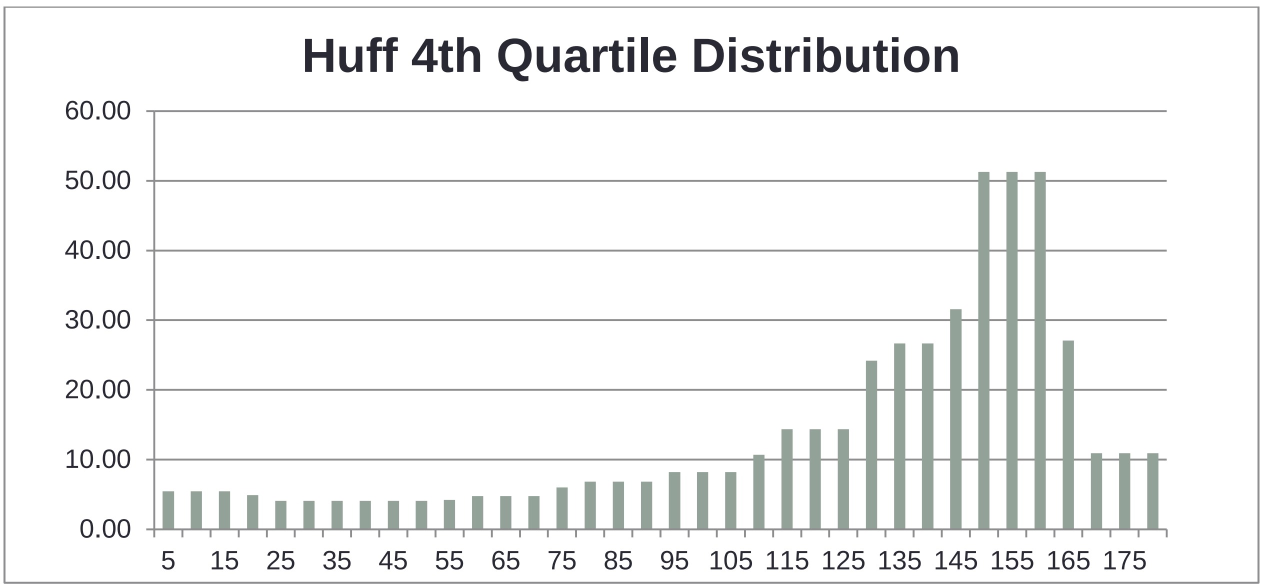
7.2.2.3 Huff Storm Distributions

The Huff distributions as shown below may become more widely used in the future as alternatives to or compliments for the Chicago profiles. The 2nd and 3rd quartiles should be used for applications in urban and rural areas, respectively.



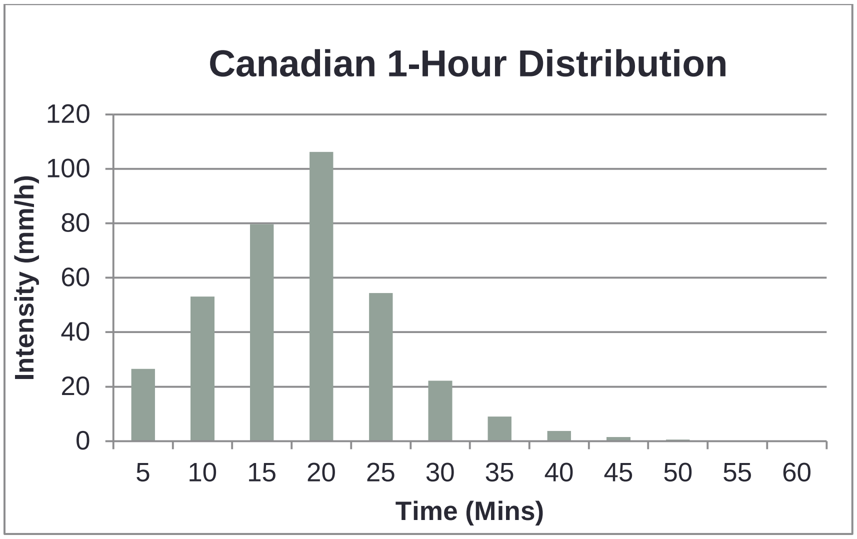



Huff 3rd Quartile Distribution
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175


Huff 4th Quartile Distribution
60.00
50.00
40.00
30.00
20.00
10.00
0.00
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175

7.2.2.4 Canadian 1-hour Urban Design Storm

The Canadian 1-hour Urban Design Storm distribution (indicated below) may also become widely used in the future. It may be used for urban areas with storm durations of 1 hour and return frequencies of 2-10 years.



Time (Min)	Return Period (Years) 2	5	10
5	22.33	26.55	29.67
10	44.66	53.10	59.35
15	66.99	79.64	89.02
20	89.32	106.19	118.70
25	45.74	54.38	60.79
30	18.65	22.17	24.78
35	7.60	9.04	10.10
40	3.10	3.68	4.12
45	1.26	1.50	1.68
50	0.51	0.61	0.68
55	0.21	0.25	0.28
60	0.09	0.10	0.11

Intensity (mm/h)

a= 21 minutes; k=7

7.2.2.5 Real Storms

Real storms, when used in conjunction with flow monitoring, can be very helpful in the calibration of hydrological models. The City presently operates four rain gauges at the following locations:

- City Hall (at the corner of Church St. and James St.)
- Linwell Fire Station (on Linwell Road, between Linfield Drive. and Howard Avenue.)
- Merritton Fire Station (at the corner of Merritt Street. and Walnut Lane)
- Port Weller Community Centre (at the south limit of Bogart Street).
- Greenhouse at Malcolmson Park (Lakeshore Road between Niagara Street and Bunting Road)

The Regional Municipality of Niagara also operates two rain gauges at the following locations:

- Decew Water Treatment Plant
- Port Dalhousie Water Pollution Control Plant.

In addition, the Niagara Peninsula Conservation Authority operates a water level and precipitation station on Walker's Creek at Cindy Drive.

Rainfall data from any or all of these sources may be used; however the corresponding sewage flow data necessary for model calibration purposes can be scarce. Monitoring may be required with portable sewage flow monitors to obtain the necessary data for model calibration and verification.

7.2.3 Computer Models

Numerous computer models and G.I.S. based add-ons have been developed to assist in the estimation of urban and rural runoff, and the design of storm drainage facilities. It is the responsibility of the user to understand the limitations of the model and its input parameters and to ensure that the results obtained from the model are reasonable.

A brief summary of the more popular computer models currently available may be found in <u>Appendix B</u>. More detailed descriptions of the assumptions, limitations and workings of the various models may be found in their respective user manuals.

The following table presents some of the possible applications for the various computer-based and manual methods to determine runoff as further discussed in Appendix B. In choosing which method to use for a particular application, one must decide on the complexities of the problem. Using a complicated computer program to design a simple storm sewer in a parking lot may be unnecessary. Conversely, using the Rational Method to design storage facilities or to determine pre-development flows in rural catchments would be equally inappropriate.

Applications for Various Hydrologic Methods

	Design				Analysis			
Method / Model	Storm Sewers	Open Channels	Storage Facilities	Major / Minor	Floodplain Mapping	Surcharged Condition	Quality Modelling	Continuous Modelling
Rational Method	Y	Y	N	N	N	N/A	N/A	N/A
SCS (Unit Hydrograph Method)	Y	Y	Y	Y	Y	N/A	N/A	N/A
Isochrone Method	Y	Y	Y	Y	Y	N/A	N/A	N/A
SWMM4	Y	Y	Y	N	N	Y	Y	Y
OTTSWMM	Y	Y	Y	Y	N	Y	Y	Y
IMPRAM	Y	N	N	N	N	N	N	N
MIDUSS	Y	Y	Y	Y	Y	N	N	N
PC OTTHYMO	Y	Y	Y	Y	Y	N	N	N
STORM	N	N	N	N	N	N	Y	Y
ILLUDAS	Y	N	N	N	N	N	N	N
HEC	N	N	N	N	Y	N	N	Y
HVM DORSCH	Y	Y	Y	N	N	Y	N	N

Most computer models require the same basic input parameters over and above the usual area, time of concentration and runoff coefficient (or CN) required for the Rational and Unit Hydrograph methods. For applications within St. Catharines, these parameters are outlined below. (Sections 7.3)

7.3 Sewer Design

This section outlines the criteria to be used for storm sewer design. Reference is made throughout this section to Ontario Provincial Standard Drawings (OPSD) when dealing with standards for sewers, manholes, catchbasins, etc. These OPSD's shall be used whenever possible.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

7.3.1 Pipe Capacity

Manning's Formula shall be used to compute the capacity of storm sewers. The capacity of the sewer shall be calculated on the basis of the pipe flowing full.

The capacity of a storm sewer shall be determined as follows:

For free flow conditions - Manning's Equation

$$Q = VA = \frac{k}{n} A\, R^{2/3} S^{1/2}$$

Where:

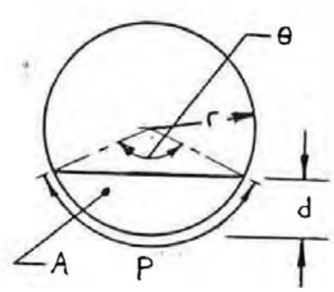
Q = flow (l/s or cfs)
V = velocity (m/s or ft/s)
A = cross-sectional area (m or ft)
$R*$ = hydraulic radius (m or ft)
= A/P
P = wetted perimeter (m or ft)
S = slope (%)
n = Manning's roughness coefficient
= 0.013 for concrete, vitrified clay, asbestos cement and PVC pipe (all sizes)
= 0.024 for CSP (all sizes)
K = 100 (Metric) or 1.486 (Imperial)

* for pipes flowing full (used for design)

$$R = {}^{D}/_{4}$$

Where D = diameter (m or ft)

For pipes flowing partially full



$R = {}^{A}/_{P}$

$\theta = 2cos^{-1}[\frac{(r-d)}{r}]$

$P = \theta\, r$

$A = \theta \frac{r^2}{2} - [(r-d) \times (r^2 - (r-d)^2)^{\frac{1}{2}}]$

Where:θ, r and d are as shown

For pressure flow conditions - Hazen Williams Equation

$$Q = kCD^{2.63}(H_f/L)^{0.54}$$

Where:

Q = flow (1/s or cfs)
D = pipe diameter (m or ft)
H_f = head loss (m or ft)
$\boldsymbol{L}$ = pipe length (m or ft)
C = coefficient for pipe condition
= 140 - extremely smooth, straight pipe, asbestos cement
= 130 - very smooth pipes, concrete, new cast iron:
= 120 - wood stave, new welded steel
= 110 - vitrified clay, new riveted steel
= 100 - cast iron after years of use
= 95 - riveted steel after years of use
= 60-80 - old pipes in bad condition
k = 278.5 (Metric) or 0.4322 (Imperial)

For orifice flow (such as for catchbasin inlet control)

$$Q = kCA(2gH)^{0.5}$$

Where:

Q = flow (l/s or cfs)
A = inlet area (m or ft)
H = head over inlet (m or ft)
g = acceleration due to gravity
= 9.81 m/s^2 (Metric) or 32.2 ft/s^2 (Imperial)
C = discharge coefficient
= 0.98 for round-edged openings
= 0.61 for sharp-edged openings
k = 1000 (Metric) or = 1.0 (Imperial)

7.3.1.1 Area
The area of the catchment contributing runoff to the point under consideration may be determined from a topographic map of the area. Area is one of the few input parameters for hydrologic simulation models that can be determined with any degree of accuracy and, as such, should not be altered in an effort to calibrate the model.

7.3.1.2 Overland Flow Length
The distance from the most hydraulically remote point in the catchment to the nearest inlet or gutter is referred to as the overland flow length and may be determined from topographic maps. When calibrating hydrologic models, changes in the overland flow length (other things remaining equal) will cause changes in the shape of the runoff hydrograph, but generally not in the peak runoff.

7.3.1.3 Slope
The slope of the catchment is considered the average ground slope along the overland flow length and may also be determined from topographic maps of the area. As with the overland flow length, changes to the slope parameter when calibrating hydrologic models will cause changes to the shape of the runoff hydrograph but will generally not affect the peak runoff.

7.3.1.4 Manning's n
Most computer models divide the catchment into pervious and impervious areas, the surface of which may be assumed to have a certain roughness coefficient, or Manning's n; the higher the value of n, the rougher the surface.

Accurate determination of an appropriate roughness coefficient for overland flow is difficult due to variability in ground cover however; the following values may be used as a guide for applications within St. Catharines:

Surface	Manning’s 'n'
Asphalt, Concrete	0.01-0.02
Lawn, Grass	0.10-0.20
Open Field	0.20-0.30
Forested Area	0.40-0.60

7.3.1.5 Percent Imperviousness

The percent imperviousness (% IMP) of a catchment refers to that percentage of the drainage area that is directly connected (hydraulically) to the drainage system. This would include streets, gutters, driveways, parking lots and rooftops that drain to the street or storm sewer. Rooftops with downspouts discharging onto grassed areas should not be considered as being impervious areas.

In developed areas, the% IMP can be readily determined from topographic maps and/or aerial photos. The extent of rooftop connections to the sewer may be determined by visual inspection and smoke testing.

The following may be used as a guide for design in undeveloped areas within St. Catharines:

Land Use	% IMP
Parks, etc.	25
Single Family Residential	45
Semi-Detached Residential	50-60
Apartments, Townhouses, Institutional	60-70
Commercial, Industrial	80-100

7.3.1.6 Depression or Detention Storage

Both pervious and impervious surfaces contain depressions of various shapes and sizes. Precipitation falling on these surfaces must fill up these depressions prior to any runoff occurring. The volume of rainfall this represents is referred to as depression or detention storage and is usually expressed in terms of inches or mm.

As a guide, the following values may be used for applications within St. Catharines:

Surface	Depression Storage	
	(mm)	(in)
Asphalt , Concrete	0.5-4.0	0.01-0.16
Flat Roof	2.5-7.5	0.10-0.30
Sloped Roof	0.5-2.5	0.02-0.10
Lawn, Grass	2.5-5.0	0.10-0.20
Open Field	5.0-10.0	0.20-0.40

7.3.1.7 Infiltration

Precipitation falling on pervious areas is subject to infiltration, or the absorption of water into the soil. The rate of infiltration will vary, depending upon the soil type, ground cover, antecedent moisture conditions, land slope and temperature. During a rainfall event, infiltration capacity is generally considered to decay exponentially from a higher initial (dry) value to a final (saturated) value.

The relationship commonly used in many hydrologic simulation models to evaluate this is Horton's equation:

$$f_p = f_c + (f_o - f_c)e^{kt}$$

Where:

k = decay coefficient (hr-1)
t = time from beginning of storm (hr.)
f_p = infiltration capacity (or loss) (mm/hr. or in/hr.)
f_c = minimum (or ultimate) infiltration rate (mm/hr. or in/hr.)
f_o = maximum (or initial) infiltration rate (mm/hr. or in/hr.)

Horton's equation is graphically represented in the following figure. The parameters of Horton's equation should be determined using field measurements and / or model calibration. If this is not available, the following values may be used for applications within St. Catharines.

