THE CITY OF
CALGARY
WATER RESOURCES

STORMWATER MANAGEMENT & DESIGN MANUAL

2011

This document can be downloaded from the *Urban Development Publications* page on the City of Calgary's website.

TERMS OF USE

The 2011 *Stormwater Management & Design Manual* is made available for use in The City of Calgary effective as of the date below.

September 30, 2011

The 2011 *Stormwater Management & Design Manual* is presented as accurate and complete as of the date indicated above. Use of this manual does not absolve any user from the obligation to exercise their professional judgement and to follow good practice. Should any user have questions as to the intent or accuracy of any specification or drawing herein, or concern that conflict may exist between the manufacturers' or suppliers' recommended installation procedures and this manual, the user is advised to seek clarification from the Manager, Water Resources, Infrastructure Planning.

PREFACE

Stormwater management is regulated provincially under both the *Environmental Protection and Enhancement Act (EPEA)* and the *Water Act*. Although provincial stormwater guidelines are available, the establishment of this document by The City of Calgary's Water Resources business unit is an integral part of stormwater management, environmental protection, and sustainability for The City of Calgary. Development of this manual involved the participation of numerous groups and individuals (as noted in the ***ACKNOWLEDGEMENTS***), many of whom had a number of years of expertise in stormwater.

This is the first revision to the 2000 *Stormwater Management & Design Manual*, which is produced by Water Resources. This manual will be updated on a regular basis as standards, designs, and regulatory requirements change or evolve. **Where bylaws, acts, regulations, policies, codes, standards, and other documents are referred to within this manual, the most recent edition or amendment applies.**

While the goal of this document is to provide a comprehensive design manual that results in effective, reliable, and economically affordable systems, the guidelines are not meant to stifle technological innovation and evolution, nor eliminate design approaches that may be appropriate for local conditions. For instance, references to "preferences" should not be interpreted as equating to "requirements". Flexibility is important for site-specific conditions. Alternative approaches may be considered if it can be demonstrated that there are better ways of achieving the same objectives. Similarly, The City of Calgary has the discretion to grant relaxations from the guidelines presented in this document, when, to the satisfaction of The City of Calgary, all other options are exhausted and safe and satisfactory operation is still ensured. At all times, the designer remains responsible for detailed design and satisfactory operation and performance.

While stormwater techniques and designs have become common-place in Alberta and Calgary, we still have much to learn, particularly when it comes to wetland design, evolving Best Management Practices (BMPs), and the effect of Chinooks on design. Calgary's rapid population and urban growth in recent years has raised concerns over environmental sustainability and the health of our rivers. As we face increasing regulatory requirements to protect our watersheds, there is also an increased need to enhance stormwater quality and to control high rates and volumes of discharge. While the use of new technologies is encouraged, there must be regard for monitoring performance and maintenance costs. Ongoing maintenance is extremely important to ensure continued effectiveness.

ACKNOWLEDGEMENTS

Water Resources gratefully acknowledges the guidance and direction involved by members in the advisory and workshop groups in developing and updating this document. Thank you to the following people:

September 2011

* indicates involvement with revisions to manual.

Water Resources

Abramovich, Olga	Cheung, Murray	Jaska, Kim *	Rajabali, Rehana *
Ahmed, Sheikh *	Crescini, Loretta	Jerome, Phil	Saunders, Doug
Arbour, Esther	De La Mare, Geri	Kidd, Ryan *	Tait, Graham
Aung-Kyaw, Thant *	Deong, Yin	Larson, Brad	Thai, Khai
Ball, Jerry	Frigo, Frank *	Letourneau, Rene	van Duin, Bert *
Bellmont, Dave	Giesbrecht, Dwayne	Jaska, Kim *	Williams, Avanthi *
Bozic, Liliana	Huynh, Lam	Malmqvist, Kristine *	Xiang, Zhong
Cayanan, May	Hamad, Akram *	Mitchell, Katherine	Yang, Mingdi *
Chau, Michael	Jamieson, Scott		

Roads

Talarico, Rob

Parks

Almasi-Klausz, Erika	Grieef, Patricia	Keffer, Mona
King, Andrew	Lang, Archie	Manderson, Chris

Consultants/Urban Development Institute (UDI) Technical Committee

Arnott, Justin - Imbrium Systems Inc.	Flynn, Michael - UDI
Aslam, Asif - AECOM *	Beverly Jarvis - UDI
Beaudreault, Maureen * - UDI	Jacobs, Paul * - Stormwater Solutions Inc.
Bozic, Liliana - Urban Systems Ltd.	Kallos, Victor - Matrix Landscape Architecture
Brandrick, Rob - Urban Systems Ltd.	Narvaez, Luis * - LGN Consulting Engineering
Carnduff, Rick * - Stantec Consulting Ltd.	Nottveit, Phil - Urban Systems Ltd.

Pasquini, Don * - AECOM/Pasquini & Associates Consulting Ltd.

December 2000

Parks

Cerveny, Kaja	Kenny, Michael	Ripley, Kyle
Elphinstone, Dave	Manderson, Chris	Ziriada, Peter

Wastewater & Drainage

Bellmont, Dave
Bouchard, Paul
Bowerman, Al
Bozic, Liliana
Brick, Bob
Broda, Barry
Colborne, Bruce
Davenport, Dan
Deong, Yin
Fedick, Terry
Jaska, Kim
Kennedy, Neil
Knudtson, Eric
Letourneau, Rene
Lyon, Christy
MacIsaac, Mike
Narvaez, Luis
Prince, Terry
Sharp, Jennifer
Shaughnessy, Ken
Shustack, Lidia

Urban Development

Grant, Ted
Norris, Ian
Simmons, Heather
Travis, Dave

Building Regulations

Amin, Tariq
Price, David

River Valleys Committee

Amell, Bernie
Morrison, Bill

Alberta Environment

Lazorko-Connon, Suzanne
Rush, Brock

Consultants (UDI Representatives)

Carnduff, Rick - Stantec Consulting Ltd.
Fitzgerald, Robin - Reid Crowther & Partners Ltd./Klohn-Crippen Consultants Ltd.
Hobbs, Curtis - Sunbow Consulting Ltd.
MacKenzie, John - Operational Solutions
Nolan, Ron - Urban Development Institute
Parent, Ted - Progressive Engineering Ltd.
Pasquini, Tony - Sunbow Consulting Ltd.
Sinden, Ron - Stantec Consulting Ltd.
Spring, Carol - Progressive Engineering Ltd.
van Duin, Bert - AGRA Earth & Environmental Ltd./ Westhoff Engineering Resources Inc.
Westhoff, Dennis - Westhoff Engineering Resources Inc.
Young, Brett - Reid Crowther & Partners Ltd.

Other Consultants and Agencies

Brunen, Jerry - Ducks Unlimited
Hayes, Ken - Inland Construction (Road Builders Association)
Lalani, Nazim - McIntosh Lalani Engineering Ltd.
Lim, Kenny - Lim Associates Inc.

MANUAL REVISION NOTICE

The 2011 *Stormwater Management & Design Manual* has been substantially re-written to remove redundancies and grammatical errors, to re-number clauses, and to generally restructure the document for ease of use. Navigating through this new version of the document is greatly simplified from previous versions:

- Clicking a ***black hyper-linked reference*** takes you to the specified section within this manual.
- Clicking a *blue hyper-linked reference* takes you to the specified document on the internet (or opens a web page on which you can locate the specified document).
- Clicking the logo at the bottom left of any page takes you to the Table of Contents.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

Water Resources uses the following industry- and government-standard abbreviations and acronyms in this manual (and other related documents):

ALIDP	Alberta Low Impact Development Partnership
AMC	Antecedent Moisture Condition
ASP	Area Structure Plan
BASINS model	Better Assessment Science Integrating point and Non-point Sources model
BC	Beginning of Curve
BF	Back to Front
BGP	Building Grade Plan
BIA	Biophysical Impact Assessments
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BPP	Better Planning Practices
BRBC	Bow River Basin Council
C	Runoff Coefficient
CB	Catchbasin
cBOD	Carbonaceous Biochemical Oxygen Demand
CCC	Construction Completion Certificate
CEAA	Canadian Environmental Assessment Act
CFA	Construction and Financing Agreement
CFD	Computational Fluid Dynamics
CN	Curve Number
COD	Chemical Oxygen Demand
CP	Community Plan
CRV	Calgary River Valleys
CSP	Corrugated Steel Pipe
DDSWMM	Dual Drainage Storm Water Management Model
DP	Development Permit
DSSP	Development Site Servicing Plan
EC	End of Curve
ECB	Erosion Control Blanket

EFDC model	Environmental Fluid Dynamic Code model
EGL	Energy Grade Line
EIA	Environmental Impact Assessment
EMC	Event Mean Concentration
EPA SWMM	Environmental Protection Agency Stormwater Management Model
EPEA	Environmental Protection And Enhancement Act
EPP	Environmental Performance Plan
ER	Environmental Reserve
ERWP	Elbow River Watershed Partnership
ESA	Environmentally Sensitive Area
ESC	Erosion and Sediment Control
EXTRAN model	Extended Transport model
FAC	Final Acceptance Certificate
FB	Freeboard
FF	Front to Back
HADD	Harmful Alteration, Disruption, or Destruction
HDPE Pipe	High Density Polyethylene Pipe
HGL	Hydraulic Grade Line
HSPF model	Hydrological Simulation Program - FORTRAN model
HWL	High Water Level
ICD	Inlet Control Device
IDF curve	Intensity-Duration-Frequency Curve
IECA	International Erosion Control Association
IPM	Integrated Pest Management
LID	Low-impact Development
LLO	Live Liquid Micro-Organism
LoA	Letter of Authorization
LOC	Licence Of Occupation
LTF	Lowest Top of Footing
(L)NWL	(Lower) Normal Water Level
LWL	Low Water Level
MDP	Master Drainage Plan

MF	Main Floor
MG	Minimum Grade (defined as Minimum Building Opening Elevation in this manual)
MH	Manhole
MMF	Minimum Main Floor
MR	Municipal Reserve
MSC	Meteorological Service of Canada
MSE	Minimum Subfloor Elevation
MSR	Municipal School Reserve
MUSIC	Model for Urban Stormwater Improvement Conceptualization
NaCl	Sodium Hypochlorite (Standard Road Salt)
NAMP{	Natural Area Management Plan
NCCHE	National Center for Computational Hydroscience and Engineering
NCWP	Nose Creek Watershed Partnership
NGO	Non-Governmental Organization
NH_3	Ammonia
NO_2NO_3	Nitrite/Nitrate
NWPA	Navigable Waters Protection Act
O&M Manual	Operating and Maintenance Manual
OGS	Oil/Grit Separator
OP	Outline Plan
OTTHYMO	University of Ottawa Hydrologic Model
OTTSWMM	University of Ottawa Storm Water Management Model
P2	Pollution Prevention
PAH	Polyaromatic Hydrocarbon
PAM	Polyacrylamide
PE Pipe	Polyethylene Pipe
PLC	Process Logic Controller
PUL	Public Utility Lot
PVC Pipe	Polyvinyl Chloride Pipe

PWL	Permanent Water Level
Q, V, and D	Flow, Velocity, and Depth
RAP	Restricted Activity Periods
RBP	River Basin Plan
RECP	Rolled Erosion Control Product
RMG	Registered Minimum Grade
RoW	Right-of-Way
RTU	Remote Terminal Unit
RUSELFAC	Revised Universal Soil Loss Equation For Application In Canada
RUSLE	Revised Universal Soil Loss Equation
SCADA	Supervisory Control and Data Acquisition
SCP	Source Control Practice
SCS Method	Soil Conservation Service Method
SMDP	Staged Master Drainage Plan
SOP	Standard Operating Procedure
SP	Special Projects And Contracts
SR	School Reserve
SUSTAIN model	System for Urban Stormwater Treatment and Analysis INtegration model
SWMHYMO	Stormwater Management Hydrologic Model
SWMM	Stormwater Management Model
SWMR	Stormwater Management Report
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
TIMP	Total Imperviousness
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOS	Top of Slab
TP	Total Phosphorus
TRM	Turf Reinforcement Mat
TSS	Total Suspended Solids
TUC	Transportation Utility Corridor

(U)NWL	(Upper) Normal Water Level
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation
VPI	Vertical Point of Intersection
WASP	Water Quality Analysis Simulation Program
WH Canal	Western Headworks Canal
WinSLAMM	Source Loading and Management Model for Windows
WMP	Water Management Plan
WP	Watershed Plan
WTD	Weeping Tile Drain
XIMP	Directly Connected Imperviousness
XP-SWMM	Expert Stormwater Management Model

CHAPTER 1: STORMWATER MANAGEMENT AND PLANNING

1.1 General - Principles, Policies, and Objectives

Stormwater management is a comprehensive approach to the planning, design, implementation, and operation of stormwater drainage infrastructure. Through effective stormwater management, drainage systems can be developed that balance the objectives of maximizing drainage efficiency and minimizing adverse environmental impacts. Stormwater runoff can carry pollutants that have been deposited on land into nearby rivers, creeks, lakes, ponds, wetlands, and groundwater, degrading water quality and aquatic habitat. Effective stormwater management can reduce or prevent pollution of our watercourses. This supports the mission of The City of Calgary's Utilities and Environmental Protection department to "*work with the community and Corporation to conserve, protect and enhance air, land and water for present and future generations*"[1].

Effective planning is necessary to provide effective stormwater management since there are few drainage systems in inhabited areas that remain in their natural state. Urbanization, or development, results in an increase in impervious ground cover and an increase in the rate of runoff. Rainstorms, which at one time would have little or no runoff in rural areas, now produce significant runoff in developed urban areas and can pollute waterways. The increased runoff also results in a corresponding increase in the concentration and types of pollutant loadings, due to nutrients, solids, metals, salt, pathogens, pesticides, and hydrocarbons.

However, there are a variety of ways to manage stormwater runoff in urban areas for both water quality and quantity control, including storage facilities such as wet ponds, dry ponds, or wetlands, or other Best Management Practices (BMPs). BMPs can be effective and practical measures to reduce or prevent pollution caused by stormwater. However, stormwater BMPs vary in their ability and effectiveness to treat pollutants. Where possible, Source Control Practices (SCPs) and Low Impact Development (LID) are supported to prevent pollution in the first place.

"The overall goal of stormwater management is to improve water quality and address water quantity problems through the implementation of stormwater controls and practices."[2]

Recently, environmental sustainability and the health of our rivers has been a growing concern, and regulatory requirements have been increasing. Increased stormwater runoff can cause erosion, increase pollutant loading, degrade receiving stream water quality, and adversely impact aquatic habitat. In support of this, there is a need to enhance stormwater quality and to control high rates and volumes of discharge. As part of The City of Calgary's *Wastewater Approval to Operate*, The City of Calgary requires an Environmental Performance Plan (EPP) that outlines

1. Source: The City of Calgary. *2009-2011 UEP Business Plan - Mission Statement,* 2008 (page A1).
2. Source: Bow River Basin Council.

environmental strategies and impacts resulting from its treatment practices; the document is reviewed by Alberta Environment annually. In support of this, the *2008 Calgary Total Loading Management Plan* was developed to help protect river health by setting targets for managing sediment and controlling the amount of aquatic growth resulting from nutrients. Although the plan discusses loadings from carbonaceous biochemical oxygen demand (cBOD), total suspended solids (TSS), phosphorous, and nitrogen, emphasis has so far largely been placed on TSS and phosphorous by providing daily targets.

To specifically address the impact of stormwater, Water Resources developed a *Stormwater Management Strategy* that was approved by Council in 2005. The main goals of the strategy are to protect watershed health by reducing both rate and volume of stormwater runoff, to ensure regulatory compliance by reducing sediment loading to the Bow River to or below 2005 levels by 2015, and to develop sustainable stormwater management practices that are applicable to both new and re-development areas.

It is clear that stormwater management principles have evolved into a multi-faceted approach for Calgary. At one time, quantity control was the driving factor, but now water quality control and volume controls are also key factors. Multiple stormwater management objectives now include:

- Incorporating stormwater management into the site design.
- Reducing runoff generated from developments.
- Improving the quality of stormwater runoff
- Protecting stream channel stability
- Protecting against downstream flooding

With all stormwater drainage planning, a balance is needed between protecting the environment and the cost of development. Experience in other jurisdictions indicates that protecting the environment can increase marketability and value if done correctly.

While this is first and foremost a stormwater management and design manual, other conditions of development may be required that are outside the scope of this document. Please contact Urban Development for more information on general development issues.

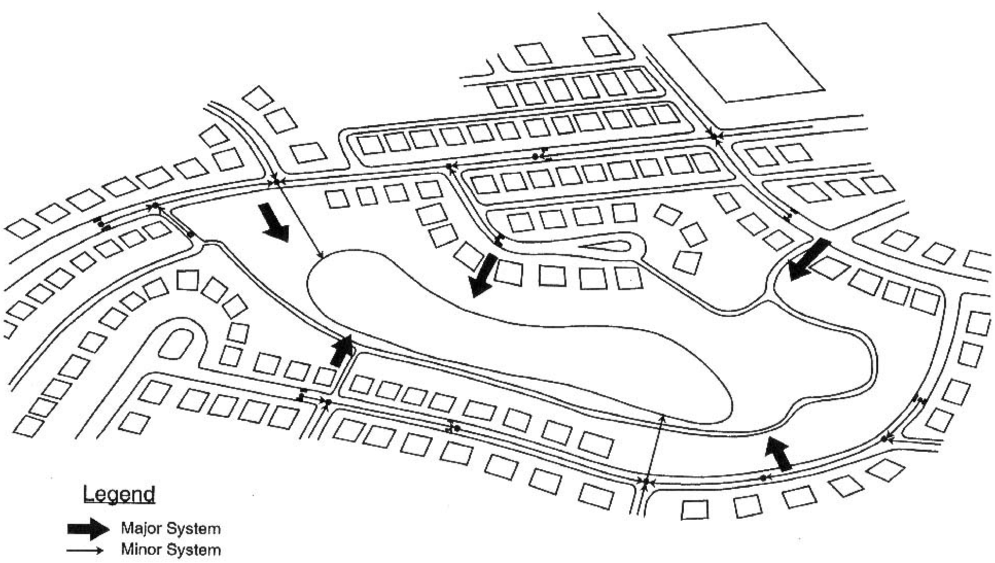
1.2 Dual Drainage Concept

Traditional stormwater drainage systems have typically consisted of an underground network of pipes and associated structures. These systems were designed to transport flows for relatively minor (or low intensity) rainstorms, as a matter of convenience. Although this worked well for smaller rainstorms, it did not work for larger ones. Since little or no consideration was given to controlling the runoff from larger rainstorm events, numerous flooding problems often occurred.

The solution to these past problems was to make allowances for these major rainstorm events in the planning and design of new developments. The division of rainstorms into **minor** and **major** events became known as the "**Dual Drainage Concept"**.

The **minor** system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events as a convenience. The **major** system conveys runoff from the extreme (high intensity, less frequent) rainstorm events that are in excess of what the minor system can handle ***Figure 1-1*** illustrates the two components of the Dual Drainage Concept. Good planning and design are critical to successful stormwater management. **All new development areas in Calgary must be designed using the Dual Drainage Concept (minor/ major system) to achieve specific levels of service objectives.**

Figure 1-1: Major and Minor Systems[3]



3. Source: Alberta Environment. *Stormwater Management Guidelines for the Province of Alberta,* 1999 (page 3-2).

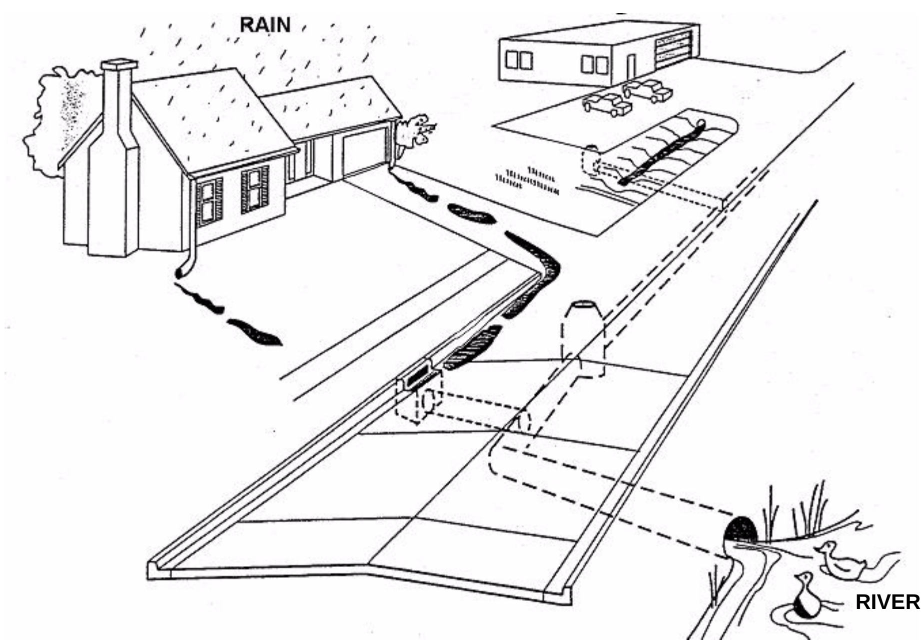
1.2.1 Minor System

The minor stormwater drainage system consists of the underground pipe network and its associated structures These components facilitate the transport of stormwater flows from minor rainstorms Components of the minor system typically include:

- Gutters and roof leaders.
- Weeping tile drains.
- Lot drainage.
- Catchbasins (CBs), inlets and leads.
- Underground pipe system.
- Manholes (MHs) and junctions.
- Source control infrastructure (such as bioswale subdrains).
- Outfalls.
- Receiving waters.

Note: Some components, such as gutters and roof leaders, are classified as both minor and major system components, since they are considered in the design of each type of system.

Figure 1-2: Minor System Components



A basic level of service is provided by the minor system. In Calgary, prior to 1952, the level of service was based on a 1:2 year storm event. Since 1952, however, this has typically been sized for the 1:5 year storm event using the unit area release rate method (L/s/ha). In most cases, the recommended minimum release rate is 70 L/s/ha. Refer to ***3.1.2 Minor System*** for more information.