SCS Hydrologic Soil Group	f_c	
	(mm/hr)	(in/hr)
A	11.25-7.50	0.45-0.30
B	7.50-3.75	0.30-0.15
C	3.75-1.25	0.15-0.05
D	1.25-0.00	0.05-0.00

Soil Type	f_o *	
	(mm/hr.)	(in/hr.)
Sandy	125	5.0
Loam	75	3.0
Clay	25	1.0

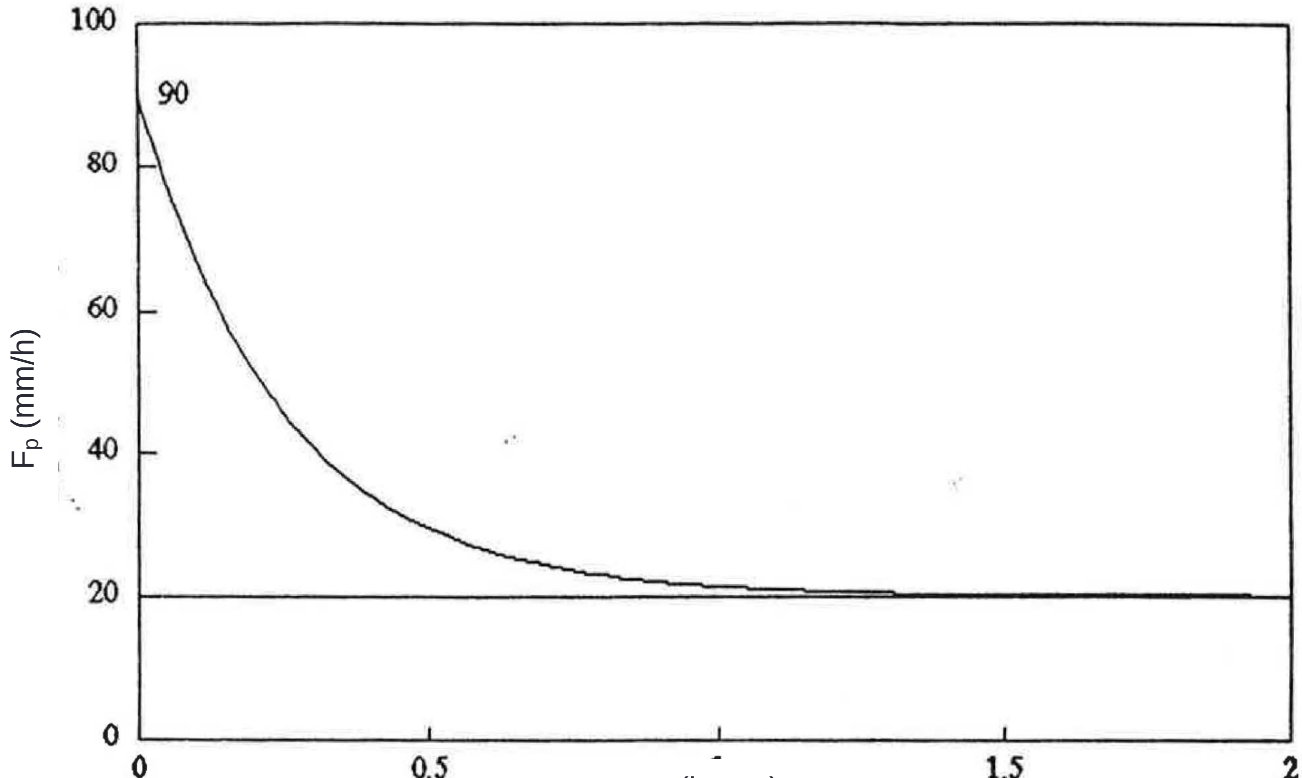
* These values are for soils with little or no vegetation. Multiply f_o by 2 for soils with dense vegetation.

k has been found to range from 3-6 hr^{-1}.

A value of k=4 hr^{-1} may be used as an average.

Horton's Equation

$F_p = F_c + (F_o - F_c)e^{(-kt)}$



*In this example: F_o=90mm/h; F_c=20mm/h

(Source: "Storm Water Management Model, Version 4 - User's Manual", U.S. Environmental Protection Agency, August 1988)

7.3.1.8 Runoff Coefficients (R)

Values for the runoff coefficient “R” shall be approved by the City Engineer. Listed below are recommended ranges of runoff coefficients:

Surface Type of Land Use	Recommended Coefficient
Parks	C=0.25
Schools	C=0.45-0.75
Single Family Residential	C=0.45
Semi-Detached	C=0.50
Row Housing, Maisonettes, Townhouses, etc.	C=0.60 -0.70
Churches	C=0.70
Apartment	C=0.65-0.70
Industrial	C=0.75
Commercial	C=0.90
Paved Areas (Asphalt, concrete, roof areas)	C=0.90 - 1.00

7.3.1.9 Slope of Storm Sewer Pipe

The pipe diameter and slope should be chosen such that an ideal velocity is obtained to minimize the settling of solids. The following are the minimum slopes which shall be provided for storm sewers:

Pipe Size	Minimum Slope in m/100m (Feet per 100 Feet)
100 mm	0.84
150 mm	0.49
200 mm	0.40
250 mm	0.28
300 mm	0.22
350 mm	0.17
375 mm	0.15
400 mm	0.14
450 mm	0.12
525 mm	0.10
600 mm	0.08
675 mm	0.067
750 mm	0.058
825 mm	0.052
900 mm	0.046
1050 mm	0.037
1200 mm	0.030
1350 mm	0.026
1500 mm	0.022
1650 mm	0.020
1800 mm	0.018
1950 mm	0.016
2100 mm	0.014

7.3.2 Velocity

The velocity in storm sewers shall be generally limited to a minimum of 0.6 m/s (2ft/s) and a maximum of 6.0 m/s (20ft/s).

For watercourses the allowable maximum and minimum velocities are as follows:

Watercourse Type	Minimum Velocity		Maximum Velocity	
	(m/s)	(ft/s)	(m/s)	(ft/s)
Grass Lined	0.3	1.0	1.5	5.0
Concrete, gabion lined	0.3	1.0	3.1	10.0

7.3.3 Minimum Pipe size

Sewer Mains 250 mm
Catchbasin Connections- 200 mm

7.3.4 Minimum Depth

The storm sewers shall be sufficiently deep to service the contributory lands and to prevent freezing.

The minimum cover to the top of pipe shall generally be 1.4 metres. Depths of cover less than this may be approved by the City Engineer where this minimum is not feasible.

In all cases, the proposed storm sewers shall be installed at sufficient depth to service lands external to the site as determined by the City.

7.3.5 Bedding and Backfill

Bedding and backfill for storm sewers shall be Granular 'A' material compacted to 100% maximum dry density and will be in accordance with current OPSDs for rigid and flexible pipe, unless otherwise approved by the City Engineer.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Where allowed, selected native backfill shall be compacted to 95% maximum dry density. The class and type of pipe bedding shall be shown on the profile for all lengths of sewer.

7.3.6 Location

Storm sewers shall be located on the south and west side of the road allowance, 1.5 metres from the centreline as shown on the Standard Drawings.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

If common trenching is required for the storm and sanitary sewer, the consulting engineer shall prepare special design standards and provide to the City the specification for such requirements. Any non-standard design for locations will require the approval of the City Engineer.

7.3.7 Manholes

Manholes shall be provided at the end of a line, at each change in alignment, grade and pipe material and at all intersections. Manhole construction and installation shall be as per current Ontario Provincial Standard Drawings (OPSD).

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

The type and size of manhole shall be specified on the profile and a detail of the benching shall be shown on the plan portion of the drawing for cases when the benching differs from the normal.

All manhole chamber openings shall be located on the upstream side of the manholes.

The maximum change in the direction of flow in any storm sewer manhole shall be 90 degrees for sewers greater than 525 mm in cases where there is more than one inlet, the maximum change in direction in a manhole shall be 90 degrees for storm sewers greater than 450 mm. The maximum change in direction of flow in manholes for sewer sizes 1050 mm and over shall be 45 degrees.

The direction of flow in any manhole will not be permitted at acute interior angles.

The minimum drop across the manhole for all straight runs shall be sufficient to maintain the design head.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

The obverts on the upstream side of a manhole shall, in no case, be lower than those on the downstream side.

When the dimensions of a manhole exceed those on Standard Drawings, the manhole must be individually designed and detailed.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Safety grating shall be provided in accordance with current Provincial Regulations made under the Occupational Health and Safety Act. Safety gratings shall be required in all manholes greater than 5.0 metres in depth. Safety gratings shall not be more than 5.0 metres apart and constructed in accordance with the current OPSD.

http://www.ontario.ca/laws/statute/90o01

7.3.7.1 Size

Maximum Sewer Diameter (Straight Through)	(Right Angle)90 Degrees	Required Manhole Diameter
≤ 600mm (24")	≤ 450mm (18")	1200mm (48")
675-825mm (27-33")	525-600mm (21-24")	1500mm (60")
900-1050mm (36-42")	675-825mm (27-33")	1800mm (72")
1200-l500mm (48-60")	900-1050mm (36-42")	2400mm (96")

7.3.7.2 Spacing

Generally manholes shall be spaced at:

- A maximum of 100 metres for pipe sizes 250mm diameter to 750mm diameter
- A maximum of 120 metres for pipe sizes 825mm diameter to 1200mm diameter
- A maximum of 150 metres for pipe sizes greater than 1200mm diameter

7.3.7.3 Benching

A bench is to be provided in all manholes (except catchbasin manholes) on both sides of the channel whenever the pipe diameter is less than the manhole diameter. The benching in the manhole shall be in accordance with the current OPSD and shall be sloped no greater than 1:4 nor less than 1:8.

7.3.8 Catchbasins

Catchbasins must be in accordance with OPSD. 705.010 and catchbasin frames and grates must be in accordance with OPSD. 400.100 (cast iron square frame with square flat grate), unless otherwise approved.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Special catchbasin and inlet structures must be fully designed and detailed.

Catchbasins are required at all low points in roads, parking lots and at intersections. Along roadways, catchbasins are required at the following maximum distances:

Road Grade	Maximum Spacing
≤ 3.0 %	110 m (350')
3.0 - 4.5 %	90 m (300')
> 4.5 %	75 m (250')

The maximum distances are based on the capacity of a standard 600mm × 600mm square grate on pavement widths of up to 9.75 metres.

Where changes of grade occur, the average gradient will determine the maximum spacing. Catchbasins should not be located within 1.5 metres of a curb depression for a driveway or sidewalk. At intersections, catchbasins must be installed so that no more than 15 metres of gutter will drain past the upstream point of tangency.

In sags, when drainage is received from more than one direction, or where the inlet capacity of a single catchbasin is exceeded double catchbasins (as per OPSD 705.02) must be installed and the maximum length of gutter contributing from each side must be 75% of the spacing permitted above. Inlet capacity can be computed using the formula from Section 7.3.1. which is:

$$Q = kCA(2gH)^{0.5}$$

No single catchbasin will drain a hard surfaced area larger than 1000 sq m (10,000 sq ft).

Catchbasin-manhole structures with sumps (as per OPSD) may be used in place of separate catchbasins and manholes.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

Catchbasins are permitted in rear yards to allow drainage to the storm system on the street.

Catchbasin leads shall be the following sizes:

- For single catchbasins - 200 mm (8") @ 0.5% (min.)
- For double catchbasins - 250 mm (10") @ 0.5 % (min.)

See Section 7.4 for catch basin connection requirements.

7.3.9 Inlet and Outfall Structures

Inlet and Outfall structures including headwalls must be fully designed and submitted in detail. The consulting engineer should contact the Niagara Peninsula Conservation Authority to ascertain permit requirements. In each case, existing topography should be shown as well as the protective works necessary to counteract erosion at the site of the structures.

Grates shall be provided on all inlet and outfall structures 600 mm in diameter and larger and shall be fully designed and detailed including locks where applicable.

In general, inlet grates shall consist of vertical parallel bars or rods sloping approximately 45 degrees away from and in the direction of the flow. Outlet grates shall consist of horizontal bars or rods placed perpendicular to the flow. Spacing between the bars or rods shall not exceed 150 mm.

7.3.10 Mainline Sewer Pipe

All storm sewers must be located as shown on the appropriate road cross-section standard.

Pipe sizes must not decrease from a larger size upstream to a smaller size downstream regardless of the increase in grade.

Subject to the approval of the City Engineer, radius pipe will be permitted to achieve changes in horizontal alignment. The minimum radius allowed for various diameters of pipe shall be as detailed in the manufacturer's specifications.

Pipe bedding and class must be designed to suit ultimate loading conditions.

A minimum clearance of 225 mm must be provided between the outside of the pipe barrels at the point of pipe crossing for storm sewers and other utilities. In the event that the minimum clearance of 225 mm cannot be obtained, then the pipes at the crossing shall be concrete encased to insure that the pipes are properly bedded.

For watermain crossings, adhere to the latest MOECC Design Guidelines. Under normal conditions the current standard is that sewers, drains, manholes and similar sources of contamination should be laid at least 2.5m horizontal separation from a watermain. This distance is measured from the nearest edges.

If the horizontal separation cannot be met then the crown of the sewer should be at least 0.5 metres below the invert of the watermain. Pipe joints between the sewer and watermain should be offset as much as possible.

Where this vertical separation is not possible then the sewer should be constructed of watermain quality pipe, pressure tested in place at a pressure of 350 kPa (50psi) without leakage in accordance of OPSS 704. Alternatively either the watermain or the sewer line should be encased in a watertight carrier pipe which extends 3m (10 feet) on both sides of the crossing, measured perpendicular to the watermain.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

7.3.11 Pipe Materials

Unless otherwise approved by the City Engineer storm sewers must be constructed of concrete pipe, polyvinyl chloride (PVC) pipe or polyethylene pipe (PE). Corrugated metal piping may be used for culverts.

Pipe sections must be joined by means of approved rubber gaskets. The classification of pipe to be used shall be clearly indicated on the plans. Below is a list of materials which can be used for storm sewer construction. Where a standard or specification is provided it is expected that the most current version of that standard / specification is used.

7.3.11.1 Concrete Pipe (circular)

Non-reinforced	100 mm (4") - 900 mm (36") - CSA A257 .1
Reinforced	300 mm (12") - 3600 mm (144") - CSA A257.2

Pipe joints (rubber gasket type) - CSA A257.3
Reinforced Concrete Sewer Pipe 300 mm in diameter and larger shall be steel reinforced, Class II, III, IV or V, as required.

7.3.11.2 Polyvinyl Chloride (PVC) Pipe

DR 35
100 mm (4") - 150 mm (6") – CSA B182.2 and CSA B182.11
200 mm (8") - 375 mm (15") – CSA B182.2 and CSA B182.11

DR 28 (building sewer service laterals)
100 (4") - 150 mm (6") - CSA B182.1 and CSA B182.11

Pipe joints - 'Ring-Tite', or approved equal

Profile Pipe
200 mm (8") - 900 mm (26") – CSA B182.4 and CSA B182.11

7.3.11.3 Corrugated Steel Pipe (CSP)

Corrugated steel pipe shall conform to A.A.S.H.O. Specifications M218, M136, M190 and M167.

7.3.11.4 Polyethylene Pipe (PE)

Polyethylene Pipe (PE) shall be manufactured in accordance with the latest revision of CSA B182.6 “Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications”. This standard applied to trenchless technology and shall be HDPE pipe.

7.4 Storm Services (Storm Building Sewers, Storm Drainage Pipe & Catch Basins)

Only one storm private drain (sanitary sewer lateral) shall be provided for each property unless otherwise approved by the City Engineer. All freehold townhouses, semi detached and single dwellings shall have individual storm private drains.

All 100mm to 300mm diameter storm private drains shall be installed in accordance with OPSD 1006.01 (rigid main sewer) or OPSD 1006.02 (flexible main sewer) and their connection to existing or proposed mainline sewers conform to the requirements listed here.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

All storm private drains with diameters greater than 300mm shall be install as per mainline sanitary sewer specifications.

7.4.1 Connection to Proposed Sewer Main

Where the diameter of the storm private drain or catch basin connection is greater than 300mm, connections to the proposed main sewer shall be made using a manhole.

Where the storm private drain or catch basin connection has a diameter less than or equal 300mm, connections to the proposed mainline sewer shall be made using a manufactured wye.

7.4.2 Connection to Existing Sewer Main

Where the diameter of the storm private drain or catch basin connection is greater than 300mm connections to the existing main sewer shall be made using a manhole.

Where the diameter of the storm private drain or catch basin connection is less than or equal 300mm connections to the existing main sewer shall be the following.

7.4.2.1 A manufactured wye can be used if:

a) The main sewer diameter is less than or equal to 450mm (18”).

7.4.2.2 A strap-on-saddle can be used if:

a) The main sewer diameter is less than or equal to 450mm (18”) AND
b) 2/3 of the main sewer diameter is greater than the diameter of the private drain

7.4.2.3 A core and insert-a-tee method can be used if:

a) the main sewer is greater than 450mm (18”)

7.4.2.4 A manufactured tee can be used if:

a) the sanitary private drain requires a vertical riser as per OPSD 1106.01 or City Standard Drawings.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

7.4.3 Pipe Size

Minimum sizes are as follows:

- One dwelling unit: 100 mm (4")
- Two dwelling units: 125 mm (5")
- Commercial / industrial sites : 150 mm (6")

7.4.4 Depth

The depth of service connections measured at the property line must be:

- Minimum – 1.80 metres
- Maximum – 2.50 meters

Risers, not exceeding 3.0 metres in depth, must be used when the invert depth of the sewer main exceeds 4.0 metres.

7.4.5 Slope

The service shall be graded as such:

- Minimum 2%
- Maximum 8%

7.4.6 Multiple Family, Commercial and Other Blocks

Parking lots, driveways, and/or other hard surfaced areas servicing multiple family, commercial and other blocks, must be drained by a properly designed internal drainage system (including catchbasins, manholes and pipe) which shall connect to the storm sewer system or other approved outfall.