1.2.2 Major System

The major stormwater drainage system conveys runoff from extreme rainfall events that are in excess of the minor underground system. Components of the major system typically include:

- Gutters and roof leaders.
- Lot drainage.
- Roads.
- Swales.
- Trap lows.
- Escape routes.
- Storage facilities (stormwater ponds).
- Outfalls.
- Receiving waters.

Note: Some components, such as gutters and roof leaders, are classified as both minor and major system components, since they are considered in the design of each type of system.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage, so it is important to examine grading plans to ensure there is an overland route that has reasonable capacity.

In Calgary, the major system must be designed for the 1:100 year storm event. Refer to ***3.1.3 Major System*** **and** ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for more information.

1.2.3 Best Management Practices (BMPs) and Source Control Practices (SCPs)

Good stormwater planning and design involves the integration of site design and stormwater management practices. Conventional stormwater design and end-of-pipe treatment facilities have limitations, so it is important to include other pollution prevention strategies to enhance the stormwater system design. This can include LID practices, stormwater BMPs, Source Control Practices (SCPs), erosion and sediment control programs, stormwater harvesting and re-use, retrofit projects, and education.

By adopting a stormwater management treatment train approach, the following benefits can be achieved:

- Runoff quantity and quality improvements.
- Pollution reduction.
- Flow rate and volume reductions.

This new approach should consider:

i) **Prevention**: Using good site design and housekeeping measures on individual sites to prevent runoff and pollution in the first place (i.e., impervious area reduction, sweeping, rainwater re-use, amended soils).

ii) **SCPs**: Controlling or minimizing runoff at or near the source (i.e., green roofs, porous pavement).

iii) **Site Controls**: Managing stormwater from several subcatchments (i.e., routing stormwater to vegetated swales, bioretention areas).

iv) **Regional Controls**: Managing runoff from several larger sites or catchments (i.e., stormwater ponds, wetlands).

Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** for more information.

1.3 Level of Service

The purpose of a stormwater drainage system is to provide a high degree of service without causing unacceptable downstream impacts. This is accomplished by balancing the cost of the system with the level of service. In Calgary, the minor storm system must be designed as a separate system from the sanitary; combined systems are not permitted.

Using the Unit Area Release Rate Method (L/s/ha), the **minor system** must be designed for a recommended minimum release rate of 70 L/s/ha. In steeper terrain, where on-street storage is minimal, the release rate should be higher.

The **major system** must be designed for a 1:100 year storm event, which is assumed to generate runoff conditions that have a probability of 1% to occur in any given year. As well, targets have also been set for runoff control volumes for the Nose Creek, West Nose Creek, and Pine Creek watersheds.

Refer to ***CHAPTER 3: STORMWATER DESIGN*** for more detailed information.

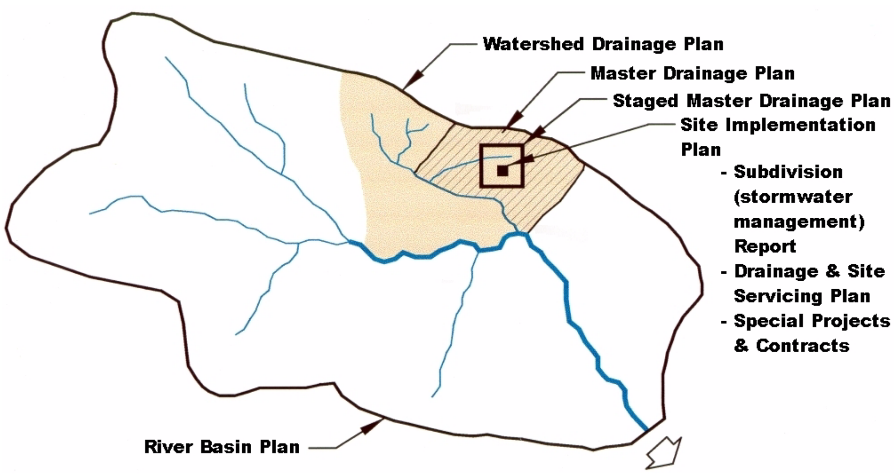
1.4 Planning Levels

1.4.1 Introduction

The integration of municipal land use planning and environmental planning has evolved considerably in the last decade. Aside from water quantity issues, water quality issues must now be given consideration. The preparation of planning documents can provide rationale and direction for the servicing and objectives for future development areas.

River basin and watershed plans provide a broad scope for drainage planning, while Master Drainage Plans (MDPs), Staged Master Drainage Plans (SMDPs), and Biophysical Impact Assessments (BIAs) provide intermediate planning levels. Detailed information is provided in the subdivision and development site servicing plans, and Special Projects and Contracts (SPs). The relationship of these planning levels is illustrated in ***Figure 1-3***.

Figure 1-3: Stormwater Management Planning[4]



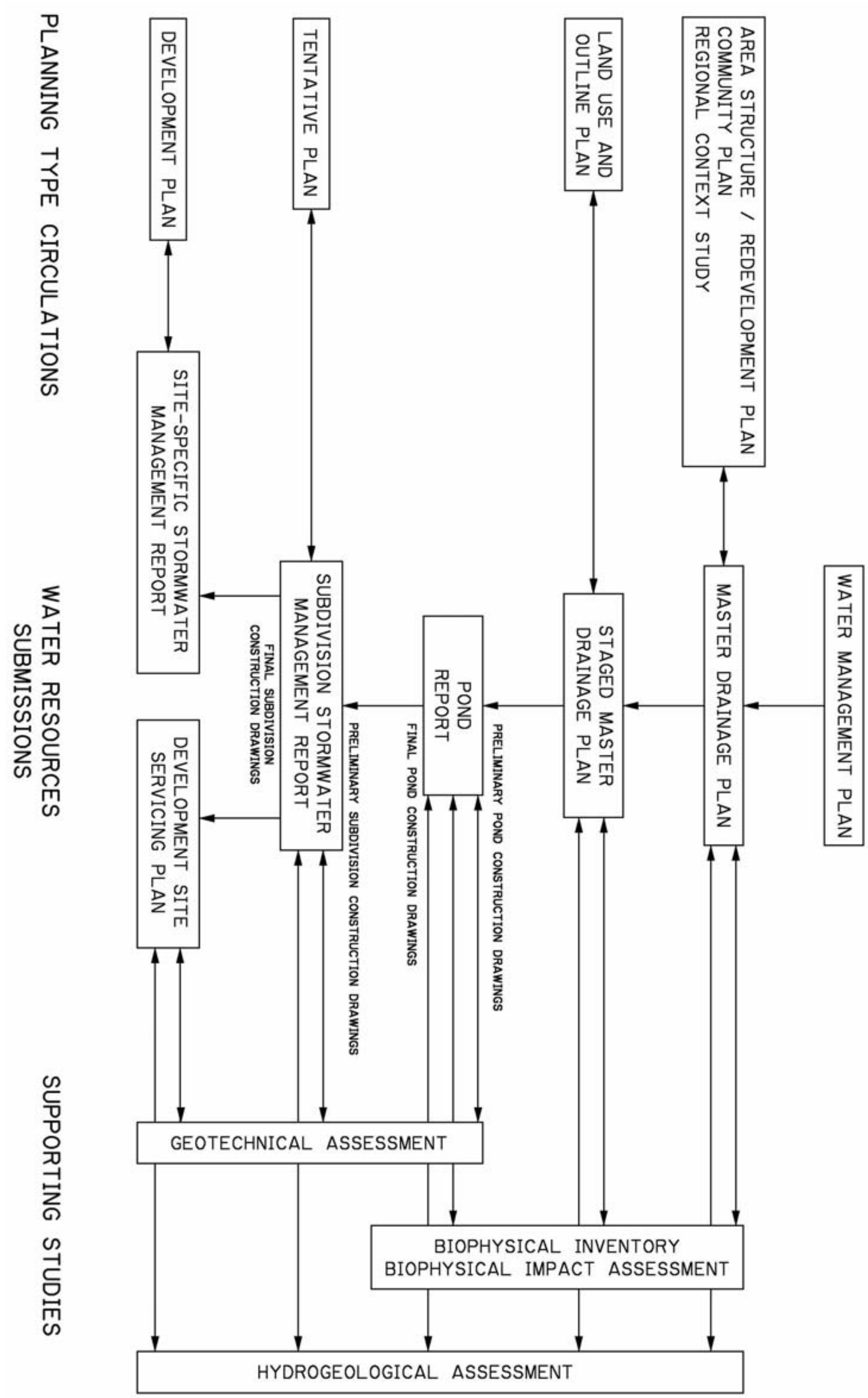
All plans, reports, and projects must be designed and prepared by qualified consultants. At a minimum, the preparation of stormwater management reports and drawings require the involvement of a Professional Engineer, but they may also include qualified consultants in environmental areas for BIAs. For more information and specific requirements, refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS***.

In general, system design and analysis should be used to provide a formalized framework for the planning process. The analysis will often include a problem definition, a needs analysis, a definition of system components, system alternatives, and a cost and benefit analysis. The procedure should be used from basic land planning through to detailed design. Repeated application of the process should result in optimal storm servicing Updating of the key planning and servicing documents is necessary.

4. Adapted from Alberta Environment. Stormwater Management Guidelines for the Province of Alberta, 1999 (page 2-7).

Reports are required to establish a technical backup that demonstrates the viability of proposals, and will ultimately provide the basis for detailed design. Specific sewer and drainage concerns must be addressed at an appropriate and increasing level of detail as the planning and development proceed. ***Figure 1-4*** illustrates the planning process.

Figure 1-4: Stormwater Management Planning



1.4.2 Regional Context Study (RCS)

A Regional Context Study (RCS), previously known as a Regional Policy Plan, is a non-statutory plan for large sectors of the city that provides a level of strategic planning between the Calgary Plan, area structure plans (ASPs), and community plans (CPs). The purpose of the study is to refine and implement The City's broader planning objectives by identifying land use, transportation, environmental, and servicing components, as well as to establish subsequent sequencing of ASPs and CPs to ensure urban growth proceeds logically and efficiently. The process includes input from landowners and other stakeholder groups, and public consultation. This level of planning is typically administered by The City of Calgary, while development of servicing (water, sanitary and stormwater) is undertaken by Water Resources.

1.4.3 River Basin Plans (RBPs)

River basin planning considers the major river basins in Alberta, and is typically a provincial responsibility. Calgary is located within the Bow River Basin. Within this basin, the supply and demand for water as a resource are major issues. With respect to stormwater management, the most significant factor is the impact on water quality due to urbanization; as a result, water quality restrictions are starting to be imposed. Stormwater pollution abatement and protection of receiving waters must be recognized.

The Province of Alberta utilizes the Bow River Basin Council as a component of the overall planning structure. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS***.

1.4.4 Watershed Plans (WPs) and Water Management Plans (WMPs)

Watershed planning considers the major tributaries to the major river basins. These storm drainage basins may be either completely or partially within the City boundary, and can include a single drainage basin or a group of sub-basins that contribute to a point in the natural drainage system. Watershed planning can also include both areas proposed for development and those expected to remain undeveloped.

Watershed Plans (WPs) provide a conceptual framework for stormwater and drainage servicing. Components are usually structural (i.e., servicing options, drainage and environmental constraints, BMPs including ponds, and alternatives) and non-structural (i.e., economic issues, staging, utility corridors, biophysical impact assessments, and performance criteria). Although drainage problems are not always evident in the early stages of development, lack of comprehensive planning at this level can lead to long-term flooding and/or pollution problems.

Watershed planning is generally carried out as a joint responsibility between the City of Calgary and the Province. Examples of watershed plan reports include Nose Creek, Pine Creek. Bow River, and Elbow River. For more information on specific recommendations and targets, refer to ***CHAPTER 3: STORMWATER DESIGN***, and for technical requirements, refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*****.**

1.4.4.1 Nose Creek Watershed Water Management Plan

The *Nose Creek Watershed Water Management Plan* was finalized in 2007 and later approved by Council the same year. The Plan was three years in the making and was researched and written by members of the Nose Creek Watershed Partnership. The Partnership, which was founded in 1998, included Alberta Environment, The City of Calgary, the City of Airdrie, the Municipal District of Rocky View, the Town of Crossfield, and the Calgary Airport Authority.

The Nose Creek watershed encompasses the northern part of Calgary and a large portion of the M.D. of Rocky View. Due to a variety of activities such as agriculture, urbanization, and its use as a transportation corridor, the watershed has come under increasing pressure to protect its riparian areas and to improve and restore water quality in the creek.

The *Nose Creek Watershed Management Plan* is a guidance document and planning tool to help guide day-to-day decision making related to water management. The Plan contains water conservation objectives and promotes the use of more sustainable stormwater management practices through implementation of maximum allowable release rates and runoff volume control targets. Implementation of LID practices will be needed to reduce runoff volumes and meet targets. To further improve water quality, recommendations are also made for riparian protection. This includes incorporating the 1:100 year floodplain, escarpments and meander belt widths to achieve appropriate setbacks, use of natural features and vegetation, a “no net loss” policy for channel length, and a long-term water quality monitoring program.

1.4.4.2 Pine Creek Watershed Study

A drainage study of the Pine Creek Watershed was undertaken in 2005 for The City of Calgary. An analysis was performed to determine the watershed's hydrologic characteristics, streamflow response, and assessment of stream channel stability. Recommendations with respect to stormwater management were then made in the *Pine Creek Watershed Study* specific to improving water quantity and quality in the Pine Creek watershed as urban development moves forward.

The Pine Creek watershed is located at the south end of Calgary and is tributary to the Bow River. Approximately 20 km of the watershed was annexed to The City of Calgary from the Municipal District of Foothills. While the watershed consists mainly of small agricultural operations and country residential developments, further urbanization will occur. The *Pine Creek Watershed Study* recommends an integrated multi-objective stormwater management approach to deal with urbanization by protecting against downstream flooding, preserving channel stability, improving stormwater runoff quality, reducing runoff generated, and incorporating stormwater management into the site design. This is accomplished through the implementation of maximum allowable release rates, flow duration controls, and source volume controls.

1.4.4.3 Bow Basin Watershed Management Plan

In 2005, the Bow River Basin Council (BRBC) recognized the need to develop a watershed management plan for the Bow Basin to align decisions across multiple jurisdictions. As a result, Phase One of the *Bow Basin Watershed Management Plan* was developed using an environmental performance management system to achieve surface water quality outcomes. The BRBC collaborated with partners and stakeholders by setting up steering and technical committees that consisted of members representing different constituencies in the watershed.

Activities and development in the watershed currently include recreation, industrial (logging, oil and gas field development, and hydroelectric generation), agricultural, and human (drinking water, parks, residential, commercial, and institutional). As a result, wetland and riparian areas have been lost and there have been insufficient flows to meet demands of the river at certain times.

The *Bow Basin Watershed Management Plan* contains reach-specific water quality objectives, targets, warning levels and baseline water quality data, and serves as a decision support tool. It was approved by Council in 2008. While Phase One of the Plan focussed largely on water quality objectives, recommendations were also made for riparian areas, source water protection, water quantity, land use planning, groundwater, wetlands, biodiversity, recreation, and industry.

1.4.4.4 Elbow River Basin Management Plan

The Elbow River is a relatively small river that provides water for a variety of needs. This includes consumptive needs (municipal and agriculture supply) and non-consumptive uses, such as recreation and fish and wildlife habitats. The upper Elbow River is the source of Calgary's drinking water and is located in the basin upstream of the Glenmore Reservoir. Water quality in the central and lower reaches of the river have been deteriorating, and increasing urban and rural development is having a negative impact on the watershed.

The Elbow River Watershed Partnership (ERWP), along with a steering committee of dedicated stakeholders and scientists, developed the *Elbow River Basin Management Plan* to address water quality degradation. The Plan was approved by Council in 2008. The *Elbow River Basin Management Plan* focuses on water quality and developing water quality objectives. The technical committee for the *Bow Basin Watershed Management Plan* was responsible for providing technical leadership for these water quality objectives. As a result, reach-specific guidelines for water quality were established and recommendations were made to protect the river's natural functions, limit land use, implement LID practices, and increase education and awareness. The intent of the Plan was to provide a safe and secure drinking water supply, to maintain healthy aquatic systems, to provide reliable quality water supplies for a sustainable economy, and to provide an integrated and inclusive stewardship of the river and watershed.

1.4.5 Master Drainage Plans (MDPs)

A Master Drainage Plan (MDP) is typically a stormwater drainage plan prepared for a large drainage area serviced by (usually) a single outfall. The drainage boundary area is usually determined by existing drainage boundaries or by watershed plans. The drainage area should not be based on jurisdictional or property boundaries, as this may not provide the best servicing concept for the area. The MDP generally covers a portion of the area served by the watershed plan.

The MDP should be developed through the evaluation of alternatives that provide an acceptable level of service while meeting the objectives of the WP and satisfying any constraints imposed by topography, land uses, and land ownership. The MDP should identify and locate major stormwater ponds, other BMPs, trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Preliminary designs of the major ponds and BMPs may be developed and included in the plan.

This level of planning is typically administered by The City of Calgary, while development of the MDP is normally undertaken by Water Resources. However, if the area is being developed ahead of the scheduled budget, the developer/ consultant will undertake development of the MDP in consultation with The City (Water Resources) and the Province (Alberta Environment). Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.6 Staged Master Drainage Plans (SMDPs)

A Staged Master Drainage Plan (SMDP) is essentially a stormwater drainage plan prepared for a large area that may or may not be serviced by an outfall. The SMDP generally covers a portion of the area served by the MDP plan An SMDP is not necessarily required in all circumstances. An MDP may be sufficient provided there is enough detail, the catchment boundaries have not significantly changed, or there is no significant deviation from the stormwater management system proposed. As with an MDP, the drainage area for an SMDP should not be based on jurisdictional or property boundaries, as this may not provide the best servicing concept for the area.

Similar to an MDP, the SMDP should be developed through the evaluation of alternatives that provide an acceptable level of service while meeting the objectives of the WP or MDP, and satisfying constraints imposed by topography, land uses, and land ownership. The SMDP should identify and locate major stormwater ponds, other BMPs, trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Preliminary designs of the major ponds and BMPs should be developed and included in the plan.

This level of planning is typically administered by The City of Calgary, with the development of the SMDP generally undertaken by the developer/consultant in support of a Land Use and Outline Plan (OP) application in consultation with The City (Water Resources) and the province (Alberta Environment). Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.7 Community Drainage Plans

Community Drainage Studies are carried out to address drainage problems in existing communities. Often, the drainage systems in these communities were designed and constructed in an era in which the design philosophy was considerably different from current standards and guidelines. Typically, since the principal design focus in the past was only on the minor system, no MDP or SMDP reports exist for these communities.

As part of these studies, the current level of service and conceptual design-level options to improve the level of service are identified. The performance of potential upgrades is examined and planning-level life-cycle cost estimates are prepared. Based on evaluation criteria, including public consultation feedback, the preferred upgrades are selected. Recommendations for additional analysis and/or design during the subsequent detailed design of the recommended drainage improvements are included as well.

The preparation of these studies is typically initiated and administered by Water Resources, Planning & Analysis, with the studies being undertaken by a consultant. The preliminary and detailed design of any improvements identified is subsequently supervised by Water Resources, Infrastructure Delivery. Although the scope of these studies is usually tailored to the project at hand, refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.8 Pond Reports

A Pond Report must be prepared for all dry ponds, wet ponds, and stormwater wetlands, including zero-discharge facilities such as (temporary) evaporation ponds, in support of the construction drawings for the pond in question. A Pond Report is not necessarily required in all circumstances; its contents can be included in the preceding SMDP report. If details of the pond are likely to change significantly after submission of the SMDP report, a separate Pond Report is required. As with an MDP and SMDP, the drainage area for a Pond Report should not be based on jurisdictional or property boundaries, but should reflect the entire upstream catchment area.

The Pond Report should include all details relevant to the design, construction, and operation of the stormwater pond in question. The Pond Report should demonstrate how the design objectives from preceding MDP and SMDP reports are met, and should provide details pertaining to the water levels in the pond, the sizing of the forebay (or equivalent), and how water quality enhancement is accomplished. The Pond Report should also identify whether any embankments need to be classified as a dam under the Water Act and include a dam safety assessment, if needed.

The Pond Report is generally prepared by the developer/consultant. The Pond Report (or Pond Report embedded in preceding SMDP report) must have been reviewed and approved by both Water Resources and Alberta Environment before construction of a pond can commence. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.9 Subdivision Stormwater Management Reports (SWMRs)

Detailed Subdivision Stormwater Management Reports (SWMRs) must be prepared for areas covering subdivisions within previously approved OPs and areas subject to redevelopment. Subdivision reports are commonly referred to as SWMRs or overland drainage reports. A Subdivision SWMR is required for **each** subdivision development phase, and will correspond to an applicable set of construction drawings. The report will include a detailed hydrologic and hydraulic analysis for the subdivision or OP area, and any related details.

At this level, details pertaining to the storm sewer and related structures, hydraulic grade line analysis (where required), 1:100 year storage requirements, trap lows, escape routes, BMPs, and water quality requirements, are some of the items that should be included.

The SWMR is generally undertaken by the developer/consultant. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.10 Development Site Servicing Plans (DSSPs)

A Development Site Servicing Plan (DSSP), formerly known as a Mechanical Site Plan, is a drainage and servicing plan that is generally prepared for multi-family, industrial, manufacturing, and commercial areas. Larger industrial and commercial areas may also require an SWMR to be submitted.

The DSSP must include drainage details such as 1:100 year volume requirements, trap lows, roof top storage, escape routes, storm and sanitary servicing, and water quality improvements.

The DSSP is generally undertaken by the land owner or their designated consultant. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.11 Special Projects and Contracts (SPs)

All special projects and contracts (SPs) are required to conform to stormwater management designs and policies, whether they are designed within The City by other business units or through external consultants. In general, an SWMR should be submitted.in support of the design; if stormwater ponds are required as part of the project, they must be included in the SWMR, submitted as separate reports, or submitted as a SMDP report, whichever is appropriate. The type of report required will be dependent on the amount and level of detail required, and the areas serviced. The report(s) should correspond to an applicable set of construction drawings.

The report should include a detailed hydrologic and hydraulic analysis, and provide details pertaining to the storm sewer and related structures, hydraulic grade line analysis, 1:100 year storage requirements, stormwater ponds, trap lows, escape routes, BMPs, erosion and sediment controls, and water quality requirements (as required).