7.4.7 Velocity

The velocity in the service shall fall into this range:

- Minimum velocity – 0.80m/s
- Maximum velocity – 3.65 m/s

7.4.8 Sump Pump Connection to Storm Lateral

Connections from the sump pump to the storm service shall be made as per the City's Standard Drawing. An adequate air break must be provided on the sump pump connection outside the dwelling

7.5 Construction

Construction of all storm sewers and service connections in the City must be in accordance with the current and appropriate Ontario Provincial Standard Specifications, Niagara Peninsula Standard Contract Document and City of St. Catharines Standard Drawings. All storm sewer construction will be inspected by a City inspector or designate.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

http://www.niagararegion.ca/business/tenders/npscd/

8.0 **Water Distribution System**

8.1 Hydraulic Design

8.1.1 Design Water Demands

Determination of watermain design flows must conform to the latest editions of the Ontario Ministry of the Environment and Climate Control publication "Design Guidelines for Drinking-Water Systems 2008" and the Regional Municipality of Niagara publication "Project Design and Technical Specifications Manual".

http://www.ontario.ca/ministry-environment-and-climate-change

8.1.2 System Pressures

The maximum sustained operating pressures must not exceed 700 kPa (102 psi). Where pressures in localized area are above this level, pressure-reducing valves may need to be installed.

The distribution system must be sized to meet normal peak demands. Under conditions of simultaneous maximum day and fire flow demands, the pressure must not drop below 140 kPa (20 psi). Under normal operating conditions, the pressure shall not drop below 275 kPa (40 psi).

All watermains shall be capable of withstanding minimum design pressure of 1035 kPa (150 psi) regardless of the working pressure in the system or the rating necessary to meet the structural requirements of the trench condition. (Design pressure = maximum sustained internal hydrostatic pressure to which the pipe is to be subjected, excluding transient pressures).

8.1.3 Friction Factors

The following C factors should be used for the design of water distribution systems regardless of pipe materials:

Pipe Diameter (mm)	C-Factor
150	100
200 to 250	110
300 to 600	120
Over 600	130

The above C factors represent long term values. A C factor of 130 should be used to calculate maximum velocities for transient pressure estimations, and for checking pump motor sizes for runout conditions.

8.2 Watermains and Appurtenances

8.2.1 Sizes

Sizes and looping of watermains will be determined at the preliminary stage of the development. The minimum size requirements are:

- Residential Areas – 150 mm diameter minimum for watermains supporting hydrants. Size as low as 50mm could be used past the last hydrant on dead end cul-de-sacs.
- Industrial Areas – Sized according to the anticipated demand for industrial subdivisions.

8.2.2 Depth of Cover

The minimum depth of cover to watermains should not be less than the depth of frost penetration.

The depth of cover must not be less than 1.70 metres measured in a vertical plane above the pipe from the top of the pipe to the finished ground elevation. It will be the responsibility of the consulting engineer to justify any reduction in the depth of cover less than 1.70 metres.

Frost protection measures are required for watermains or water services having a depth of cover less than the minimum required in the Niagara Peninsula Standard Contract Document (NPSCD). Insulation of watermains or water services shall also be according to the requirements in the NPSCD.

http://www.niagararegion.ca/business/tenders/npscd/

8.2.3 Pipe Material

All material, fittings and appurtenances shall be CSA and the American Water Works Association (AWWA) approved. Polyvinyl chloride pipe must be as per NPSCD and OPSS 441 standards/requirements.

http://www.raqsb.mto.gov.on.ca/techpubs/ops.nsf/OPSHomepage

8.2.4 Vertical Separation between Watermains and Sewers

Under normal conditions, the surface to surface vertical separation between the sewer and the watermain shall be at least 0.5 metres. Vertical separation between watermains and sewers must be in accordance with latest version of the Ontario Ministry of the Environment publication Design Guidelines for Drinking-Water Systems 2008

http://www.ontario.ca/ministry-environment-and-climate-change

8.2.5 Horizontal Separation between Watermains and Sewers

Under normal conditions, watermains must be laid with a horizontal separation of at least 2.50 metres from any sewer. The distance should be measured from the nearest edges. Horizontal separation between watermains and sewers must be in accordance with the latest version of the Ontario Ministry of the Environment publication Design Guidelines for Drinking-Water Systems 2008

http://www.ontario.ca/ministry-environment-and-climate-change

8.2.6 Separation of Watermain and Sewers – Special Conditions

Under unusual conditions, where a significant portion of the construction will be in rock, where it is anticipated that severe dewatering problems will occur, or where congestion with other utilities will prevent a clear horizontal separation of 2.50 metres, a watermain may be laid closer to a sewer, provided that at least 0.50 metres of vertical separation is provided between the two pipes. Such separation must be existing material or compacted backfill.

Where this vertical separation cannot be obtained, the sewer must be constructed of materials and with joints that are equivalent to watermain standards of construction and shall be pressure tested to assure water tightness. Where possible the watermain should be placed at a higher elevation than the sewer. Alternatively, the watermain could be installed in a casing pipe for localized conflicts.

In rock trenches, facilities should be provided to permit drainage of the trench to minimize the effects of impounding of surface water and/or leakage from sewers in the trench.

8.2.7 Crossings of Watermains Over and Under Sewers

Under normal conditions, watermains must cross above sewers with sufficient vertical separation to allow for proper bedding and structural support of the watermain and sewer main.

When it is not possible for the watermain to cross above the sewer, the watermain passing under a sewer shall be protected as follows:

A vertical separation of at least 0.50 metres shall be provided between the sewer and the watermain.

Existing sewers must be adequately supported to prevent excessive deflection of joints and settling.

The length of watermain must be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

City Standard Drawings could be used for achieving localized vertical separation.

8.2.8 Utility Crossings

Where watermains cross over or under utilities other than sewers, the clearance and type of crossing provided must conform to the requirements of the particular utility involved and provide proper bedding and structural support of the watermain and utility.

8.2.9 Dead Ends

Wherever possible, the distribution system should be designed to eliminate dead-end sections. Where dead-ends cannot be avoided, they must be provided with a fire hydrant, flushing hydrant or a 50 mm blowoff for flushing purposes.

8.2.10 Line Valves

8.2.10.1 Type

Line valves must be as per the requirements in Niagara Peninsula Standard Contract Document (NPSCD).

http://www.niagararegion.ca/business/tenders/npscd/

8.2.10.2 Sizes

The sizes of the line valves must be the same size as the watermain.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

8.2.10.3 Number, Location and Spacing

A minimum of two valves are required at a tee intersection and a minimum of three valves are required at a cross intersection. The valves must be located at the point where the projections of the street line intersects the watermain, or as per the City's Standard Drawings.

In general, valve spacing must not be more than 150m in industrial and commercial areas and 240m (or one block) in other areas.

8.2.10.4 Air Release Valves

Air release valves shall be placed at all significant high points of the distribution system. In addition, an attempt shall be made to locate hydrants at high points or at dead ends, thereby eliminating the need for air relief valves and/or blow-offs.

8.2.10.5 Drain Valves
Drain valves must be located at the low points of all watermains of 600 mm diameter and greater.

8.2.10.6 Valve Boxes and Chambers
All valves 300 mm diameter and smaller must have valve boxes and specified direct bury operators must be used.

All valves 400 mm diameter and larger must be installed in valve chambers. The tops of valve boxes and valve chamber manhole covers will be set flush with finished grade. The top of the roof slab of valve chambers must be 0.30 metres minimum to 0.45 metres maximum below the profile of the finished pavement.

Chambers or pits containing valves, blow-offs, metres or other such appurtenances to a distribution system must not be connected directly to any sanitary or combined sewer, nor may blow-offs or air-relief valves be connected directly to any such sewer.

Such chambers or pits shall be drained to the surface of the ground where they are not subjected to flooding by surface water, to absorption pits or to a sump within the chamber where ground water level is above the chamber floor or storm sewer.

In order to minimize the total number of chambers on any project, care should be exercised in locating the line valves, air reliefs, drains, etc., with a view to combining these functions in a single chamber where possible.

8.2.11 Fire Hydrants
Fire protection for industrial and commercial development must be reviewed upon application. Hydrant installation shall be as per City Standard Drawings.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

8.2.11.1 Hydrants-Numbers and Spacing

Hydrants must be installed on all watermains 150 mm diameter and larger with the following maximum allowable spacing:

- 150 metres in residential areas, or to provide for a maximum hose length of 75 metres,
- 100 metres in industrial and commercial areas to provide for a maximum hose length of 50 metres. The maximum hose length to Siamese connections for buildings shall be as per the applicable regulations.

8.2.11.2 Secondary Valves and Boxes

All hydrant leads must be 150 mm in diameter and shall include hydrant secondary valve and box installed at an appropriate location on the hydrant lead. When possible it is preferred that hydrant secondary valves are not within the travelled sections of the road.

8.2.11.3 Hydrant Use for Construction

Existing hydrants can be used for flushing and testing of new watermains. Existing hydrants cannot be used for any other purpose during construction unless specifically allowed by the City.

For a permitted use of a hydrant, the contractor is required to fill out a hydrant use application. This application is available on the City's website or through the Transportation and Environmental Services office. The hydrant use application form must be completed and submitted well in advance of the intended use to allow for processing and installation of a backflow prevention device on the required hydrant.

For City projects, the installation of a backflow device and the use of water from a hydrant are not charged to the contractor. Charges as noted on the hydrant use application form apply to private developments for both private service connections and services to be assumed by the City and other projects.

8.3 Water Service Connection

In new developments, the service connections must be installed in accordance with the City Standard Drawings terminating at the property line.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

No service connection is permitted to watermains greater than 400 mm diameter or a Regional trunk watermain unless specifically permitted by the Region of Niagara.

8.3.1 Pipe Sizes

The minimum size for service connections is 20 mm diameter except when the length of the connection from the main to the building setback exceeds 30 metres. In this case the minimum size will be 25 mm diameter.

Service connections for multiple family dwellings must be sized to provide capacity equivalent to a 20 mm diameter connection to each dwelling unit.

Service connections for blocks, commercial and industrial areas must be sized according to the intended use.

8.3.2 Location

Water service connections must be installed at the front of a single family lot as per the Standard Drawings.

Water service connections are not be located under a driveway, if possible. The location of water service connections for semi-detached lots must suit the house style in accordance with the Standard Drawing.

http://www.stcatharines.ca/en/documents/documentuploads/officialdocumentsandplans/doc_635622927775086542.pdf

8.3.3 Depth

Water service connections must be installed 1.70 metres below finished grade.

Water services having less than the minimum cover allowed as per the NPSCD Niagara Peninsula Standard Construction Document must be insulated as per the requirements in the NPSCD.

http://www.niagararegion.ca/business/tenders/npscd/

8.3.4 Mainstops

All domestic water service connections must have mainstops installed at the watermain equal to the water service connection diameter as per requirements in the NPSCD.

8.3.5 Curb Stops and Boxes

All service connections must have curb stops and boxes installed as per requirements in the NPSCD at approved locations.

8.3.6 Materials

Water service connection 50 mm diameter or less must be type K copper or polyethylene. Water service connections larger than 50 mm diameter must be polyvinyl chloride. All material, fittings and appurtenances shall be CSA and the American Water Works Association (AWWA) approved.

8.3.7 Water Metering

Meters must be installed within the private property and must comply with the City's current water use by-law. Where there is more than one building located on a property the water meter must be installed in a pit at the property line in accordance with the drawings as provided in City Standard Drawing and the water use by-law. A design of the meter pit must be submitted for all meters greater than 50mm in diameter. The model type must be provided for all meters 50mm and smaller. Meter pits must be designed to fit model types in use by the City. Acceptable model types are to be confirmed by the City's meter foreman.

8.4 Cathodic Protection

Cathodic protection must be provided for all metalic pipes and appurtenances as per requirements in the NPSCD.

http://www.niagararegion.ca/business/tenders/npscd/

9.0 **Lot Grading**

New development lot grading must conform to the storm sewer section of this manual and the Ministry of the Environment Stormwater Management Planning Design Manual. Lot grading design must be prepared by a professional engineer or an Ontario land surveyor.

http://www.ontario.ca/ministry-environment-and-climate-change

The drainage design of any development must address any drainage presently flowing onto the site, through the site and from the site.

At the time of final acceptance the consulting engineer will provide the City with an as-built grading plan for the development showing the finished grade of all key points. Minor variations may be accepted, provided the intent of the proposed approved plan is achieved.

It will be the responsibility of the consulting engineer to ensure that lot grading is completed to the satisfaction of the City Engineer. Lot grading must be in accordance with the approved drawings.

Any deviation from the overall grade plan may require approval of the City Engineer.

9.0 Objectives

The grading plan will be reviewed and, therefore, should be designed with the following objectives in mind:

- The development property drainage plan will ensure that the site drainage is contained within its' own property. Post-development flows from the site must not exceed pre-development flows, unless there is sufficient evidence showing capacity of the receiving stormwater system.
- The establishment of independent and adequate drainage for each lot. This can be provided by either rear to front drainage (Preferred Option) or split drainage intercepted in a rear yard swale, catchbasins, etc.
- The establishment of lot and house grades will be compatible with existing topography and surrounding development. This must be completed with the building design in mind.
- The establishment of gradual gradation without terraces, steep slopes, or abrupt changes in grade is preferred. These are not only difficult to maintain, but also accentuate the artificiality of the new topography.
- Defined ditching should be avoided.

9.1 Design Criteria

9.1.1 Slope

The maximum allowable difference in elevations between abutting lots along the rear lot line is 0.3 metres.

The slope should be located on the lower property.

Slopes of less than a 3:1 are not permitted unless approved by the City Engineer.

Grass surfaces must have a minimum slope of 2%.

Grading around houses and buildings must direct the water away from the structure.

9.1.2 Swales

The use of rear yard swales, embankments or retaining walls should be minimized.

Swale depth will vary depending on location and safety consideration. The preferred minimum swale depth is 0.1m and maximum depth is 0.5m.

Swales must be located as far from the structures as possible.

All swales must have under drainage, (weeping tiles) and be connected to an acceptable outlet.

The maximum runoff allowed in a swale between two houses is the drainage from those two yards.

The maximum swale length shall not exceed 90 metres. Such drainage must not outlet along the surface between houses. Not more than eight lots (two lots each way) that are back to back, or six lots (three lots each way) along one side of the road allowance, shall be serviced by one basin.

When rear lot catchbasins are installed to pick up surface drainage, the municipality will maintain them, in which case, easements must be provided by the developer. These must be identified in the subdivision/ development agreement. The width of such easements shall be a minimum of 3.0m but may be greater depending on the site conditions.

The proposed elevations at the boundary of the subdivision will match existing elevations.

Provision is to be made to prevent ponding of water on lands bordering the subdivision/ development.

9.1.3 Driveways

Where below grade garage driveways are designed, the portion between the property line and street must drain towards the street. If their use is proposed, the proponent must ensure that a suitable degree of flood protection is provided.

Reverse driveway drainage facilities may not be connected by gravity to the storm sewer system unless it can be demonstrated that surcharging by the storm sewer system during the 1:100 year storm will not cause them to flood.

9.1.4 Pre-Grading

The development lands must be pre-graded prior to issuance of building permits and the consulting engineer must verify that such work has been done. Pre-grading requires that all lot corners, rear yard catchbasins, swales (including under drainage and sod 5 meters either side of catchbasin) and boulevards have been constructed in accordance with the general grading plan. Pre-grading must also ensure that runoff from the private properties does not flow onto the municipal road allowance until such time as the lots have been sodded, and ensure the maximum depth of any water pooling does not exceed 0.6m.

Appendix A –Rainfall Data –Design Storms

APPENDIX A
RAINFALL DATA - DESIGN STORMS

A.1 General

Rainfall distribution, both in time and in space, is a random process which has to be simulated by means of artificial design storms of various return frequencies, for the purpose of stormwater runoff analysis. The return frequency of a particular design storm represents the likelihood of that storm occuring. For example, a 1:5 year design storm will occur, on average, once every five years; a less frequent more intense storm, say the 1:100 year design storm, will occur, on average, once every 100 years.

It must be remembered that, in general, the return frequency of the runoff is not the same as the return frequency of the rainfall that caused the runoff. It would therefore be desirable to use design floods rather than design storms in the analysis of storm drainage facilities, however due to a lack of sufficient runoff data, this is usually not possible. As a result, engineers have traditionally used design storms, in various forms, for the purpose of stormwater runoff analysis.

This Appendix discusses the various Intensity-Duration-Frequency (IDF) curves and design storms that have been used in previous storm sewer studies throughout St. Catharines and recommends those to be used in the future.

A.2 IDF Curves

Although not a design storm per se, the IDF curve is widely used in conjunction with the Rational Method in the design of storm sewers.