The SP is generally undertaken by the land owner, which is often The City of Calgary. A designated consultant is often used on behalf of the land owner. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

1.4.12 Open Space Plan

The *Open Space Plan* is a policy document that identifies broad principles, policies and strategies for the acquisition and development of open space in Calgary. It was developed to provide a single, comprehensive, and integrated source of policy on open space and was adopted by Council in July 2002. Through specific policies, plans, and procedures on land use, the *Open Space Plan* provides broad direction for day-to-day procedures as well as direction for decision-making on community plans, area redevelopment plans, and development proposals.

Two objectives of the *Open Space Plan* are to:

- "Promote connected open space systems and protect natural areas and water quality in areas of future urban growth".
- "Consider, where appropriate and in the interests of land efficiency, locating stormwater management facilities within Municipal Reserve (MR), Municipal School Reserve (MSRs, and Environmental Reserve (ER) lands, provided this can be done in a manner that maintains the area's environmental, recreational and aesthetic integrity".[5]

Innovative design for stormwater management should include the use of BMPs, including wet ponds, dry ponds, wetlands, SCPs, lot drainage patterns, storm conveyance methods, swales, trenches, and end-of-pipe practices. The goal is to integrate stormwater facilities more effectively, enhance aesthetic value, enhance habitat, and educate the public. Also included in the *Open Space Plan* is information on BIAs and Identification and Delineation of Wetlands.

1.4.13 Biophysical Impact Assessments (BIAs)

Environmental planning is an important component to the municipal land use planning process. To ensure overall environmental objectives are being met, a BIA is to be conducted as outlined in The City of Calgary Parks' *Open Space Plan*.

The BIA outlines the existing conditions, potential impacts and appropriate mitigating measures of the affected and surrounding lands. The purpose of the BIA is to examine the potential impacts and mitigation of development on biophysical elements (ecosystems, landforms and habitats), as well as to successfully integrate

5. Source: The City of Calgary. *Open Space Plan,* 2003 (page 5).

stormwater management (utilities and facilities) within the planning area. This includes an inventory of the following:

- Topography.
- Geology and Geomorphology.
- Pedology.
- Biological resources.
- Cultural resources.
- Hydrology and water bodies.
- Aesthetics.

A BIA is an effective information tool that aids the decision making process. To be effective, the BIA should done in collaboration with Parks and Water Resources to meet mutual objectives. The consultant must contact Parks for BIA scope, requirements, and issues to be addressed. A BIA may be quite simple or complex, depending on the area (community) and/or its size. Environmental strategies might be provided in the Natural Area Management Plan (NAMP) prepared by Parks. If a NAMP is available for the area, natural habitat types are identified For more information, refer to ***11.1.9 Special Projects and Contracts (SPs)***.

CHAPTER 2: AUTHORIZATIONS AND PROCESSES

2.1 General

This section outlines the procedures and authorizations required for construction of stormwater drainage systems. It is the responsibility of the landowner or developer undertaking the project (or their designated consultant) to comply with the statutory requirements governing the work. Approvals from all required authorities having jurisdiction are required; this includes, but is not limited to, those mentioned in the following sections.

There are three jurisdictions that could require authorizations for construction of stormwater systems or works: the federal government, the provincial government, and the municipal government. The owner or developer (or designated consultant) is responsible for preparing the applications and required information, which must then be forwarded to Water Resources. Water Resources will make the formal application(s) to the required authorities having jurisdiction, since The City of Calgary is typically the permit holder. Construction of work is not permitted without the necessary permits or authorizations in place. Contact Water Resources for application and information requirements.

2.2 Federal

2.2.1 Navigable Waters Protection Act

The *Navigable Waters Protection Act (NWPA)* is administered by Transport Canada and is designed to protect the public right of navigation in Canadian waters. Should an improvement involve construction or placement in, on, over, under, through, or across any "navigable water", such as the Bow River, either a permit or an exemption from the requirement must be obtained from Transport Canada.

Transport Canada defines "navigable water" as "any body of water capable of being navigated by floating vessels of any description for the purpose of transportation, commerce or recreation." "Navigable water" includes canals and any other body of water created or altered as a result of the construction of any work. Typically, this work includes storm outfalls, crossings, and riverbank stabilization. Authorizations issued under the NWPA trigger an environmental review under the *Canadian Environmental Assessment Act (CEAA)*. Refer to ***2.2.3 Canadian Environmental Assessment Act*** for more information.

Water Resources will normally make the application to Transport Canada for a permit on behalf of the owner or developer (or their designated consultant).

2.2.2 Fisheries Act

The main part of the current *Fisheries Act (F-14)* dealing with the protection of fish habitat is a straightforward prohibition that states “no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat”. Where work or an improvement could cause harmful alteration, disruption, or destruction (HADD) of fish habitat, legal approval must be obtained from Fisheries and Oceans Canada. The approval may take the form of an Operational Statement, a Letter of Advice, or an Authorization. If an approval is granted, the “alteration, disruption or destruction” of fish habitat will be subject to conditions prescribed in the Operational Statement, Letter of Advice, or Authorization.

An Authorization is used as a last resort when there is no other way to preserve fish habitat, and its issuance triggers an environmental review under the *Canadian Environmental Assessment Act (CEAA)*. Refer to ***2.2.3 Canadian Environmental Assessment Act*** for more information.

A report from a qualified fisheries consultant may be required prior to an Authorization being issued. It is the responsibility of the owner or the developer (or their designated consultant) to comply with the conditions set out in the Authorization. If work can be conducted in a way that eliminates the HADD, a Letter of Advice might be issued instead of an Authorization. The Letter of Advice will confirm the conditions that are required to avoid a HADD of fish habitat. Please note that a new bill was introduced in 2007 to modernize and make improvements to the Act; the new *Fisheries Modernization Bill (C-32)* is still under review.

Water Resources will make the application to Fisheries and Oceans Canada on behalf of the owner or developer (or their designated consultant).

2.2.3 Canadian Environmental Assessment Act

The *Canadian Environmental Assessment Act (CEAA)* is federal legislation that requires environmental assessments for proposed projects or activities that are to be carried out on federal lands, and where the Government of Canada has decision-making authority. It has been in force since 1995. The Act ensures that proposed projects and activities do not cause significant adverse effects on the environment, and that there is an opportunity for public participation. *The Fisheries Act* and the *Navigable Waters Protection Act (NWPA)* are both triggers for a more detailed federal environmental review under the CEAA. Refer to ***2.2.1 Navigable Waters Protection Act*** and ***2.2.2 Fisheries Act*** for more information.

The *Inclusion List Regulation (SOR/94-637)* under the CEAA lists related projects that may require an environmental assessment. Section 14 of the Act describes the levels of review: screening, comprehensive study, mediation, and review panel. If an activity triggers a CEAA review, documents will be posted on the CEAA website for a 15 day public review.

2.3 Provincial

2.3.1 Environmental Protection and Enhancement Act

On September 1, 1993, Alberta's *Environmental Protection and Enhancement Act (EPEA)* and its associated regulations came into force, replacing nine former acts. The purpose of *EPEA* is to support and promote the protection, enhancement, and wise use of the environment, and is administered by Alberta Environment (AENV). In general, the Act specifies what is to be regulated, as well as the regulatory processes and applications. Refer to the following documents for more information:

- *EPEA* *Activities Designation Regulation, Alta Reg 276/2003*.
- Alberta Environment's *Stormwater Management Guidelines for the Province of Alberta*.
- Alberta Environment's *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*.
- Alberta Environment's *Municipal Policies and Procedures Manual*.

2.3.2 Wastewater and Storm Drainage Regulation (119/93) and Activities Designation Regulation

2.3.2.1 Storm Drainage Systems

Pursuant to the *EPEA*, the *Wastewater and Storm Drainage Regulation*, and the *Activities Designation Regulation*, a written authorization is required from Alberta Environment for the construction, operation, or reclamation of a storm drainage system for subdivisions approved by The City of Calgary.

An Application for Registration must be submitted to obtain the authorization from Alberta Environment.The City of Calgary (Urban Development) will apply for authorization and submit engineering drawings provided by the owner or developer (or their designated consultant) to Alberta Environment as required. ***Figure 2-1*** and ***APPENDIX A: Alberta Environment Registration Process*** of this document outlines the typical application and approval process.

2.3.2.2 Stormwater Ponds

Pursuant to the *EPEA* and *Wastewater and Storm Drainage Regulation (119/93)*, a written authorization from Alberta Environment is required for the construction or modification of storm drainage treatment facilities, including stormwater ponds. An Application for Registration must be submitted to obtain the authorization. A Pond Report (approved by The City, Water Resources) is required prior to Water Resources submitting the application for registration to Alberta Environment.

The owner or developer (or designated consultant) is responsible for preparing and submitting the required information outlined in the *Wastewater and Storm Drainage Regulation (119/93)* to Water Resources, including Alberta Environment's

Application Form and Guide for Registration to Construct and Operate a Municipal Storm Drainage System. Water Resources, Development Approvals will complete the application for registration and submit it to Alberta Environment. Refer to ***Figure 2-1*** for more information.

Note: If a storm drainage system for a subdivision drains to a stormwater pond, a Pond Report must be submitted and approved by Water Resources, Development Approvals, prior to submitting the subdivision drawings to Urban Development. Stormwater management facilities must be constructed prior to, or in conjunction with, the first phase of development in the Outline Plan area.

2.3.2.3 Outfalls

Pursuant to the *Code of Practice for Outfall Structures on Water Bodies* made under the *Water Act* (refer to ***2.3.3 Water Act***) and *Water (Ministerial) Regulation, Alta Reg 205/1998*, all outfall activities (including placing, constructing, installing, maintaining, replacing, or removing an outfall structure on a water body) must comply with the requirements of the Code. The owner, developer, or designated consultant must coordinate with Water Resources to provide required notice to Alberta Environment and to ensure that the outfall structure activity is carried out in accordance with the planning, design, construction, monitoring, and reporting requirements of the Code.

2.3.3 Water Act

The *Water Act* and its associated regulations came into force on January 1, 1999, replacing the *Water Resources Act.* The purpose of the *Water Act* is to support and promote the conservation of water. Pursuant to the *Water Act*, approval is required for any work that is designated as an 'activity' under the definitions. Activities may include, but are not limited to, instream work and/or bank disturbances. A licence is required to impound water for the purpose of water management, flood control, and flow regulation, or for the diversion of water. Exceptions to the requirement of an approval or a licence are located in *Water (Ministerial) Regulation, Alta Reg 205/1998*, including submission of a Code of Practice notification for certain activities.

2.3.3.1 Code of Practice for Outfall Structures on Water Bodies

Pursuant to the *Code of Practice for Outfall Structures on Water Bodies*, when an activity such as the placement, construction, installation, maintenance, replacement or removal of all or part of an outfall, or an activity associated with the these works occurs, a notification should be sent to Alberta Environment, Water Administration. Water Resources will submit the notification on behalf of the owner or developer (or designated consultant). A report from a qualified aquatic environmental specialist (fisheries consultant) may be required.

2.3.3.2 Dam and Canal Safety

Dam and Canal Safety is covered under Part 6 of the *Water (Ministerial) Regulation (205/1998)*. A *"*dam*"* is defined as a *"barrier constructed for the purpose of storing water, including water containing any other substance, that*

i) provides for a storage capacity of 30,000 cubic metres or more, and

ii) is 2.5 metres or more in height when measured vertically to the top of the barrier,

iii) from the bed of the water body at the downstream toe of the barrier, where the barrier is across a water body, or

iv) *from the lowest elevation at the outside limit of the barrier, where the barrier is not across a water body and includes a works related to the barrier."*

If a stormwater pond meets the above criteria, additional review and approval under Part 6 of the *Water (Ministerial) Regulation, Alta Reg 205/1998* will also be required. A dam safety assessment, including drawings of the pond and supporting geotechnical reports, must be submitted to Water Resources. Water Resources, after internal review, will forward the information to Alberta Environment, Dam Safety Branch as part of the review process.

Note: Ponds with an embankment not classified as a dam under the Water Act, but with a total (i.e., dead + live) 1:100 year storage volume of more than 10,000 m^3 and an embankment of more than 1.0 m above original ground, will be assessed on a case-by-case basis (refer to ***6.1.7 Geotechnical***). Contact Water Resources for more information.

2.3.3.3 Wetlands

Before land development is allowed to impact naturally occurring wetlands, approval under the *Water Act* is required. Wetland management within Alberta is regulated through Section 36 of the Water Act, together with the current interim policy (*Wetlands Management in the Settled Area of Alberta - an Interim Policy*) and the *Provincial Wetland Restoration/Compensation Guide*. An update of the provincial interim wetland policy is in the public consultation stage.

Alberta Environment's priority is to avoid impacts to wetland areas whenever possible. If avoidance is not an option, Alberta Environment requires developers to explore options to reduce impacts to wetland areas or compensate for the disturbance. In Calgary, applications to alter wetlands must be submitted by the developer/consultant to Alberta Environment after The City of Calgary's Parks business unit has accepted the mitigation proposal. The submission to Alberta Environment must include (1) the wetland compensation proposal and (2) a legal agreement. Refer to ***2.4.2.2 Calgary Wetland Conservation Plan*** and contact Parks for more information.

2.3.4 Calgary Restricted Development Area Regulations

Under the *Government Organization Act,* any surface disturbing activity or change in land use within areas governed by the *Calgary Restricted Development Area Regulations, Alta Reg 212/1976* requires the consent of the Minister of Infrastructure. In Calgary, this includes lands in the Transportation Utility Corridor (TUC). The owner or developer (or designated consultant) should contact the TUC Coordinator at Alberta Infrastructure and Transportation directly regarding TUC issues.

2.3.5 Public Lands Act

Where a proposed facility may encroach on crown lands, a disposition through a Licence of Occupation (LOC) is required under the *Public Lands Act.* This also applies to facilities or work that affect all permanent and naturally occurring bodies of water, and all naturally occurring rivers, streams, watercourses, and lakes. Construction of an outfall discharging to a major watercourse would be an example.

Where a Licence of Occupation (LOC) is involved, Water Resources will apply directly to Sustainable Resource Development on behalf of the owner or developer (or designated consultant). If an approval under the *Water Act* is required for an activity not covered under the *Code of Practice for Outfall Structures on Water Bodies*, a one-window application process can be used for both the AENV approval and the Public Lands disposition. Where a disposition other than an LOC is involved, the owner or developer (or designated consultant) should apply directly to Public Lands Alberta, Ministry of Sustainable Resource Development and forward a copy to Water Resources.

2.3.6 Stormwater Reports

Master Drainage Plan (MDP) reports, Staged Master Drainage Plan (SMDP) reports, and Pond reports must be reviewed by Water Resources. If required, Water Resources will forward copies of the report(s) to Alberta Environment for review at their request.

2.4 Municipal

Stormwater drainage systems are regulated by several City of Calgary bylaws and Council-approved Plans. There are two departments in The City of Calgary that must review and approve stormwater drainage systems: Water Resources and Parks.

2.4.1 Water Resources

The City of Calgary's Water Resources business unit is responsible for reviewing stormwater reports and construction drawings. All reviews and/or authorizations from the various jurisdictions must be in place prior to issuance of construction permission by The City. ***Figure 2-1*** illustrates the planning and approval process within The City of Calgary, including the interaction with the outfall and pond notification and registration process administered by Alberta Environment. Refer to ***APPENDIX A: Alberta Environment Registration Process*** for more information.

i) All stormwater reports (MDP, SMDP, Subdivision, and Stormwater Pond), as well as Biophysical Impact Assessments (BIAs) and Development Site Servicing Plans (DSSPs) (as required) must be submitted for review and approval by Water Resources. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

ii) All MDP reports, SMDP reports, and Pond reports might also be reviewed by Alberta Environment. Water Resources will forward copies of the report(s) to Alberta Environment for review if required.

iii) All BIAs must be reviewed and supported by Parks. In addition, Alberta Environment, Water Sciences Branch, must review BIAs where ponds are adjacent to watercourses. Parks support is required for Watershed Plans and/or MDP Reports that are impacted by the BIAs. Where required, Parks will inform the River Valleys Committee of report submissions; refer to ***2.4.3 Bow River Basin Council*** regarding the mandate of the River Valleys Committee.

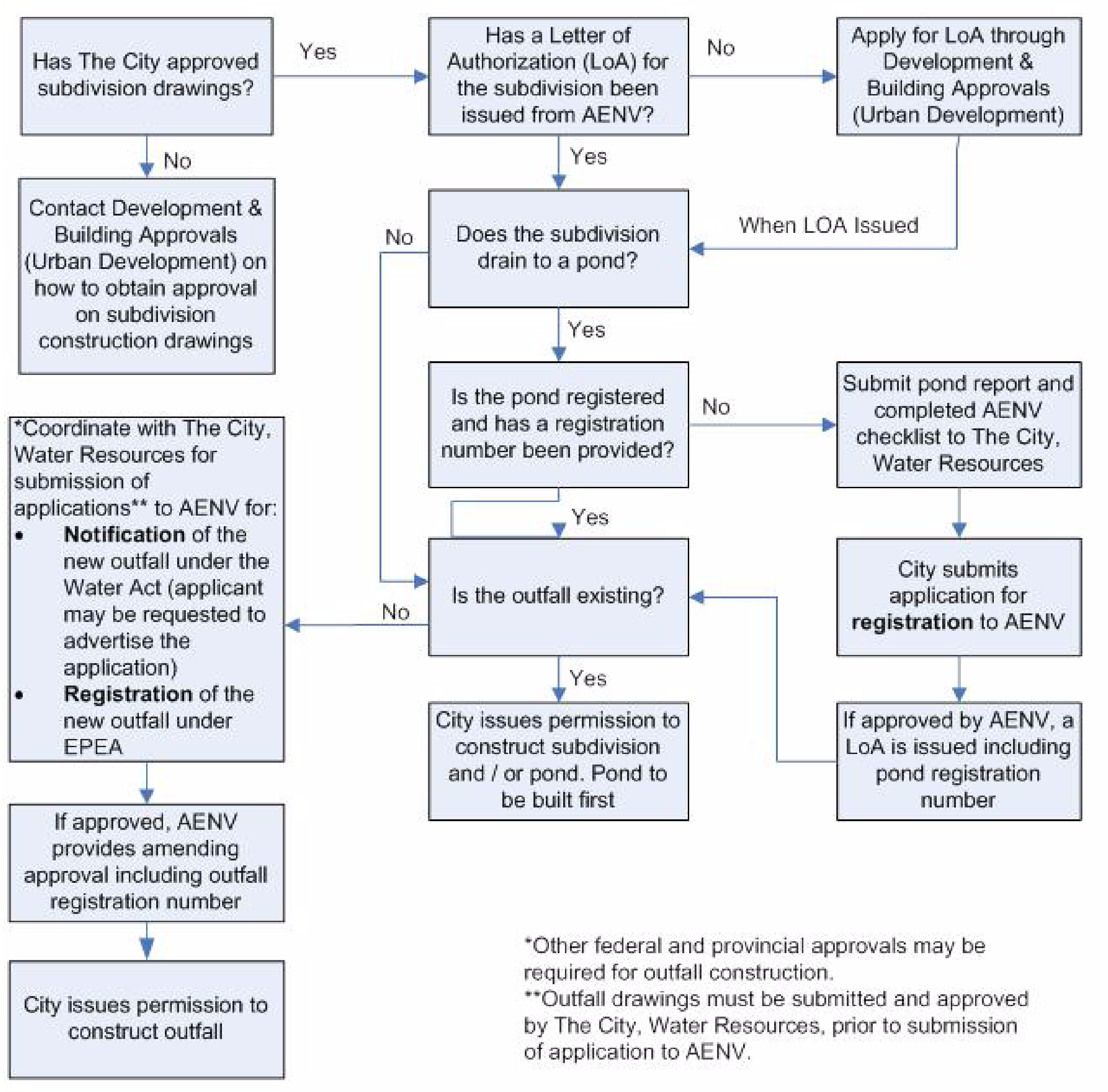
   Although it is not mandatory, the owner or developer (or designated consultant) is encouraged to meet and discuss the planned proposal with the River Valleys Committee, Parks, and Water Resources prior to preparing the final report(s) for areas within river valleys. Communication in the early planning stages among all of the groups will provide an opportunity for a unified solution that will advance the subsequent approval and construction processes. The owner or developer (or designated consultant) may forward copies of the report(s) or pertinent information to these groups as required.

iv) All preliminary and final subdivision construction drawings (including landscaping drawings) must be submitted for review and approval. Construction drawings must be submitted directly to Urban Development, Development & Building Approvals; the drawings will then be circulated to Water Resources and other business units as required.

Development & Building Approvals will also circulate construction drawings that include the locations of stormwater ponds and outfalls to Alberta Environment.

v) Special drainage projects, stormwater ponds, and outfalls require the review and approval of Water Resources.

Figure 2-1: Subdivision, Pond, and Outfall Approval Process-Coordination with Alberta Environment



2.4.2 Parks

Water Resources works closely with The City of Calgary's Parks business unit on the review and approval of stormwater infrastructure, such as stormwater ponds, Source Control Practices (SCPs), and BMPs such as Low Impact Development (LID).

2.4.2.1 Biophysical Impact Assessments

Parks is involved in the review and approval of BIAs, MDP reports, and SMDP reports as they pertain to stormwater pond locations, sizes, and impacts to the adjacent areas and the Master Urban Park Plan. This also includes outfalls and other special drainage features.

Parks must be included in the planning and development of BIAs, MDP reports, and SMDP reports as early as possible in the design process. It is the responsibility of the owner or developer undertaking the work (or their designated consultant) to work jointly with Parks and Water Resources towards an acceptable unified solution.

Water Resources will not issue approval for MDP and SMDP reports until Parks supports the recommendations in the BIA report(s). The BIA is to be done in collaboration with Parks and Water Resources to meet mutual objectives.

2.4.2.2 Calgary Wetland Conservation Plan

It has been estimated that close to 90% of the pre-settlement wetlands in Calgary have been lost.[6] Wetlands play an important role by improving water quality and quantity, reducing flooding and soil erosion, providing bio-diversity, moderating climate conditions, contributing to an aesthetic urban design, and providing educational and recreational opportunities. However, improper planning and development and poor stormwater management can have a detrimental effect on natural wetlands and their sustainability.

In 2004, Council approved the *Calgary Wetland Conservation Plan* to set priorities, explore alternatives for wetland conservation, and guide future urban development. Wetlands may be protected as Environmental Reserves (ERs) through the *Municipal Government Act* or through provincial legislation such as the *Water Act* and *Public Lands Act*.