An IDF curve is a plot of rainfall intensity versus storm duration for storms with a certain return frequency, and has the following general form:

$$i = a/(t+c)^b$$

where: i = rainfall intensity
t = storm duration
a,b,c = coefficients for a storm with a given return frequency at a given location

IDF curves are statistically produced from data collected at individual rainfall stations. The Atmospheric Environment Service (AES) of Environment Canada (formerly the Department of Transport [DOT] - Meteorological Branch) operate and regularly update the IDF curves for each station across Canada.

The following is a list of the various IDF curves that have been used in previous drainage or sewer studies for St. Catharines :

(i) $i = 7.6/t^{0.41}$ (in/hr)

- A 10 year return curve recommended for use by Proctor and Redfern ("St. Catharines - Grantham Amalgamation Study" - Oct. 1959) after study of available rainfall data and comparison with design IDF curves from other municipalities in Southern Ontario. It was used until circa 1966.

(ii) DOT - Niagara Peninsula

- A family of IDF curves, shown in Figure A.1, developed by the DOT from rainfall data collected at a number of rainfall gauging stations throughout the Niagara Peninsula (the station in St. Catharines operated from 1952-1964).
- Recommended for use by Proctor and Redfern ("Storm Drainage Study St. Patrick's - St. George's Wards" - Nov. 1966) and used as St. Catharines' design storms ever since. The following formulae were developed to approximate the 5 and 25 year curves:

  $i = 106/(t+18)$ (in/hr) - 5 year design curve presently used to size storm sewers

  $i = 17/t^{0.5}$ (in/hr) - 25 year design curve presently used in open channel design (with a 1 foot freeboard)

(iii) AES Stations

- Rainfall data has been collected at AES stations in St. Catharines (Niagara District Airport) and Vineland since 1954 and 1963 respectively. The current IDF curves (based on data collected until 1986) for the two stations are shown in Figures A.2 and A.3.

- Caution should be exercised in the use of the IDF curves for St. Catharines because of distortion caused by one or two intense storms in the 1970's.

- A drainage study by Gore & Storrie ("Report on the Geneva Street Area Sewer Systems" - 1980) recommended using a combination of IDF curves for various durations:

  (a) for durations of less than one hour, the present St. Catharines design curves (given in (ii), above) were recommended.

  (b) for durations of more than two hours, the AES curves for St. Catharines (then based on data collected until 1979) were recommended.

  (c) for durations between one and two hours, interpolated values between (a) and (b) were recommended.

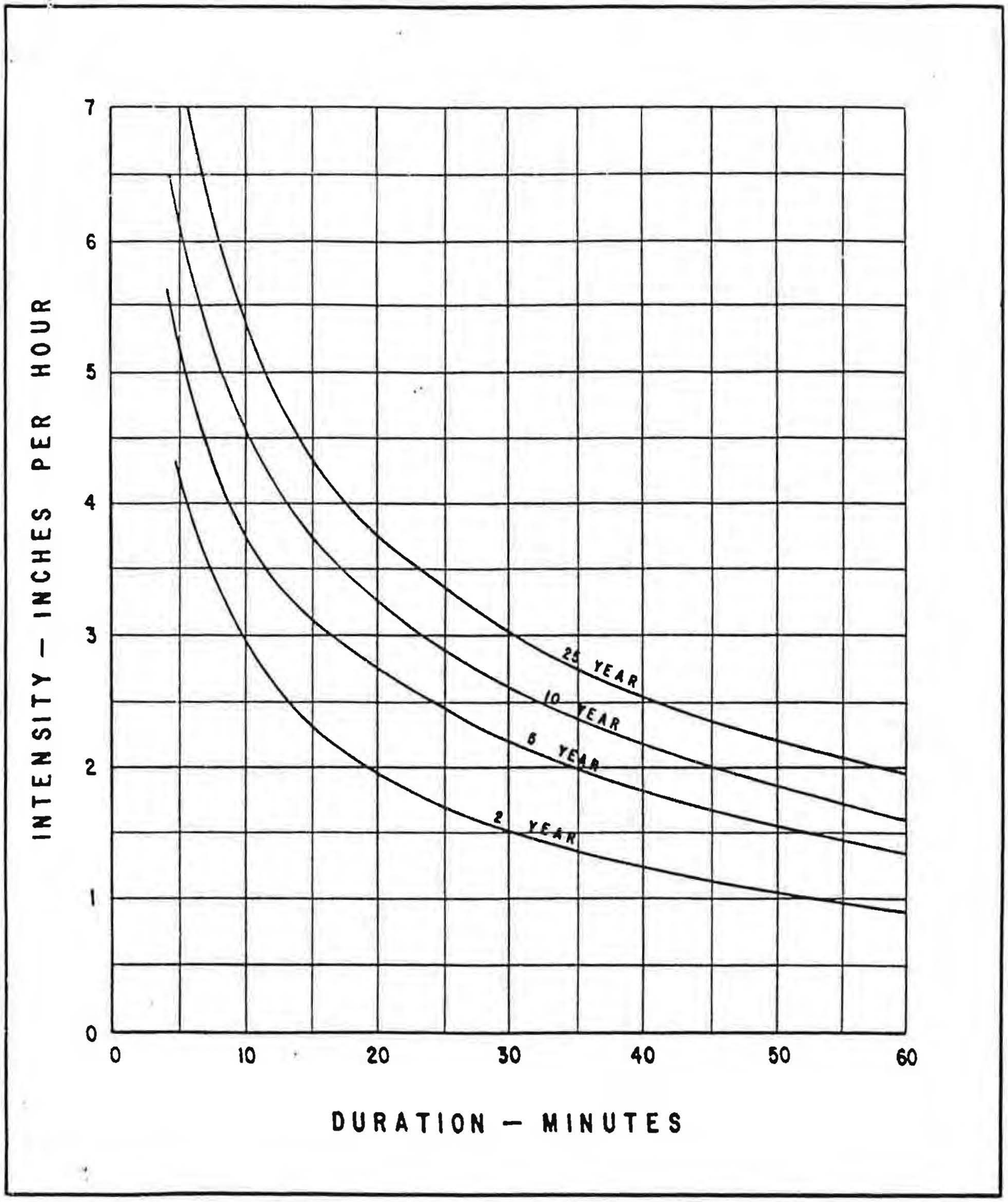


Figure A.1 IDF Curves - DOT Niagara Peninsula - 1966

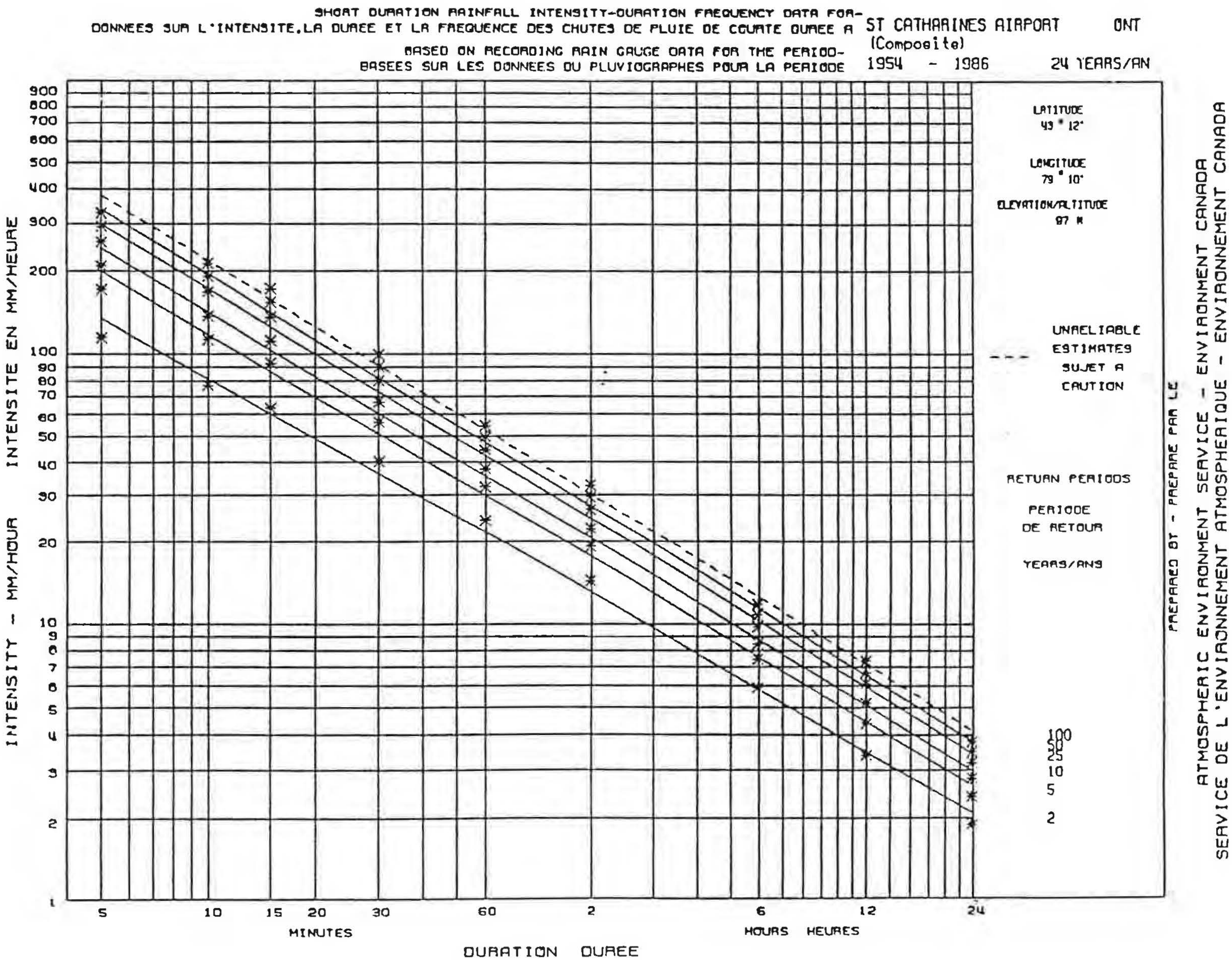


Figure A.2 IDF Curves - AES St. Catharines - 1954-1986

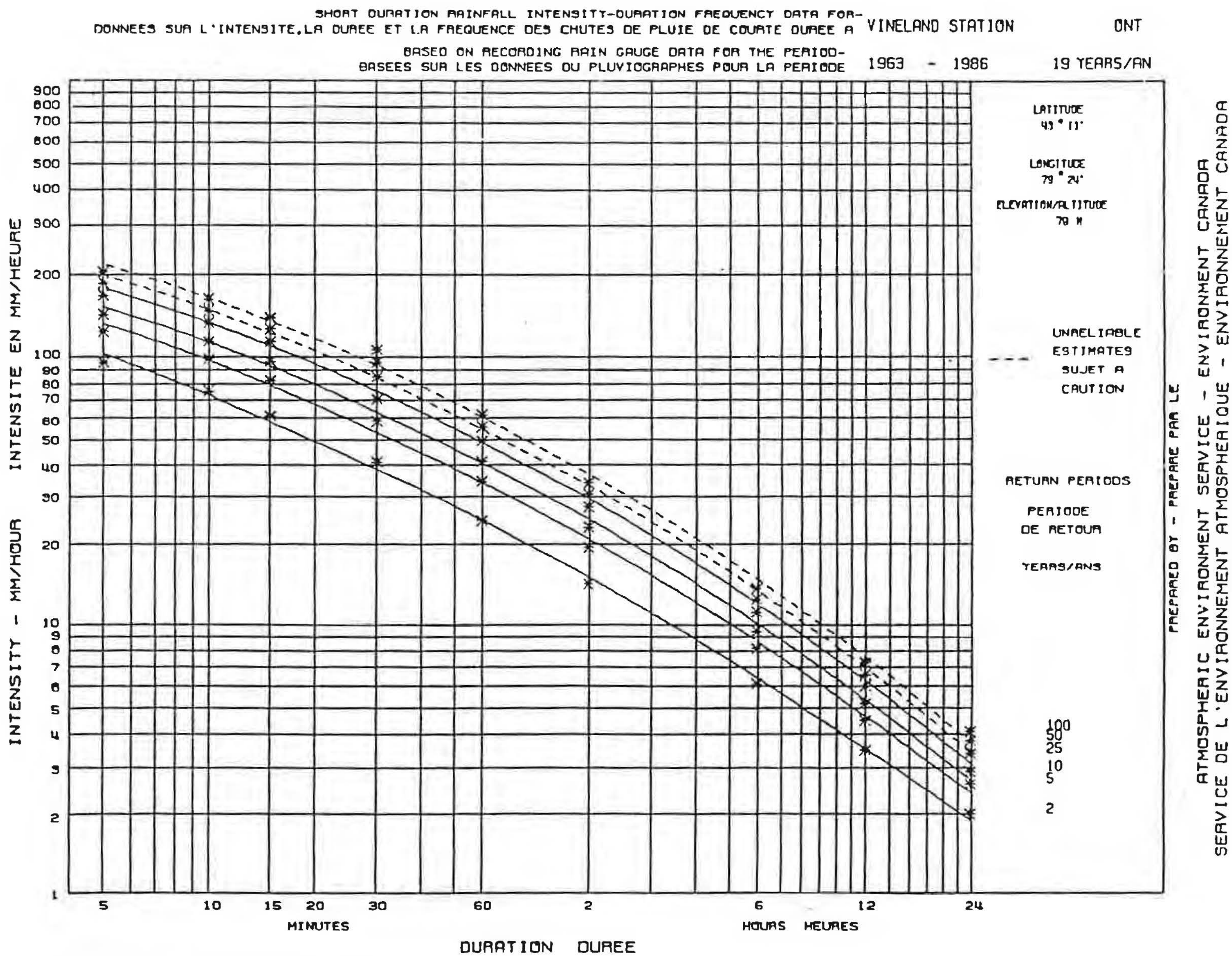


Figure A.3 IDF Curves - AES Vineland - 1963-1986

- Previous studies by DeLCan ("Merritton Area Drainage Study" - May 1979; "Facer N.I.P. Area Sewer System Study" - Sept. 1981) utilized IDF curves from the Vineland AES station for analysis.

(iv) MTC Rainfall Intensity Atlas

- The Systems Design Branch of the MTC compiled the Rainfall Intensity Atlas for Ontario in 1973, using data from weather stations throughout the province. Only stations having at least 10 years of recorded data were used (the longest having 41 years). Since none of the individual stations had a 100 year return curve and only four had a 50 year return curve, the 50 and 100 year return curves for the atlas were determined from an extrapolation of existing data.

  - A floodplain study by Philips Planning and Engineering ("Floodplain Mapping Study of Dick's Creek" - February 1980) utilized a set of IDF curves for St. Catharines based on this atlas. These curves are shown in Figure A.4.

(v) Rainfall Frequency Atlas for Canada

- The AES of Environment Canada published this atlas in 1985, using rainfall data from 504 gauges across Canada. All stations had at least 7 years of recorded data, 315 had a record of 10 or more years and 48 had a record of 20 years or more.

- A set of IDF curves for St. Catharines derived from this atlas were previously presented in Table 3.1 and Figure 3.1.

In an effort to update and standardize the IDF curves for St. Catharines, the following is recommended:

(i) Because of the larger data set from which they were derived, the set of IDF curves presented in Table 3.1 and Figure 3.1 (derived from the Rainfall Frequency Atlas for Canada) should be adopted for use.

(ii) Approximately every five years, the IDF curves from the AES station in St. Catharines should be reviewed. If deemed necessary in an effort to better statistically represent the rainfall distributions in this particular area, the City should revise their IDF curves accordingly.

A.3 Chicago Design Storm

The Chicago design storm profile (Keifer & Chu, 1957) is developed from the coefficients of the applicable IDF curve.

For an IDF curve of the following form:

$$i = \frac{a}{(t+c)^b}$$

the rainfall intensity before and after the peak can be described as follows:

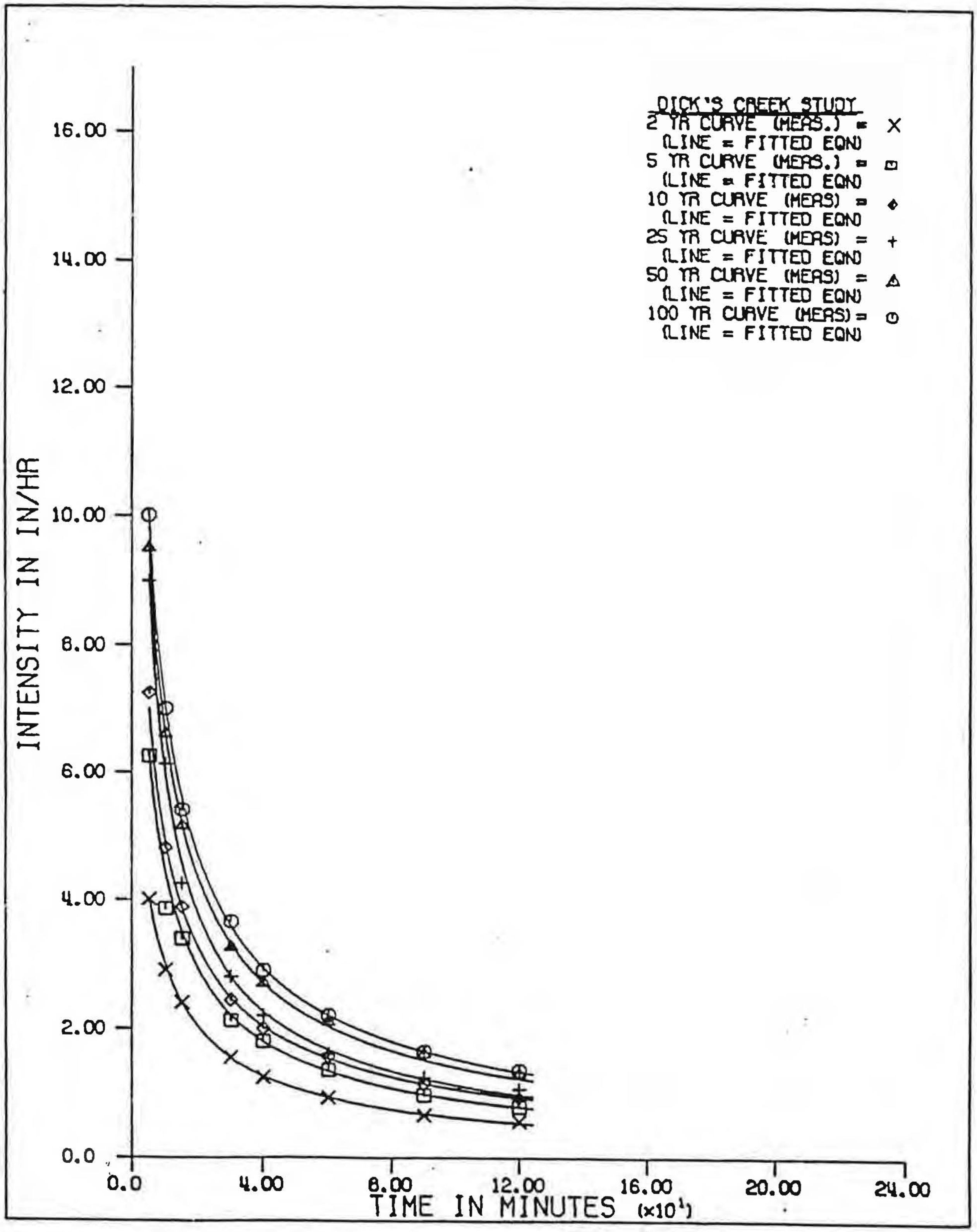


Figure A.4 IDF Curves - MTC Rainfall Intensity Atlas

$$i_b = \frac{a[(1-b)\frac{t_b}{r}+c]}{(\frac{t_b}{r}+c)^{1+b}} \quad ; \quad i_a = \frac{a[\frac{(1-b)t_a}{(1-r)}+c]}{(\frac{t_a}{1-r}+c)^{1+b}}$$

Where:

a,b,c = coefficients as per IDF curve
r = ratio of time before the peak to the total duration time
i_b = rainfall intensity before peak
i_a = rainfall intensity after peak
t_b = time before peak
t_a = time after peak

The value of 'r' is commonly assumed to be equal to 0.375, although this value should be derived from analysis of actual excessive rainfall events. Such an analysis was performed on data from the Royal Botanical Gardens rain gauge and resulted in an 'r' value of 0.46 ("Storm Drainage Criteria Manual for the City of Burlington - April, 1977). Assuming that rainfall patterns in St. Catharines are similar to those in Burlington, it is recommended that an 'r' value of 0.46 be adopted for future drainage studies in the City of St. Catharines that use Chicago design storms.

For design purposes, the above defined hyetograph must be discretized. Because of the generally 'peaky' nature of the Chicago storm profile (high ratio of peak intensity to average intensity) it has been suggested in the "Ontario Urban Drainage Design Guidelines" (April, 1987) that a 10 minute time interval be used in Southern Ontario for storm durations of one to four hours. However, all previous drainage studies for St. Catharines have used 5 minute intervals and it should be noted that the IDF curves (from which the Chicago storms are created) were originally derived from discrete rainfall data having minimum durations of 5 minutes. Therefore, a time increment of 5-10 minutes is appropriate, keeping in mind that shorter increments may lead to unrealistically high peak intensities.

In summary, the Chicago storm profile may be used for St. Catharines in the following manner:

- for the analysis of urban watersheds only
- the coefficients a, b and c are to be determined based on the applicable IDF curves discussed in Section A.2
- a value of r = 0.46 should be used
- time increments of 5-10 minutes should be used, keeping in mind that small increments may lead to unrealistically high peak intensities for the design storm
- the storm duration will generally be from three to four hours

The Chicago storm should not be used for large rural areas, since the storm tends to underestimate the peak flows in these types of watersheds. The SCS 24 hour design storm is better suited for rural watersheds.

A.4 SCS Type II Rainfall Distribution

The SCS type II rainfall distribution (Figure A.5 and Table A.1) is another popular non-dimensional storm distribution pattern. It is most commonly used for storm durations of 3, 6, 12 and 24 hours. For a given storm duration, the total storm depth may be obtained from an IDF curve with the desired return frequency.

The SCS 24 hour type II storms generally have lower peak intensities and higher total volumes than the Chicago storms. This feature is desirable for use in rural watersheds since peak flows in these areas are generally determined by the storm volume and not the peak intensity.

As a result, the SCS 24 hour type II design storm is recommended for use in rural watersheds. Type II distributions with shorter durations may be used in conjunction with Chicago storms in urban watersheds. Larger time increments may be used with longer duration storms.

A.5 Huff Storm Profiles

Another alternative to the Chicago type storms are a family of non-dimensional storm distribution patterns proposed by Huff (Huff, F.A., "Time Distribution of Rainfall in Heavy Storms", Water Resources Research, Vol. 3, No. 4, 1967, pp 1007-1019), based on data collected from 1955-1966 from 49 rain gauges spread over 1026 sq km (400 sq miles) in east-central Illinois. Huff developed four curves (Figure A.6, Table A.2), corresponding to the median distribution for which the heaviest rainfall occurs in the 1st, 2nd, 3rd or 4th 'quartiles' of the storm distribution. As shown below, it was found that shorter duration storms generally have 1st and 2nd quartile distributions while 3rd and 4th quartile storms typically have longer durations.

Quartile	% of Cases for given durations #12 hr	12-24 hr	#24 hr	Quartile Frequency (%)
1	45	29	26	32
2	50	33	17	34
3	35	42	23	25
4	22	26	52	9
All	42	33	25	100

Generally, shorter duration storms are more critical in urban watersheds while long duration storms produce greater peak flows in rural watersheds.

Based on this, it is recommended that for applications in St. Catharines, the 2nd quartile distribution should be used for urban watersheds and the 3rd quartile storm for rural watersheds. The total depth of rainfall for the desired storm duration can be obtained from the appropriate IDF curves.

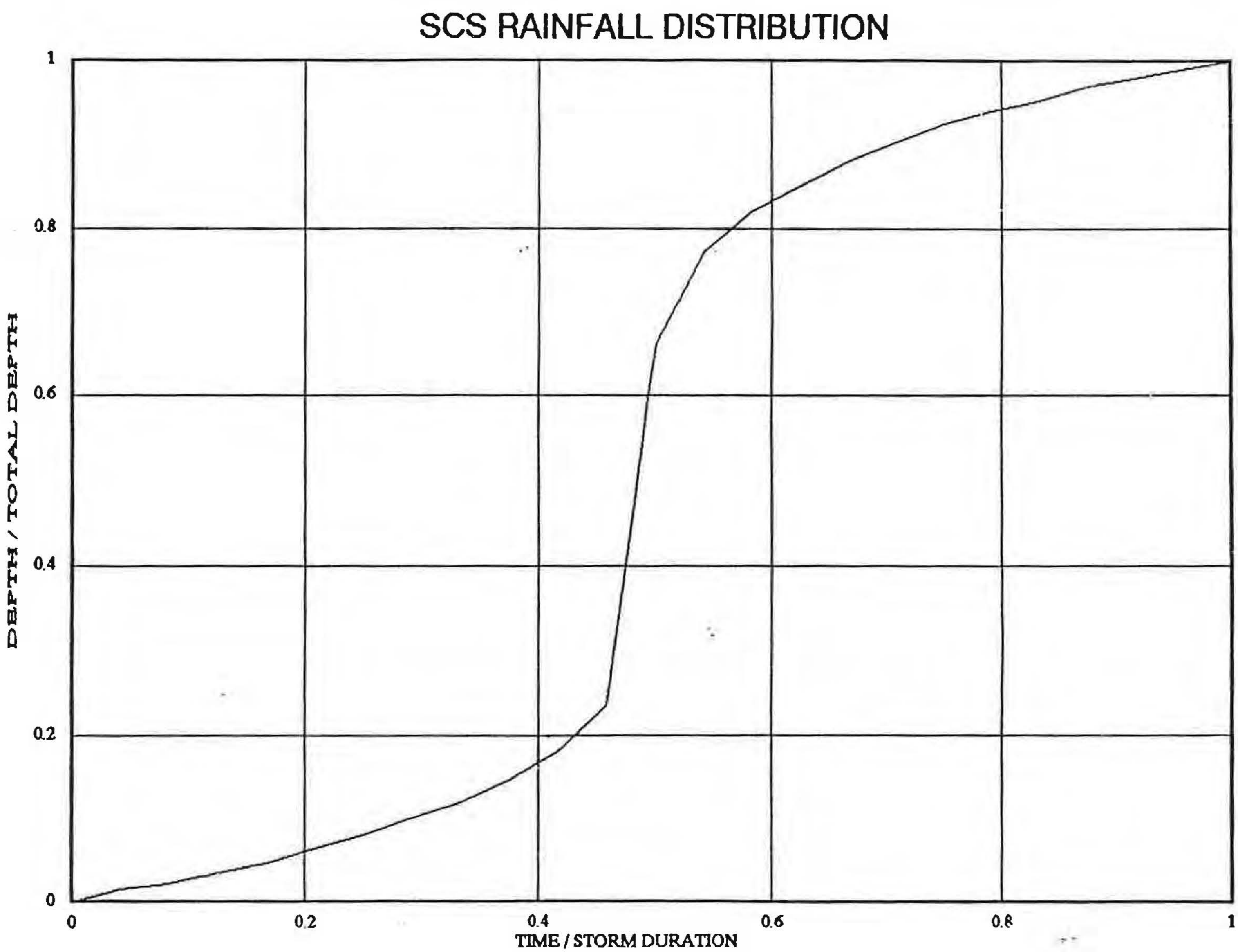


Figure A.5 SCS Type II Rainfall Distribution

Table A.1 SCS Type II Distribution
Source : RTAC Drainage Manual, 1982, pp 2.19

Storm Duration 3h	6h	12h	24h	Curve Ordinate
			1	0.015
	0.5	1	2	0.022
			3	0.035
0.5	1.0	2	4	0.048
			5	0.065
	1.5	3	6	0.080
			7	0.100
1.0	2.0	4	8	0.120
			9	0.147
	2.5	5	10	0.181
			11	0.235
1.5	3.0	6	12	0.663
			13	0.772
	3.5	7	14	0.820
			15	0.852
2.0	4.0	8	16	0.880
			17	0.902
	4.5	9	18	0.925
			19	0.940
2.5	5.0	10	20	0.952
			21	0.969
	5.5	11	22	0.980
			23	0.990
3.0	6.0	12	24	1.000

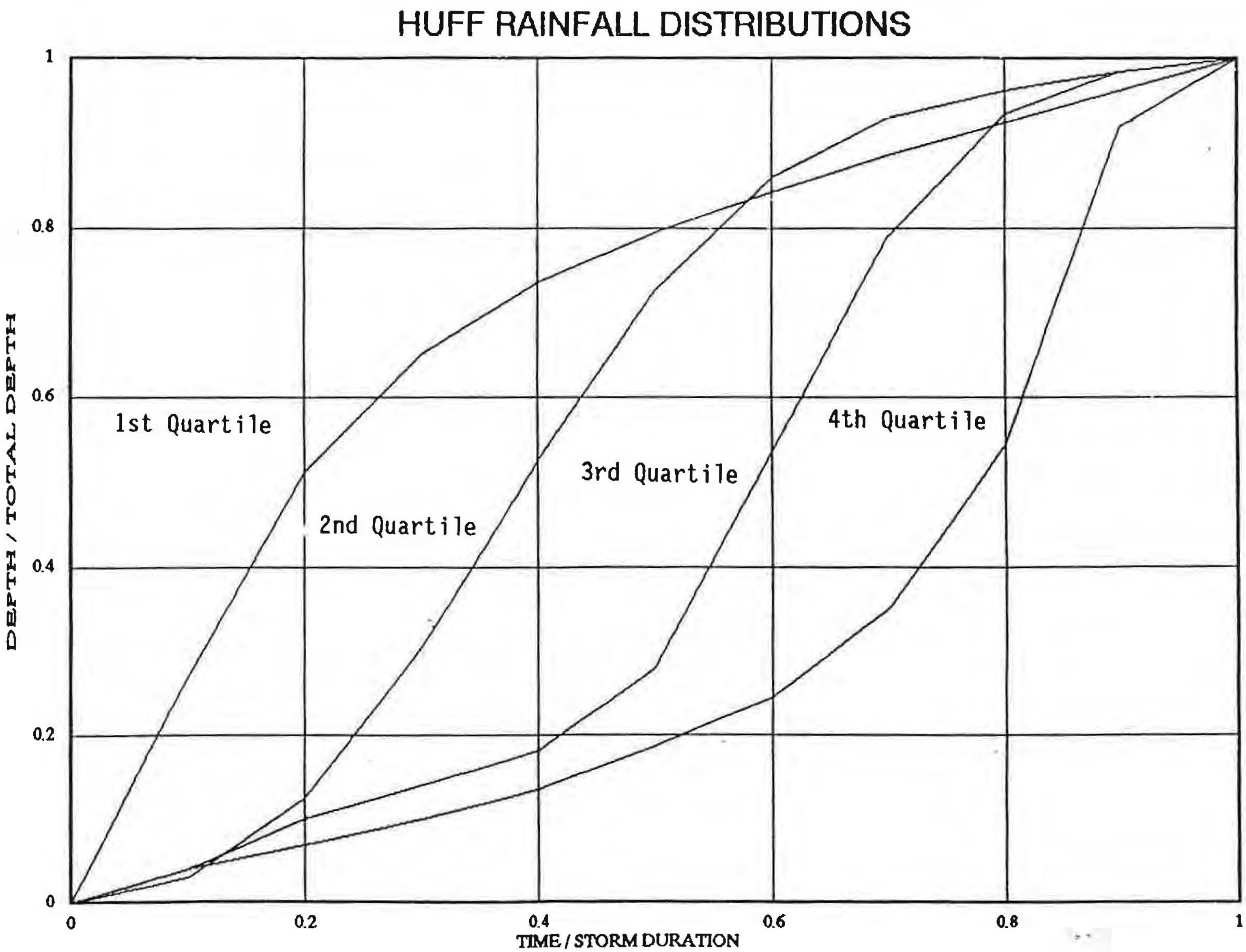


Figure A.6 Huff Rainfall Distributions

Table A.2 Huff 4 - Quartile Rainfall Distribution Patterns

Ratio of Time to Storm Duration	Curve Ordinates for Huff Quartile # 1	2	3	4
0.0	0.000	0.000	0.000	0.000
0.1	0.269	0.031	0.040	0.040
0.2	0.512	0.125	0.100	0.070
0.3	0.652	0.305	0.140	0.100
0.4	0.735	0.525	0.180	0.135
0.5	0.795	0.725	0.280	0.185
0.6	0.842	0.860	0.535	0.245
0.7	0.885	0.930	0.790	0.350
0.8	0.925	0.962	0.935	0.545
0.9	0.963	0.985	0.985	0.920
1.0	1.000	1.000	1.000	1.000

A.6 Canadian 1 Hour Urban Design Storm

Using rainfall data from 45 AES stations across Canada, a two parameter 1-hour urban design storm has recently been developed as an alternative to the Chicago storm. (Watt, W.E. et al, "A 1-h urban design storm for Canada", Canadian Journal of Civil Engineering, Volume 13, No. 3, June 1986, pp 293 - 301). A mathematical model for the design storm, comprising of linear rise and exponential decay components, is of the following form:

$$i = ht/a \qquad \text{for : } 0 \leq t \leq a$$

$$i = he^{-k(t-a)/(t_d-a)} \qquad \text{for : } a < t \leq td$$

where : i = intensity (mm/hr or in/hr)
h = peak intensity (mm/hr or in/hr)
$= D/[a/2 + (t_d - a)/k]$

D = total rainfall depth (mm or in) (as determined from the appropriate IDF curve for a storm of duration t_d)
a = time to peak (hr)
k = decay coefficient
t = time (hr)
t_d = storm duration (hr)

For five 'long-term' AES stations across Canada, a 1-hour urban design storm was developed by optimizing the parameters 'k' and 'a' using the historical storm data. The mathematical model was then extended on a regional basis, thereby developing a 1-hour urban design storm for each of the 45 AES stations. The two AES Stations closest to St. Catharines that were used in the study had the following parameters (note that St. Thomas is one of the five 'long-term' stations):

Station	a (min)	k
St. Thomas	24	7
Toronto	21	7

Because of the relative proximity to Toronto, it is recommended that St. Catharines adopt the parameters from the Toronto station (a = 21 minutes; k = 7), if this 1-hour urban design storm is to be used.