Principles and goals of the *Calgary Wetland Conservation Plan* include:

- Conservation and sustainability.
- "No Net Loss" through a mitigation policy.
- Regional planning.
- Management of wetland habitats.
- Wetland monitoring and Research & Development programs.
- Public education.

6. Source: The City of Calgary. *Calgary Wetland Conservation Plan,* 2004 (page 6).

As part of the implementation plan, Parks (in collaboration with Ducks Unlimited) identified approximately 8000 wetlands using the Stewart and Kantrud (1971) Wetland Classification Methodology. As well, Environmental Significance Assessments are being conducted to help identify priority wetlands. Any impacts or mitigation strategies affecting natural wetlands must be reviewed and approved by Parks.

All wetland impacts in the City of Calgary are also subject to the policies of the Calgary Wetland Conservation plan. Stewart and Kantrud Class 3 or higher wetlands are considered to be Environmental Reserve pursuant to the *Municipal Government Act*, and as such shall be protected from disturbance or loss. Where Calgary Parks has determined that a wetland loss cannot be reasonably be avoided or minimized wetland compensation will be required. Compensation for loss will require an approval from the City of Calgary and a parallel approval under the *Water Act*. Contact Calgary Parks for more information on wetland compensation and Parks' process.

Note: In cases of disturbance to wetlands, the City of Calgary requires compensation for Stewart and Kantrud Class 3 or higher wetlands, whereas Alberta Environment also requires compensation for Class 1 and 2 wetlands!

2.4.2.3 Principles for Stormwater Wetlands Management

Parks and Water Resources/Water Services developed *Principles for Stormwater Wetlands Management in the City of Calgary* in July 2009. The document defines natural and stormwater (engineered or constructed) wetlands and provides a tool to assist in the planning, design, and management of stormwater wetlands. The intent is provide balance between Parks' objective of designing stormwater wetlands as sustainable ecological systems with amenity values and Water Resources/Water Services' objective of using stormwater wetlands for stormwater management.

The four main objectives of the document are to:

i) Provide a tool to guide the planning, design, and management of stormwater wetlands as well as the approval processes for The City, developer, and other stakeholders.
ii) Supplement gaps in current planning, design, and management information for stormwater wetlands, with special focus on engineered natural stormwater wetlands and balancing ecological, amenity, and treatment requirements.
iii) Provide procedures that summarize management (operation and maintenance) roles and responsibilities of Parks and Water Resources/Water Services for stormwater wetlands.
iv) Ensure significant issues for stormwater wetlands are addressed based on a review of available information and field studies.

Until such time as a detailed design manual specific to stormwater wetlands is developed, it is recommended that the *Principles for Stormwater Wetlands*

Management in the City of Calgary be used in conjunction with this manual and any other existing City of Calgary documents.

2.4.3 Bow River Basin Council

The Bow River Basin Council (BRBC) is a multi-stakeholder non-profit organization dedicated to conducting activities for the improvement and protection of the waters of the Bow River Basin (Alberta) watershed. In Calgary, the Bow River Basin encompasses the Bow River, the Elbow River, Nose Creek, West Nose Creek, Fish Creek, and Pine Creek. The BRBC recognizes the Bow River Basin as a fragile and unique resource that should be conserved and protected by balancing multiple uses and ensuring that the needs of all stakeholders are met. Refer to the BRBC's *website* for more information.

The objectives of the BRBC are achieved by:

- Sharing perspectives and exchanging information.
- Prioritizing water use management issues that may affect the quality or quantity of groundwater or surface water, riparian zones or aquatic ecosystems.
- Participating in water use management and planning activities.
- Developing water use management procedures and performance measures.
- Encouraging the implementation of cooperative water use management strategies.
- Participating in activities that promote increased awareness of water use management activities.

The BRBC is typically interested in river basin planning issues. Although the BRBC is a non-regulatory group, it is important to involve them in River Basin studies, and where required, in Watershed studies. One of the current goals of BRBC is to determine and help set future in-stream water quality objectives. This has been done with the *Bow River Watershed Management Plan* for the Bow River and the *Elbow River Basin Management Plan* for the Elbow River (i.e., the Reach just upstream of the Glenmore Reservoir). In time, these in-stream objectives could form part of the provincial regulatory requirements for water quality.

2.4.4 Partnerships

Over the years, Water Resources has participated in various partnerships with a goal of helping to protect and enhance water quality and water quantity in our watersheds. Four of these key partnership are Calgary River Valleys (CRV), the Elbow River Watershed Partnership (ERWP), the Nose Creek Watershed Partnership (NCWP), and the Alberta Low Impact Development Partnership (ALIDP). These partnerships are not regulatory groups, but they all work collaboratively to help implement appropriate actions.

2.4.4.1 Calgary River Valleys (CRV)

Calgary River Valleys (CRV) is an independent, volunteer-driven organization established in 2010 to build on twenty years of work by the Calgary River Valleys Committee. Its mandate is to champion the protection, appreciation, and stewardship of Calgary's rivers, creeks, wetlands and watershed resources. CRV works with The City of Calgary, regional agencies, other levels of government, local communities and individuals to help preserve, enhance and promote Calgary's river system as an invaluable and irreplaceable public amenity.

CRV provides an established network of informed and engaged citizens and groups who share common concerns for the stewardship of Calgary's natural features, bringing together many diverse interests for discussion, education, and action. Its aim is to ensure that the cumulative effects of urban development and recreational activities are anticipated and planned so as to protect and preserve natural processes and habitats.

The partnership between The City and CRV serves several strategic purposes, including:

- To share knowledge and raise awareness about the values and importance of Calgary's river system.
- To collaborate in the development and implementation of policies that protect Calgary's water resources.
- To facilitate citizen engagement and present informed public perspectives to The City of Calgary Council and Administration.
- To facilitate projects that preserve, restore or enhance Calgary's watershed assets.

CRV's unique position as an independent, City-endorsed non-governmental organization (NGO) contributes to its effectiveness in consulting openly with the general public, industry and all levels of government.

Refer to the CRV *website* for more information.

2.4.4.2 Elbow River Watershed Partnership (ERWP)

The ERWP is a multi-stakeholder partnership involving government, private sector and public interest groups. ERWP's mission is to support and encourage all stakeholders in the Elbow River Watershed to protect and enhance water quality and water quantity. Their goals are achieved by:

- Encouraging individuals and communities to take responsibility to protect and enhance water quality and quantity in the Elbow River Watershed.
- Encouraging the use of new technologies for water conservation.
- Encouraging best water management and land use practices.
- Supporting cooperation, coordination, and knowledge-sharing among stakeholders.

• Minimizing the negative impacts of land uses on water quality and quantity.
• Increasing awareness and understanding of the watershed.

Refer to the ERWP *website* for more information.

2.4.4.3 Nose Creek Watershed Partnership (NCWP)

The NCWP was formed in 1998. The goal of the partnership is to protect riparian areas and to help return water quality in the Nose Creek watershed to its natural levels. The Partnership consists of the municipal districts of Rocky View, The City of Calgary, the City of Airdrie, the Town of Crossfield, and the Calgary Airport Authority, with technical assistance provided by Alberta Environment, the Bow River Basin Council, Ducks Unlimited, Trout Unlimited Canada, Alberta Transportation and Infrastructure, Fisheries and Oceans Canada, and other organizations. The NCWP has been commissioning various studies to gain greater understanding of the watershed. This includes water quality monitoring, groundwater investigations, instream flow needs investigations, and riparian health assessments. The NCWP has been instrumental in the development of the *Nose Creek Watershed Water Management Plan*. All partners involved in the NCWP are determined to work together to achieve the objectives set in the Watershed Management Plan.

Refer to the NCWP *website* for more information.

2.4.4.4 Alberta Low Impact Development Partnership (ALIDP)

The ALIDP was created in the fall of 2004 in response to the need to protect and maintain the integrity of the natural environment while promoting the growth, prosperity and quality of life in Alberta's communities. The ALIDP is a not-for-profit society, funded by memberships, and has a diverse base including municipal and provincial government, watershed stewardship groups, universities, corporations, and individuals with an interest in promoting LID practices.

The ALIDP focuses on education and outreach to enable government and stakeholders to develop and implement LID initiatives. This is accomplished by conferences, workshops, seminars and field trips; in addition, its website provides resources and a forum for members to exchange thoughts and ideas and get pertinent questions answered by the larger LID community. As a knowledge and research network, the Partnership encourages resource sharing and research collaboration, including demonstration projects. This ensures individual stakeholders can achieve maximum benefits from LID tools suitable for Alberta conditions. Over the last few years, the Partnership has collaborated with the City of Calgary Water Resources in organizing its annual week of erosion and sediment, stormwater, and LID courses for staff and industry.

Refer to the ALIDP *website* for more information.

2.4.5 Municipal Bylaws

There are several municipal bylaws that regulate and affect how storm drainage is addressed during and after construction. Good design and construction practices help ensure the bylaws are being met. Each bylaw addresses drainage from different perspectives; for more information contact Water Resources or visit the *Bylaws* page on the City of Calgary's website.

2.4.5.1 Drainage Bylaw 37M2005

The *Drainage Bylaw* regulates storm drainage and infrastructure between private and public (municipal) lands. Under the bylaw, a permit (typically a Drainage or Dewatering Permit) is required before allowing any discharge of impounded water from a parcel of land to be directed into The City's storm drainage system. This excludes normal operation of the drainage system, but it does include situations where a pond (including those on private land) must be drained for maintenance and repair purposes, and where excavations are required during construction activities.

The bylaw may also require an owner or occupant to treat, impound, or retain storm drainage on their property, and to ensure that treatment devices (such as oil/grit separators) are maintained and kept in good working condition. The main intent of the bylaw is to ensure that the Storm Drainage System, human health and/or safety, property, and/or the environment are not negatively impacted from storm drainage.

2.4.5.2 Community Standards Bylaw 5M2004

The *Community Standards Bylaw* regulates neighbour-to-neighbour issues and nuisances that can impact livability. Under the "Nuisances Escaping Property" section, drainage or water from a private property cannot be discharged onto a neighbouring property. This typically includes directing rainwater from downspouts and eaves troughs, hoses, or other means. In the "Excavations and Ponding Water" section, no excavations, drains, ditches, or other depressions are permitted to be a danger to public safety.

2.4.5.3 Lot Grading Bylaw 32M2004

The *Lot Grading Bylaw* ensures that properties are graded properly at the completion of the construction process and that they are in compliance with the approved grades. This is to ensure that storm drainage is being controlled as intended and not causing drainage or flooding problems. A "Lot Grading Permit" is required for duplex, semi-detached or single-detached dwellings, multi-family housing developments, and buildings on commercial or industrial sites prior to the beginning of construction on the parcel. Afterwards, an "As Constructed Grade Certificate" is required to be submitted within 12 months of the issuance of the Permission to Occupy. Fines may be issued for failure to obtain a Lot Grading Permit or to file an As Built Grade Certificate. The process is regulated through Water Resources, Development Approvals.

2.4.5.4 Utility Site Servicing Bylaw 33M2005

The *Utility Site Servicing Bylaw* sets out the terms and conditions under which utility service and inspection will be provided. A utility service includes the connection to the municipal owned stormwater collection system.