This design storm which was previously presented in Table 3.4 may be used as an alternative to, or in addition with, the more common (yet peaky) Chicago design storm. If used, this design storm should be subject to the following limitations:

- storm durations of 1 hour
- storms with return periods of 2 - 10 years
- use in urban areas only

A.7 Real Storms

Real storms, when used in conjunction with flow monitoring, can be very helpful in the calibration of runoff models. Previous drainage studies have had varying degrees of success in calibrating the runoff models but have generally been hampered by a lack of adequate flow data. While rainfall data are available from a number of sources, it has been left up to the consultants to obtain their own dry and wet weather flow data.

A.8 Regional Storm

For St. Catharines, the regional storm (as defined by the MNR) is based upon Hurricane Hazel (Oct. 1954) as follows:

HOUR	INTENSITY (mm/hr)	(in/hr)	ACCUMULATED RAINFALL (mm)	(in)
0-36	2.1	0.08	73.7	2.90
37	6.3	0.25	80.0	3.15
38	4.3	0.17	84.3	3.32
39	6.4	0.25	90.7	3.57
40	12.7	0.50	103.4	4.07
41	16.7	0.66	120.1	4.73
42	12.7	0.50	132.8	5.23
43	23.2	0.91	156.0	6.14
44	12.7	0.50	168.7	6.64
45	12.7	0.50	181.4	7.14
46	52.8	2.08	234.2	9.22
47	37.8	1.49	272.0	10.71
48	12.7	0.50	284.7	11.21

For drainage areas of more than 26 sq km (10 sq mi), the regional storm rainfall should be reduced as follows :

DRAINAGE AREA sq km	sq mi	REDUCED %
≤ 26	≤ 10	100.0
26-45	11-17	99.2
46-65	18-25	98.2
66-90	26-35	97.1
91-115	36-45	96.3
116-140	46-55	95.4
141-165	56-65	94.8
166-195	66-75	94.2
196-220	76-85	93.5
221-245	86-95	92.7
246-270	96-105	92.0

A.9 Recommended Design Storm Uses

Based on the above discussion, the following applications are recommended for St. Catharines:

(i) URBAN WATERSHEDS

- IDF curves may be used, in conjunction with the Rational Method, for the sizing of storm sewers.

- For more detailed analysis of storm sewer systems (including the sizing of storage facilities), more advanced hydrologic models are needed. These models require design storm hyetographs as input.

    - The Chicago storm profile is one of the more common design storms for urban areas and should continue to be used in St. Catharines.

    - It should be noted that some investigators consider the Chicago profiles to yield unrealistically 'peaky' design storm hyetographs.

    - Other, more recently developed design storms (such as the 1-hour urban design storm and the Huff profiles) may become more widely used in the future as alternatives or compliments for the Chicago profiles.

    - The SCS 24 hour type II storm distribution generally produces lower peak intensities but higher total volumes than the Chicago storms. Because of this feature, the SCS storm distribution, while intended mainly for use in rural watersheds, should also be considered when designing storage facilities in urban areas, as well as floodplain mapping.

    - It would be prudent to run the hydrologic models for all of the various types of design storms discussed. In addition, real storms, when used in conjunction with flow monitoring are useful in calibrating hydrologic models.

(ii) RURAL WATERSHEDS

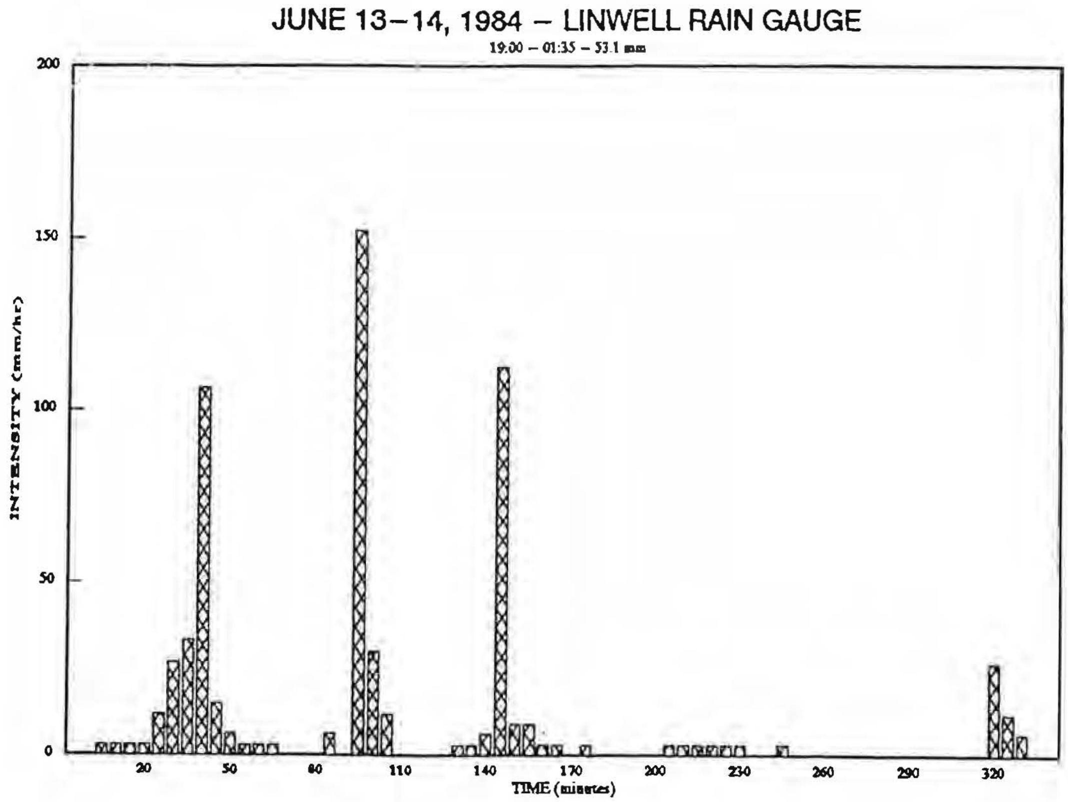
- The SCS 24 hour type II storm distribution should be used when analyzing rural areas, the pre-development conditions of areas scheduled for future urbanization as well as floodplain mapping.

- As with urban areas, real storms used in conjunction with flow monitoring are useful in calibrating hydrologic computer models.

- The 100 year storm should be used for floodplain mapping and the design of major storm drainage elements such as open channels or watercourses.

- For the purpose of comparison, it may be desirable to use the 3rd quartile Huff profile (with a 24 hour storm duration) in addition to the SCS 24 hour type II storm distribution.

For the purpose of comparison, Table 3.3, Figures 3.2 and 3.3 present the recommended 1:5 year hyetographs for the Chicago, SCS Type II, Canadian 1 hr and Huff 4-Quartile distributions for a 3 storm hour duration. In addition, Figure A.6 presents two of the larger real storm hyetographs recorded in St. Catharines over the last few years.



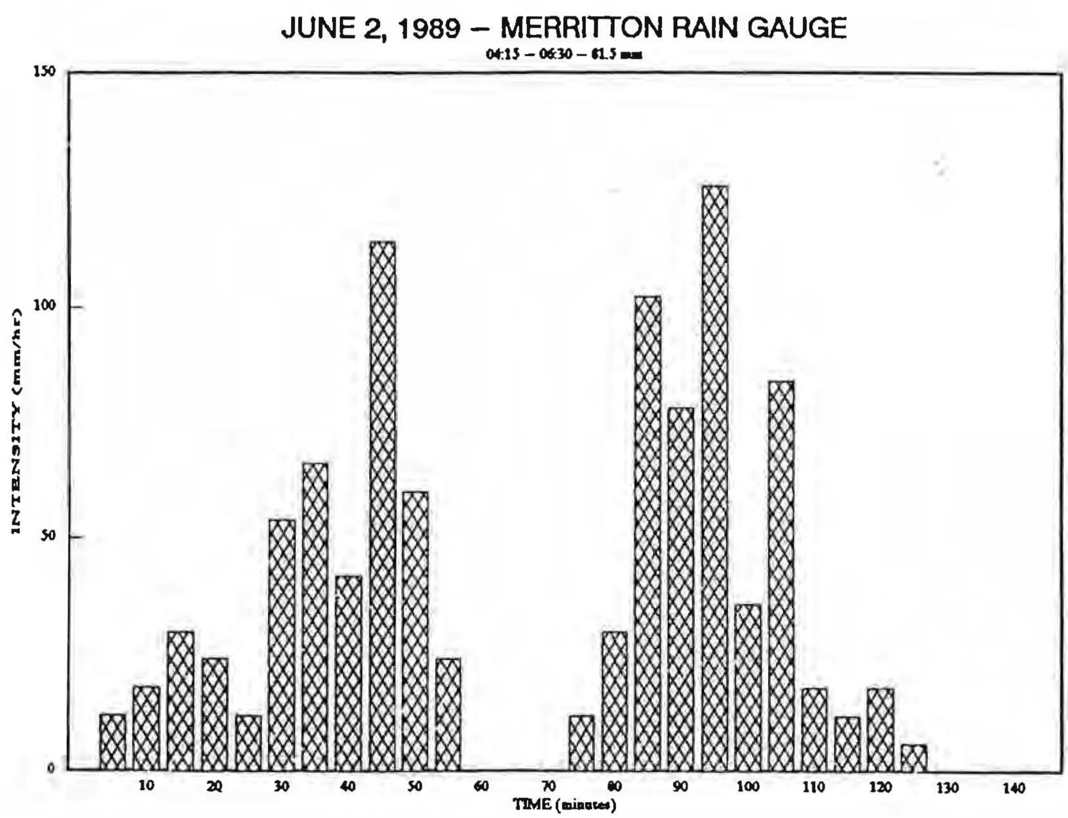


Figure A.7 Real Storm Hyetographs

Appendix B – Hydrologic Analysis

APPENDIX B
HYDROLOGIC ANALYSIS

B.1 General

The process by which rainfall becomes runoff forms the basis of stormwater drainage design. The methods by which this process is modelled can range from the simple yet popular Rational Method to the more sophisticated computer simulation models such as the Storm Water Management Model (SWMM). This appendix deals with the more popular manual and computer simulation methods presently available.

B.2 Manual Methods

B.2.1 Rational Method

The Rational Method, originally introduced in 1889, is still the simplest and most popular technique used for estimating peak flows in a sewer system. It is based on the following equation:

$$Q = kCiA \qquad [B-1]$$

where:
- Q = peak discharge (cms or cfs)
- C = runoff coefficient
- i = rainfall intensity (mm/hr or in/hr)
- A = drainage area (ha or acres)
- k = 0.00278 (Metric)
  = $1.008 \simeq 1$ (Imperial)

Drainage Area (A)

The area of the catchment contributing runoff to the point under consideration is the only parameter of the Rational Method that can be determined precisely. The areas can be delineated and measured from a contour map.

Runoff Coefficient (C)

The runoff coefficient (C) of a drainage area takes into account the many physical characteristics of the catchment that affect runoff, such as infiltration, ground slope, ground cover, detention and depression storage, drainage area shape and antecedent soil and precipitation conditions. Because of all of these variables, determination of an appropriate runoff coefficient is difficult.

Average values of C commonly used in current practice are given in Table B.1. For areas with different major land uses, a composite C value, comprising of an area-weighted average of the 'C's from the different land uses, should be used. The coefficients given in Table B.1 are for storms with return frequencies of 10 years or less. With more intense storms, infiltration and other losses have less of an effect on runoff and as such the runoff coefficients presented in Table B.1 should be increased. This

C

Table B.1 Typical Runoff Coefficients

Type of Drainage Area	Runoff Coefficient, C
Lawns :	
Sandy soil, flat, <2%	0.05-0.10
Sandy soil, average, 2-7%	0.10-0.15
Sandy soil, steep, >7%	0.15-0.20
Heavy soil, flat, <2%	0.13-0.17
Heavy soil, average, 2-7%	0.18-0.22
Heavy soil, steep, >7%	0.25-0.35
Business :	
Downtown areas	0.70-0.95
Neighbourhood areas	0.50-0.70
Residential :	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment dwelling areas	0.50-0.70
Industrial :	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, Cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets :	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.95

Source : "Design and Construction of Sanitary and Storm Sewers", ASCE Man. Eng. Practice No. 37 and WPCF Man. Practice No. 9, 1960.

can be accomplished by multiplying the right-hand side of Equation [B-1] by a frequency factor, C_f given below:

Recurrence Interval (years)	C_f
25	1.10
50	1.20
100	1.25

Note: The product of C x C_f should not exceed 1.0

Rainfall Intensity (i)

The first step in determining the average rainfall intensity is to determine the time of concentration of the catchment. Having established this, the average intensity for a storm duration equal to this time of concentration is derived from an IDF curve with the desired return frequency.

Time of Concentration (t_c)

The time of concentration (t_c) of a catchment is the time required for water to travel from the most hydraulically remote point in the catchment to the outlet or point of design. The t_c essentially consists of two components - the flow time in the sewers and the inlet time.

The flow time in the sewers is determined by simply dividing the length of the sewer by the full flow velocity in the pipe, as determined from Manning's equation.

The inlet time (overland flow runoff to the nearest inlet) can be determined in a number of ways, some of which are outlined below :

(i) Standard inlet time.

- simply use a constant inlet time for all catchments (presently, 10 minutes for St. Catharines)

(ii) Upland Method

- developed by the Soil Conservation Service (SCS)
- meant for determining t_c for rural catchments
- involves dividing the overload length by the velocities obtained from the nomograph shown in Figure B.1

(iii) Kinematic Wave Equation

- used in the SWMM - Runoff algorithm
- derived for flow over a rectangular plane surface
- based on the assumption that t_c is dependent upon the effective rainfall intensity

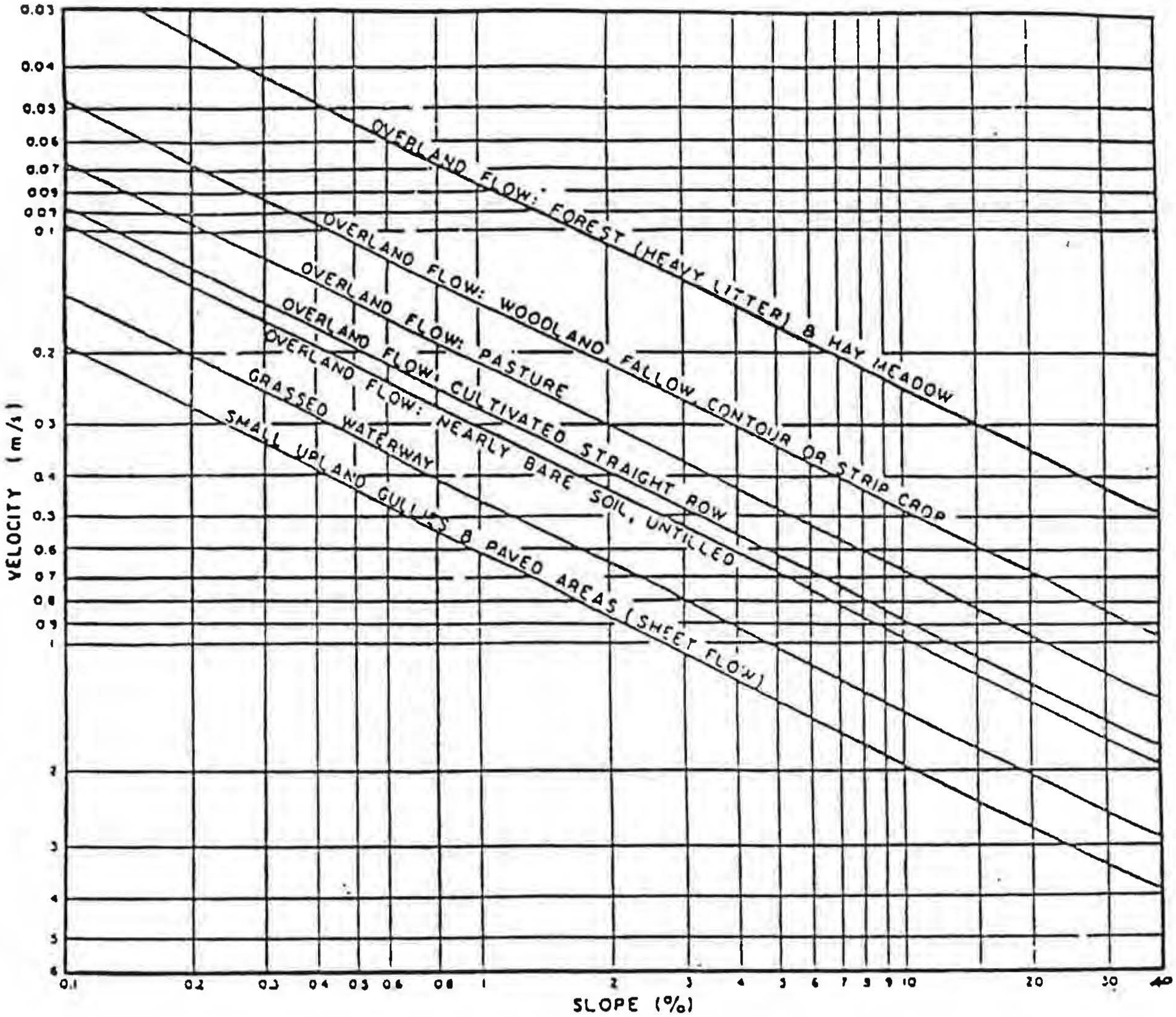


Figure B.1 Upland Method for Estimating Time of Concentration
(Source : "SCS National Engineering Handbook", 1972)

$$t_c = k(Ln/S^{0.5})^{0.6}/i^{0.4}$$

where:
- t_c = time of conc'n (min)
- L = overland flow length (m or ft)
- S = overland flow slope (m/m or ft/ft)
- n = Manning's 'n'
- i = effective rainfall intensity (mm/hr or ft/hr)
- k = 6.839 (Metric)
- = 0.939 (Imperial)

(iv) Airport Drainage Method

- developed by the U.S. Department of Transport
- intended for estimating inlet times for airfield drainage systems, but should also be applicable for very small rural basins and simple urban systems

$$t_c = k(1.1\text{-}C)L^{0.5}/S^{0.33}$$

where: t_c, L, S as before
- C = runoff coefficient (as per Rational Method)
- k = ~~0.702~~ (Metric) 0.713
- = ~~0.271~~ (Imperial) 0.394

Note: Recommended for use in the MTC Drainage Manual for C<0.4

(v) Bransby - Williams Formula

- developed by Williams (1974) & according to research by French, Pilgrim & Laurenson (1974) is one of the more acceptable ways of predicting t_c
- doesn't take soil characteristics into account and may underestimate t_c for wooded or permeable basins
- the RTAC Drainage Manual suggests an upper area limit of 25 sq km (6250 acres)

$$t_c = kL/(S^{0.3}A^{0.1})$$

where: t_c, L, S as before
- A = watershed area (sq km or acres)
- k = 0.01445 (Metric)
- = 0.00765 (Imperial)

Note: Recommended for use in the MTC Drainage Manual for C≥0.4.

(vi) Kirpich Formula

- developed by P.Z. Kirpich (Civil Engineering, Vol 10, No. 6, June 1940, p. 362)
- recommended by American Iron & Steel Institute (AISI) "Modern Sewer Design" for use in large watersheds

$$t_c = kFL^{0.77}/S^{0.385}$$

where: t_c, L, S as before
k = 0.0195 (Metric)
= 0.0078 (Imperial)
F = 1 for well defined natural drainage basin (bare earth, mowed grass)
= 2 for general overload flow (surface not maintained at all)
= 0.4 for asphalt or concrete surface
= 0.2 for concrete channels

(vii) Kerby Formula

- assumes t_c is a function of land use

$$t_c = (kLn/S^{0.5})^{0.467}$$

where: t_c, L, S as before
k = 2.187 (Metric)
= 0.667 (Imperial)
n = roughness factor as below:

Surface	n
- impervious, uniform	0.02
- lawn, grass	0.10
- forested area	0.60
- grazing area	0.20

(viii) SCS CN Method

- developed by SCS to determine lag times for natural basins (time from centre of rain mass to peak or runoff)

$$t_c = 1.67\ t_l$$

$$t_l = kL^{0.8}(1000/CN - 9)^{0.7}/S^{0.5}$$

where: t_c, L, S as before
t_l = lag time (min)
CN = curve number as per SCS tables
k = 0.00816 (Metric)
= 0.00316 (Imperial)

Selection of an appropriate method of calculating the inlet or overland flow time is difficult due to the variability of the catchment characteristics. The different methods listed above will all give very different results and any one method will not be applicable in all cases. The following procedures are recommended :

(a) for small urban subcatchments, 2 ha (5 acres) in area or less, use an inlet time of 10 minutes

(b) for urban subcatchments larger than 2 ha in size, follow the procedures outlined in the MTC Drainage Manual:
- use Airport Drainage Method (as in (iv) above) for $C<0.4$
- use Bransby - Williams Formula (as in (v) above) for $C\geq0.4$

(c) for rural subcatchments, or for determining pre-development flows, the SCS Unit Hydrograph Method (described in Section B.2.2 below) is more appropriate to use than the Rational Method. As such, the SCS CN Method described in (viii) above should be used to calculate the lag time and subsequently the t_c.

The Rational Method is subject to the following assumptions and/or limitations:

- the method should only be used for the design of storm sewer systems within urban areas 200 ha (500 acres) in size, or less
- the rainfall intensity is assumed to be uniform in time and in space
- the runoff coefficient represents a lumping of all of the physical characteristics of the entire drainage area and is assumed to be constant over time
- the return frequency of the runoff is assumed to be the same as that of the rainfall
- it can only be used to estimate the peak runoff and not the actual storm runoff hydrograph, which is one of the requirements for channel routing or designing storage facilities

B.2.2 SCS Unit Hydrograph Method

Unit hydrograph methods are generally used where the Rational Method cannot be applied, such as when dealing with larger and/or rural drainage areas, designing storage facilities or designing the major system. A unit hydrograph can be defined as the runoff hydrograph produced by one inch of excess rainfall applied over a drainage area for some specified period of time. It is derived from an analysis of historical records or through regression equations based on watershed characteristics. However, the necessary rainfall runoff data is usually not available, and thus a synthetic unit hydrograph must be developed.

The U.S. Soil Conservation Service (SCS) developed a synthetic triangular unit hydrograph as shown in Figure B.2. The parameters are as follows:

D = excess rainfall period (see below) (hrs)
L = lag time of watershed (hrs)
T_p = time to peak (hrs)
T_r = time to recede (hrs)

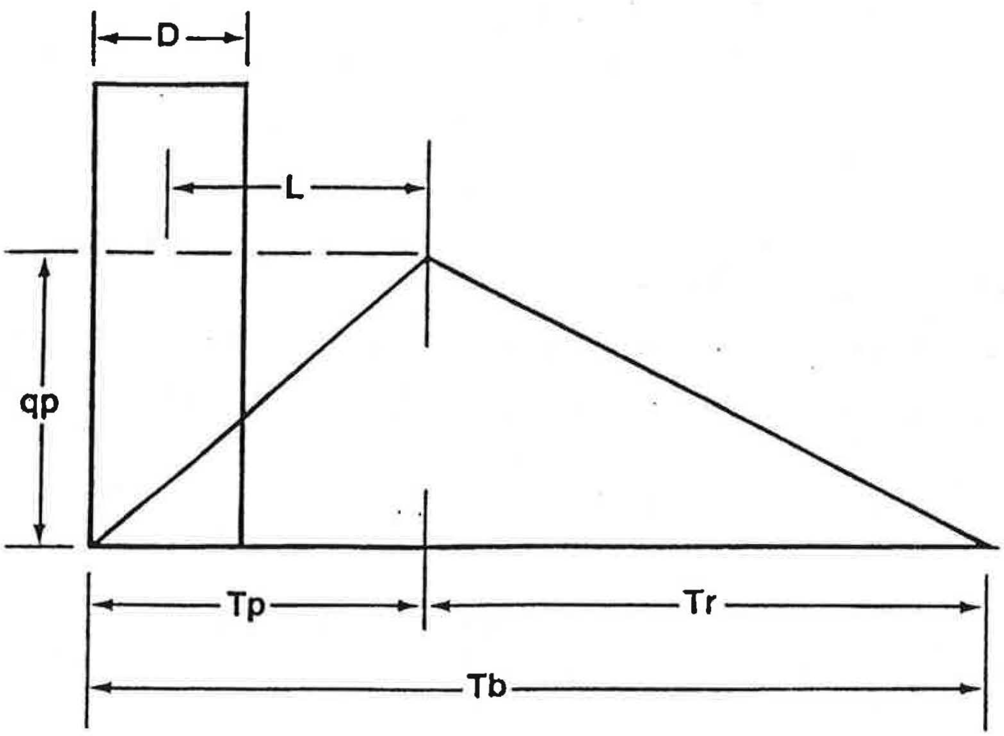


Figure B.2 SCS Unit Hydrograph
(Source : "Modern Sewer Design", AISI, 1980)

T_b = time base (hrs)
q_p = $kbAQ/T_p$ [B-2]

where: q_p = peak runoff (cfs or cms)
A = area (sq. miles or sq. km)
Q = runoff (inches or mm)
b = 484 (an Average constant - can vary from 300 in very flat areas to 600 in very steep terrain)
k = 1 (Imperial)
= 0.0004345 (Metric)

Note: T_c = time of concentration (hrs)
D = 0.133 T_c (generally used relationship - values of D should not exceed 0.25T_c as this will cause an underestimation of the peak runoff)
L = 0.60 T_c
T_b = 2.67 T_p
T_r = 1.67 T_p
T_p = D/2+L

To aid in determining the runoff potential of different soil types, the SCS have defined four hydrologic soil groups (from 'Modern Sewer Design', AISI, 1980)

A - low runoff potential soils having a high infiltration rate even when thoroughly wetted (consisting mostly of deep, well to excessively drained sands or gravel)

B - soils having a moderate infiltration rate when thoroughly wetted (consisting mostly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture)

C - soils having a slow infiltration rate when thoroughly wetted (consisting mostly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture)

D - high runoff potential soils having a very slow infiltration rate when thoroughly wetted (consisting mostly of day soils with a high swelling potential, soils with a permanent high water table, soils with a clay layer at or near the surface and shallow soils over nearly impervious material)

In addition to the four hydrologic soil groups, the SCS method also considers three levels of Antecedent Moisture Conditions (AMC):

AMC I - soils are dry but not to the wetting point. This is the lowest runoff potential and not usually used for design purposes.

AMC II - the average case.

AMC III - heavy or light rainfall and low temperatures have occurred during the five previous days. This is the highest runoff potential and is used for low frequency (ie 1:100 yr) storms.

Once the hydrologic soil group and appropriate land use have been determined, the curve number (CN) parameter for the area can be determined from Table B.2. (Note that these CN values are for AMC II. Refer to Table B.3 for the appropriate conversions for AMC I and AMC III)

Once the CN for the area is established, the runoff can be determined as follows :

$$S = k\,(1000/CN - 10) \qquad [B\text{-}3]$$

$$Q = (P - I_a)^2/(P - I_a + S) \qquad [B\text{-}4]$$

where: S = potential abstraction parameter (mm or in)
P = total precipitation (mm or in)
Q = runoff (mm or in)
I_a = initial abstraction (mm or in)
- this must be satisfied before any runoff can occur
- it has been common practice to assume that $I_a = 0.2S$, however, this has recently been criticized as being too high in some cases, leading to an underestimation of the runoff

k = 25.4 (Metric)
= 1 (Imperial)

Once Q has been established, q_p can be determined using equation [B-2].

The following steps should be used in applying the SCS Unit Hydrograph Method :

1. Required Input: area, soil type, AMC, land use, T_c, storm hyetograph and duration

2.
- determine CN from Table B.2
- calculate D, T_p, and T_b
- for Q = 1 inch (or 1 mm), calculate q_p using equation [B-2] to obtain the triangular unit hydrograph (T.U.H.)
- discretize the T.U.H. using time increments of D
- discretize the input hyetograph and determine the cumulative rainfall using time increments of D
- using this cumulative rainfall and equations [B-3] and [B-4], determine the cumulative and incremental runoff

3.
- each incremental triangular hydrograph is obtained by multiplying the appropriate incremental runoff by the ordinates of the T.U.H.
- the total hydrograph is obtained by summing up all of the incremental triangular hydrographs.

The SCS Unit Hydrograph Method is subject to the following assumptions and/or limitations :

- the method was originally developed for use in rural watersheds and for SCS 24 Hour Type II distribution design storms (see Appendix A)

Table B.2 Typical Runoff Curve Numbers (AMC II)

Land Use Description		Hydrological Soil Group A	B	C	D
Cultivated land					
without conservation treatment		72	81	88	91
with conservation treatment		62	71	78	81
Pasture or range land					
poor condition		68	79	86	89
good condition		39	61	74	80
Meadow (good condition)		30	58	71	78
Wood or forest land					
thin stand, poor cover, no mulch		45	66	77	83
good cover		25	55	70	77
Open spaces, lawns, parks, golf courses, etc.					
good condition (grass cover > 75% of area)		39	61	74	80
fair condition (grass cover on 50-75% of area)		49	69	79	84
Commercial and business areas (85% imperviousness)		89	92	94	95
Industrial Districts (72% imperviousness)		81	88	91	93
Residential					
Avg. lot size	Avg % impervious				
0.05 ha (1/8 acre) or less	65	77	85	90	92
0.10 ha (1/4 acre)	38	61	75	83	87
0.15 ha (1/3 acre)	30	57	72	81	86
0.20 ha (1/2 acre)	25	54	70	80	85
0.40 ha (1 acre)	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads					
paved, with curbs and storm sewers		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

Note : For a more detailed description of agricultural land use CN's, refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, August, 1972

Source : "Modern Sewer Design", American Iron and Steel Institute (AISI), 1980

Table B.3 Conversion of Curve Numbers

CN for AMC II	CN for AMC I	CN for AMC III
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50
25	12	43
20	9	37
15	6	30
10	4	22
5	2	13
0	0	0

Source : "Modern Sewer Design", AISI, 1980

- drainage areas should be limited to 51 sq km (20 sq miles)
- drainage areas should be homogeneous, with a constant CN value
- the method assumes the area has a linear runoff response; some studies have found that this method underestimates the runoff volume for light rainfall
- the initial abstraction of $I_a = 0.2S$ is generally considered to be too high for certain areas (with CN < 90)
- hand calculations using this method area tedious and time consuming and thus it is recommended that computer versions of the model be used instead.

B.2.3 Isochrone Method

The Isochrone Method may also be used as an alternative to unit hydrograph methods, to obtain runoff hydrographs. It is based on the assumption that the response of a watershed to rainfall is a function of the watershed travel time. This method involves dividing the watershed into isochrones, or lines showing equal travel time to the catchment outlet. A time area curve is derived by plotting the areas between the isochrones against time. This is combined with the design storm hyetograph to obtain the runoff hydrograph at the outlet.

The British Road Research Laboratory (BRRL) developed a model using this Isochrone Method. The BRRL Method assumes that only directly connected impervious areas contribute.significant flows during major rainfall events. The testing of numerous catchments led to the following criteria being established for application of the BRRL Method:

- the directly connected impervious area covers at least 15% of the catchment.
- the recurrence interval of the design storm is less than 20 years.
- the catchment has an area of 13 sq km (5 sq miles) or less

Hand calculations using this method become tedious, especially for longer storm durations and/or larger catchments. The BRRL Method has been adapted into a computer model known as the Illinois Urban Drainage Area Simulator (ILLUDAS), which is recommended in place of manual calculations.

B.3 Computer Simulation Models

Numerous computer models have been developed to assist in the estimation of urban and rural runoff and the design of storm drainage facilities. Most of these models were originally developed for use on main frame computer systems, however the popularity of microcomputers has led to "PC" versions of these models which are considerably more user-friendly and do not require the user to have nearly as much computing experience. However, the user-friendliness of the computer models also present the danger that they may be used incorrectly or incompetently. It is the responsibility of the user to understand the limitations of the model and it's input parameters and to ensure that the results obtained from the model are reasonable.

The following is a brief summary of the more popular computer simulation models currently available.

B.3.1 SWMM

The Stormwater Management Model (SWMM) was originally developed by the U.S. Environmental Protection Agency (EPA) in 1971, with updated versions being released in 1975, 1982 and the latest version, SWMM4 in 1988. It is one of the more popular and comprehensive mathematical models presently used. SWMM was originally tested and verified on selected catchments varying in size from 73 to 2185 ha (183 to 5463 acres) in four U.S. cities and later in numerous catchments in both U.S. and Canadian cities. It can perform both quantity and quality analysis for single event and continuous simulation. SWMM is organized into various service and computational sub-programs. These sub-programs, or 'blocks' are briefly described below:

Service Blocks :

EXECUTIVE -
- acts as the major organizational block from which all other blocks are called
- provides interactive, free-format data input and error checking
- produces fixed format input data files for other blocks

COMBINE -
- collates different data sets (from different computational blocks) into one (for input into another computational block)
- combines different data sets and nodes into a single data set and one node

STATISTICS -
- performs simple statistical analysis on continuous or single event data

Computational Blocks :

RUNOFF -
- simulates both the quantity and quality of runoff from the pervious and impervious areas of a drainage basin (up to ten water quality constituents can be simulated)
- uses arbitrary rainfall and/or snowfall hyetographs as input and makes a step by step accounting of snowmelt, depression storage, infiltration losses, overland and gutter flow to determine the hydrograph and pollutographs at the basin inlet
- can route the inlet flows through a pipe network (for simple cases)

TRANSPORT -
- routes the flows through the sewer system in a more sophisticated manner than the RUNOFF block can
- simulates dry weather flow, infiltration and pollutograph routing
- models various hydraulic elements such as pumps and weirs

- cannot model pressure flow, networks under surcharge, networks with flow reversals or networks having looped connections

EXTRAN - developed by Water Resources Engineers (WRE) for a study in San Fransisco in 1973, the model was originally known as the WRE Transport Model
- the EPA incorporated this model into the SWMM package in 1974, calling it the Extended Transport Model, or EXTRAN
- performs dynamic routing of flows through the sewer system allowing it to simulate branched or looped networks, backwater effects, free surface flow, surcharged or pressure flow, flow reversal and flow through various hydraulic elements such as weirs, orifices and pumping stations
- cannot simulate pollutant routing; the TRANSPORT block should be used for this purpose

STORAGE/ TREATMENT - simulates the routing of flows and pollutants through a dry or wet weather storage treatment plant containing up to five units or processes

RECEIVE - this block is no longer supported in the latest version of SWMM4

When using SWMM, the following points should be considered:

- the execution time for moderately complex sewer systems can be in the order of hours, especially when the EXTRAN block is used
- when using the EXTRAN or TRANSPORT blocks, numerical instability may result because of inappropriate selection of the time step or the total simulation period (refer to the User's Manual for more details)
- the modelled sewer system should be calibrated using real storms and the resulting flows (and the pollutant, if quality simulation is desired)
- hydrographs can be predicted fairly accurately with only moderate calibration, however pollutographs require more extensive calibration to yield reliable quality simulations
- the model was not developed for use in rural or undeveloped areas

Although originally developed for use on a main-frame computer, a microcomputer version of SWMM4 is now available. An earlier microcomputer version known as PCSWMM3 developed by Computational Hydraulics Incorporated is no longer supported.

Another popular microcomputer version kwown as OTTSWMM was developed as part of the Implementation of Storm Water Management (IMPSWM) Program at the University of Ottawa. It distinguishes itself from other SWMM models by it's ability to route flows through both the minor and major systems and it is comprised of four main sub-models :

(a) the surface runoff sub-model, SWMM-RUNOFF
(b) the inlet sub-model which calculates runoff into the sewers and by-pass flow which represents the major system flow

(c) the minor system sub-model which routes the inlet flows through the sewer network
(d) the major system sub-model which routes the flows exceeding the capacity of the storm inlets through the street network (which is assumed to form the major system)

OTTSWMM also has the following features :

- there are two sub-models for the design/analysis of storage facilities for the minor and major system flows
- it can be interfaced with the EXTRAN model for the analysis of sewer systems under surcharge
- an important aspect of OTTSWMM is it's consideration of inlet control (the efficiency, spacing and restriction of inlets, or catchbasins) in determining the major and minor flows

B.3.2 HYMO

The Hydrologic Model (HYMO) was originally developed in 1973 by the U.S. Department of Agriculture for planning flood protection projects and forecasting floods. The model was verified on 34 watersheds in the U.S. varying in size from 1.3 to 64.1 sq km (0.5 to 25 sq miles) and has been calibrated in Canada mainly for watersheds larger than 25.6 sq km (10 sq miles). HYMO transforms rainfall data falling on the subcatchments of a watershed into runoff hydrographs and routes these hydrographs through streams, valleys or reservoirs. Through the use of a modified soil loss equation, it can also compute the amount of sediment produced by a storm at any point on a watershed.

HYMO is a popular model for master drainage plans because it is easy to use and does not required detailed physical input data, which is usually not available at the planning stage. It essentially consists of a series of subroutines, each of which relates to a specific hydrologic command, such as compute or route a hydrograph. These commands can be written in different sequences as a program such that, for example, a hydrograph can be computed for a certain subcatchment, then routed through a channel to a point downstream where it can be added to a hydrograph computed for another subcatchment, and so on. Such a HYMO program starts at the most upstream part of the watershed and proceeds downstream, one reach at a time.

It should be stressed that HYMO was originally developed for computing runoff hydrographs for rural watersheds. It uses the SCS CN procedure for computing the excess rainfall (see Equations [B-3] and [B-4] in Section B.2.2) and a 2 parameter gamma distribution equation for deriving the instantaneous unit hydrograph. The two parameters (a recession coefficient, k [hrs] and a time to peak, T_p [hrs]) are estimated by built-in empirical formulae based on the physical characteristics of the basin. These hydrologic procedures have been found to underestimate the peak flows when applied to urban watersheds. As a result, major calibration efforts would be required for analysis of post-development or urbanized flows. As previously mentioned, the SCS CN procedure has also been found to underestimate the runoff for light rainfall.

Other limitations of HYMO include the following:

- spring rainstorm/snowmelt runoff is not computed
- stream/valley routing applies only to open channel flow and thus cannot be used for sewer pipe design
- dry weather flow and water quality modelling (except natural sediment yield) are not considered

A modified version of HYMO known as OTTHYMO is widely used across Canada and is capable of computing the runoff from both rural and urban watersheds. A package of simplified microcomputer versions of OTTHYMO known as MICROHYMO 1,2,3 is also widely used across Canada.

OTTHYMO
- developed by the IMPSWM Program in 1982.
- maintains the same structure as HYMO, however the hydrologic procedures have been changed in order to simulate the runoff hydrographs from both rural and urban watersheds.
- the following four commands have been added to the HYMO structure:

i) COMPUTE NASHYD
   - a new command for computing runoff hydrographs for rural watersheds
   - based on a conceptual model (proposed by Nash, 1957) made up of a "cascade of linear reservoirs"
   - the Nash model has two parameters that require user input: T_p, the time to peak and N, the number of reservoirs (N is essentially a shape parameter that determines the shape of the unit hydrograph and has been found to vary from 2.2 to 4.5; a value between 4.0 to 4.5 should be used to produce a shape close to a triangular unit hydrograph)
   - the rainfall losses are computed using a modified CN procedure with a user supplied initial abstraction. The initial abstraction (I_a) can be obtained from measurements based on an Antecedent Precipitation Index (API) which is a hydrologic index of antecedent moisture conditions. The CN calibrated for this I_a based on measurements is known as CN*. This CN* value is required for input, not the CN value. (unless I_a = 0.2S, in which case CN* = CN)

ii) COMPUTE URBHYD

   - a command for simulating runoff hydrographs from urban watersheds
   - based on a conceptual model made up of two linear reservoirs in parallel for simulating runoff from the pervious and impervious areas of the watershed. Each linear reservoir has a storage coefficient which is calculated as a function of the time of concentration based on kinematic wave theory. Once this is known, the unit hydrograph can be obtained
   - rain falling on the directly connected impervious area is subject to depression storage. Rain falling on the non-directly connected impervious area is assumed to run onto the pervious area. Rain falling on the pervious area

is subject to depression storage and infiltration losses which can be calculated using the modified CN procedure (as in the COMPUTE NASHYD command) or using the Horton equation as described in Section 4.3
- the hydrographs from the two linear reservoirs are combined internally to produce one output hydrograph for the watershed

iii) KINROUTE

- a command for routing flows through pipe systems not under surcharge
- based on the kinematic wave model
- also has the capability of sizing pipes

iv) COMPUTE DUHYD

- a command used to generate separate hydrographs for the major and minor flows from the total runoff hydrograph
- the cutoff value can be based on the minor system design level

MICROHYMO 1,2,3

- a package of simplified microcomputer versions of OTTHYMO distributed by Andrew Brodie Associates Inc.

i) MICROHYMO 1 (LUMPHYD)

- an interactive version of the two main OTTHYMO sub-models, NASHYD and URBHYD
- cannot route the hydrographs
- intended mainly for training purposes

ii) MICROHYMO 2 (FASTHYMO and PLANHYMO)

FASTHYMO

- intended for fast results and verification in preliminary studies using NASHYD and URBHYD sub-models
- user defines a set of default values for various parameters as well as a set of design storms
- input to the NASHYD and URBHYD sub-models is simplified
- cannot route the hydrographs
- can run several different storms without user intervention

PLANHYMO

- a simplified version of OTTHYMO that can generate hydrographs for mixed urban and rural watersheds, route them through a system of channels and reservoirs and store the results at various points
- a separate parameter file is set up, as in FASTHYMO, to simplify input

- does not contain the KINROUTE or DUYHD sub-models and uses a simplified channel routing routine
- the process starts upstream and works down through the drainage network, as in the HYMO and OTTHYMO models

iii) MICROHYMO 3 (PC OTTHYMO)

- essentially a microcomputer version of the mainframe OTTHYMO model
- considered as mainly a modeller's tool and is recommended for more complex master drainage plan studies, studies requiring calibration of parameters, etc.

When using OTTHYMO or the MICROHYMO 1,2,3 package, the following points should be considered:

- runoff from the urban and rural areas are simulated using two different models
- the URBHYD and NASHYD models are not the same as that used in the original HYMO program
- rainfall losses are determined using the CN* parameter, rather than the more common CN

B.3.3 MIDUSS

Micro Interactive Design of Urban Stormwater Systems (MIDUSS) was developed by Dr. Alan A. Smith formerly of McMaster University and is distributed by Alan A. Smith, Inc. (Version 4.7 was released in November, 1990). It is a very versatile and interactive design oriented package which allows the user to quickly examine various design alternatives for such things as pipes, channels, detention ponds and diversion structures. The design proceeds in a downstream direction, similar to the HYMO structure. MIDUSS has the following features:

- it will accept any one of five different types of design storm hyetographs as input:

  i) an historical storm from file or keyboard
  ii) a Chicago Design Storm
  iii) any one of Huff's four quartile mass-rainfall distribution curves
  iv) a Canadian 1 hour Design Storm recently proposed by Watt
  v) a user defined mass-rainfall distribution

- the catchment is divided into pervious and impervious areas and separate effective rainfall hyetographs are calculated for each, based on infiltration losses
- infiltration losses can be calculated in either of three ways:

  i) the SCS CN Method (using a regular SCS CN or a runoff coefficient, C for which an equivalent CN is calculated) with a user defined initial abstraction

ii) the Horton Method plus depression storage (one of the options of the SWMM-RUNOFF algorithm)
iii) the Green-Ampt Method (another option of the SWMM-RUNOFF algorithm)

- surface runoff can be calculated in either of four ways:

  i) a modified version of the SCS Unit Hydrograph Method with the important exception that the t_c (and thus the time to peak, T_p) varies dynamically with the effective rainfall; based on kinematic wave theory
  ii) a modified version of the Rational Method in which the t_c varied dynamically with the effective rainfall; based on kinematic wave theory
  iii) the SWMM-RUNOFF algorithm with the restriction that the infiltration losses in the pervious and impervious areas are calculated using the Horton Method
  iv) a single linear reservoir model, similar to that used in the URBHYD command of OTTHYMO

- routing through channels or pipes is done based on the Muskingham Method, which allows for the attenuation of the inflow hydrograph.
- reservoir routing requires the user to input the depth-discharge and depth-storage volume relationships along with the desired peak outflow.
- hydrographs and/or hyetographs can be presented, in either graphical or tabular form at any point in the catchment (inflow and outflow hydrographs can be plotted on the same graph to show the routing effects of the pipe, channel or reservoir).

MIDUSS is subject to the following limitations:

- because of its relatively recent development, MIDUSS has not received the same degree of testing and verification as have the older models such as SWMM and HYMO. However, because MIDUSS incorporates various aspects of these older models in its methodology, it should not be considered as being untested.
- snowmelt runoff and water quality modelling are not considered
- backwater effects are not considered (hydraulic grades of surcharged pipes are given)

B.3.4 IMPRAM

The Improved Rational Method (IMPRAM) was originally developed as part of the IMPSWM Program and is distributed by Andrew Brodie Associates Inc. It is essentially a microcomputer version of the Rational Method and as such is subject to the same assumptions and limitations.

The "improved" aspect of IMPRAM deals with the introduction of a routing coefficient, C_r which is multiplied with the regular runoff coefficient, C. Studies done by IMPSWM revealed that, for larger watersheds, flows determined using the Rational Method were systematically lower than those using SWMM. C_r was introduced to account for this difference, and is assumed to equal 1.0

for areas less than 8 ha (20 acres). For larger areas, C_r is greater than 1.0 and is determined as a function of the area and the imperviousness ratio.

Because most sewer design is still done using the Rational Method, IMPRAM could be useful as an alternative to hand calculations. Since the data files can be stored and edited, alterations to a proposed sewer system design could be easily checked and run for different design storms.

B.3.5 ILLUDAS

The Illinois Urban Drainage Area Simulator (ILLUDAS) was originally developed by the Illinois State Water Survey in 1974 for the hydrologic design of storm drainage systems in urban areas. It was verified in the U.S. for 21 urban and 2 rural catchments ranging in size from 0.16 ha to 21 sq km (0.30 acres to 8.3 sq miles).

Rainfall subject to depression storage and infiltration losses are calculated using Horton's equation. Standard infiltration curves were derived for use with ILLUDAS for blue-grass turf on Illinois soils of hydrologic groups A, B, C and D.

Overland runoff simulation is based on the Isochrone Method (Section B.2.3). Runoffs from grassed and paved areas of each sub-basin are simulated separately and added at the inlet. A simple storage routing technique is used to pass the hydrograph from one inlet to the next. This procedure does not account for surcharge and backwater effects in the pipe. Reservoir routing is not available. Snowmelt runoff and stormwater quality modelling is not considered.

B.3.6 STORM

The Storage Treatment Overflow Runoff Model (STORM) was developed by the U.S. Army Corps of Engineers in 1976 to analyze the quantity and quality of stormwater runoff on a continuous basis (STORM is a continuous simulation model). It is useful for general planning purposes to estimate the approximate storage and treatment capacities required to reduce stormwater overflows to desired levels.

Overland runoff is calculated on an hourly basis by either a simple runoff coefficient method allowing for depression storage or the SCS Method. STORM accounts for evapotranspiration, infiltration from initial abstraction and percolation during dry weather periods. Snowmelt computations are also considered.

STORM maintains a continuous accounting of six pollutants as well as an accounting of the storage treatment rate and the amount of overflow of pollutants from storage. The procedures used for stormwater quality modelling are similar to those used in SWMM with the exception that STORM cannot route the pollutants. The major limitation of STORM is that it cannot perform channel or reservoir routing.

B.3.7 HEC-2

The HEC-2 model was developed by the U.S. Army Corps of Engineers in 1973 and computes a continuous water surface profile in a channel using the standard step method. The river channel may be of any cross-section and the profiles can be computed and plotted for either sub or super-critical flow. HEC-2 can also take into account the effects of different hydraulic elements such as culverts, weirs, embankments, bridges and dams.

B.3.8 HVM-DORSCH

The Hydrograph Volume Method (HVM) is available as a computer package distributed by Dorsch Consult Ltd. and was originally developed in West Germany. The main feature of the HVM-DORSCH model is it's detailed mathematical method of routing flows through the sewer network, based on the solution of the St. Venant energy and continuity equations (similar to the method used by the SWMM-EXTRAN model). This allows backwater effects and surcharging to be accurately modelled.

Appendix C -References

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