2.4.5.5 Streets Bylaw 20M88

The *Streets Bylaw* regulates the control, use, and management of public highways, roads, streets, lanes, alleys, etc., including the air space above and below the ground. It is an offence to place, direct, or dispose of a material on a portion of the street without a permit. As well, no person shall store, place, or dispose of any material in such a way that it may enter onto a street by any means, including natural forces. The intent is to ensure that storm drainage running off private property does not carry any material onto a street where it can make its way into the storm drainage system, and ultimately into our receiving streams. These materials can block our infrastructure, cause flooding, and negatively impact the water quality in our rivers and streams.

2.4.5.6 Sewer Service Bylaw 24M96

The *Sewer Service Bylaw* regulates the disposal of wastewater; the bylaw is currently under review for updating. Storm Drainage is not permitted to be directed or connected to the wastewater collection system. This typically includes weeping tile drains or foundation drainage.

CHAPTER 3: STORMWATER DESIGN

3.1 Drainage Systems

3.1.1 Goals and Objectives

Urban development alters the hydrology of the landscape and typically affects water quality negatively. With development, land uses change, and the amount of stormwater runoff generally increases while quality generally decreases, depending on the presence of Best Management Practices (BMPs). There are a number of ways to manage stormwater from a site. This includes conveyance, storage, treatment, re-use, infiltration, and evaporation. The overall goal of stormwater management is to improve water quality and minimize the risk of water quantity problems through the implementation of stormwater controls and practices. This closely relates to Utilities and Environmental Protection's mission to "*work with the community and Corporation to conserve, protect and enhance air, land and water for present and future generations.*" [7]

Good planning and design is critical to successful stormwater management. To help achieve these stormwater management goals, all new development and re-developed areas in Calgary must be designed using the Dual Drainage Concept (minor/major system) to achieve specific service level objectives. Best Management Practices (BMPs), which include Source Control Practices (SCPs), must be used for enhancement of water quality and potential volume control. Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** and The City of Calgary's *Stormwater Source Control Practices Handbook* (available from Water Resources upon request) for more information.

3.1.2 Minor System

Traditional stormwater drainage systems have typically consisted of an underground network of pipes and associated structures. This system was designed to transport flows for relatively minor, or low intensity, rainstorms as a matter of convenience. The minor system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events.

The minor stormwater drainage system consists of the underground pipe network and its associated structures. These components facilitate the transport of stormwater flows from minor rainstorms. Components of the minor system typically include:

- Gutters and roof leaders.
- Weeping tile drains.
- Lot drainage.

7. Source: The City of Calgary. *2009-2011 UEP Business Plan - Mission Statement* (page A1).

- Catchbasins (CBs), inlets, and leads.
- Underground pipe system.
- Manholes (MHs) and junctions.
- Source Control Infrastructure (such as bioswales).
- Outfalls.
- Receiving waters.

Some components, such as gutters, roof leaders, and bioswales may be classified under both minor and major system components, since they are considered in the design of both systems.

3.1.2.1 General Requirements

i) The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary sewer system. Combined systems are not permitted.

ii) In general, the public storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the obvert of the pipe. Sewer pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface to avoid compromising CB interception.** Also, proper aeration and venting must be considered as per ***5.5.2 Design***.

iii) On private sites, surcharge (due to back-up from the flow control from the private site to the public system) is acceptable. However, the designer must ensure that the maximum 1:100 year water level is at least 0.30 m below slab elevations if directly connected (i.e., without pumping) to the storm sewer system. This will also ensure that low-lying areas such as parkades are not negatively impacted by the backwater conditions.

iv) The minor system is to be designed according to the level of service stipulated in ***3.1.2.2 Level of Service***.

v) Where possible, the minor system is to be designed using the Unit Area Release Rate Method or the Modified Unit Area Release Rate Method. Refer to ***3.1.2.3 Unit Area Release Rate Method*** and ***3.1.2.4 Modified Unit Area Release Rate Method***. Re-developed and retrofit areas should be designed using the Modified Unit Area Release Rate Method. Contact Water Resources for more information.

3.1.2.2 Level of Service

A basic level of service is provided by the minor system. In Calgary, this has typically been sized for the 1:5 year storm event since 1952. Prior to 1952, the level of service was based on a 1:2 year storm event. In Calgary, sizing of the storm trunks was previously done using the **Rational Method** design. Unfortunately, when the drainage area exceeds 30 ha, there is a marked inequity in trunk capacity (expressed as capacity per hectare drained) in the downstream direction.

To avoid these inequities, the City of Calgary has adopted the **Unit Area Release Rate Method**. This method uniformly distributes the storm trunk capacity based on a 1:5 year storm event, on a per hectare basis, for the area tributary to the storm trunk.

For all new areas, the minor system must be designed using the Unit Area Release Rate Method. In general, and in the absence of SCPs that significantly reduce runoff volumes, the recommended minimum unit area release rate is 70 L/s/ha. In steeper terrain, where on-street storage is minimal, and in the absence of a nearby storm pond, the design rate may need to be higher.

3.1.2.3 Unit Area Release Rate Method

For all new areas, the minor system must be designed using the Unit Area Release Rate Method. The recommended minimum unit area release rate required is 70 L/s/ha.

The Unit Area Release Rate Method formula is expressed as:

Equation 3-1: Unit Area Release Rate Method:

$$Q = UARR \times A$$

where:
Q = peak runoff rate (L/s)
UARR = unit area release rate (L/s/ha)
A = area of the drainage basin (ha)

Recommended unit area release rates are as follows:

i) **70 L/s/ha** - The recommended minimum unit area release rate is 70 L/s/ha. This rate is to be used in relatively flat areas where ample trap low storage can be provided.

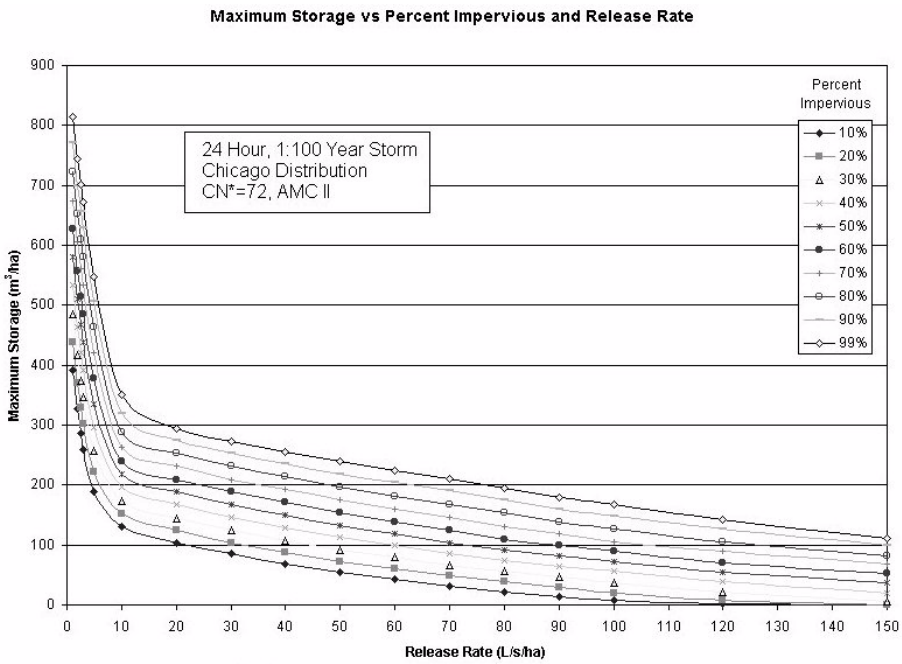
ii) **80-90 L/s/ha** - Higher release rates should be used in areas of moderate slopes where trap low storage is limited.

iii) **100-120 L/s/ha** - High release rates should be used in steep areas where trap low storage is greatly limited or for areas with high densities and/or imperviousness.

iv) Unit area release rates smaller than 70 L/s/ha will be considered on a site-specific basis only; approval from Water Resources is required. In no circumstances will a rate lower than **45 L/s/ha** be permitted. The consultant must be able to demonstrate that sufficient trap low storage is available. In general, this release rate will only be considered in the following situations:
   - In flat areas.
   - For areas adjacent to stormwater ponds where flows in excess of the storm sewer system capacity can be readily conveyed to the pond as overland flow.
   - For areas that utilize SCPs that significantly reduce the amount of runoff volume.

v) All unit area release rates should be established at the time of the Master Drainage Plan (MDP) report, where possible, to allow sizing of the storm sewer trunk, but no later than the Staged Master Drainage Plan (SMDP) report. ***Figure 3-1*** and ***Figure 4-3*** provide a preliminary planning tool for selection of unit area release rates for an area. However, these figures are a planning tool only and do not replace detailed modelling to determine the most appropriate release rates.

Figure 3-1: Unit Area Release Rate vs. On-Site Storage



In case of provision of SCPs, the reduced UARR is equal to:

Equation 3-2: Reduced Unit Area Release Rate Method

$$\textbf{70 L/s/ha (UARR conventional)} \times \frac{\textbf{Runoff Volume}_{\textbf{(LID 1:5 year condition)}}}{\textbf{Runoff Volume}_{\textbf{(Conventional 1:5 year condition)}}}$$

If a UARR of 45 L/s/ha is used, this means the runoff volume must be demonstrated to have been reduced by 35%. The runoff volume corresponding to the conventional system is based on the premise that the directly connected imperviousness equals the total imperviousness.

3.1.2.4 Modified Unit Area Release Rate Method

Until such time as all drainage catchments are designed using the Unit Area Release Rate Method, a modified method may have to be used for design of the minor system. While the modified method is preferred, use of the Rational Method is allowed when the remaining drainage area in a catchment is less than 30 ha, where there are no stormwater ponds, and where the storm trunk was originally designed using the Rational Method. The modified method should be used for re-development and retrofit areas.

The modified method involves distributing the remaining spare storm trunk design capacity at a designated tie-in location uniformly among the remaining drainage area. The designated or critical location is that point in the storm sewer system where the remaining available capacity is smallest, expressed on a unit area basis. This will result in a modified unit area release rate that will be used to size the lateral storm sewer.

The Modified Unit Area Release Rate method formula is expressed as:

Equation 3-3: Modified Unit Area Release Rate Method

$$Q = MUARR \times A$$

where:
- Q = peak runoff rate (L/s)
- MUARR = modified unit area release rate (L/s/ha)
- A = area of the drainage basin (ha)

3.1.2.5 Rational Method

The Rational Method was originally used for the design of storm sewer systems in Calgary. It was replaced by the Unit Area Release Rate Method in the 1990s, except for **remaining catchment areas** that were originally designed using the Rational Method method, provided the remaining area is greater than, or equal to, 30 ha. Areas larger than 30 ha should be designed using the Unit Area Release Rate Method or the Modified Unit Area Release Rate Method. The use of the Rational Method should be limited where possible, even for areas smaller than 30 ha.

The Rational Method is a runoff estimation method based on an empirical formula relating the peak flow rate to the drainage area, the rainfall intensity, and a runoff coefficient. The method has been widely used due to its simplicity, but there are limitations. As a result, The City of Calgary is moving away from this method.

The rational formula is expressed as:

Equation 3-4: Rational Formula

$$Q = 2.78\,CiA$$

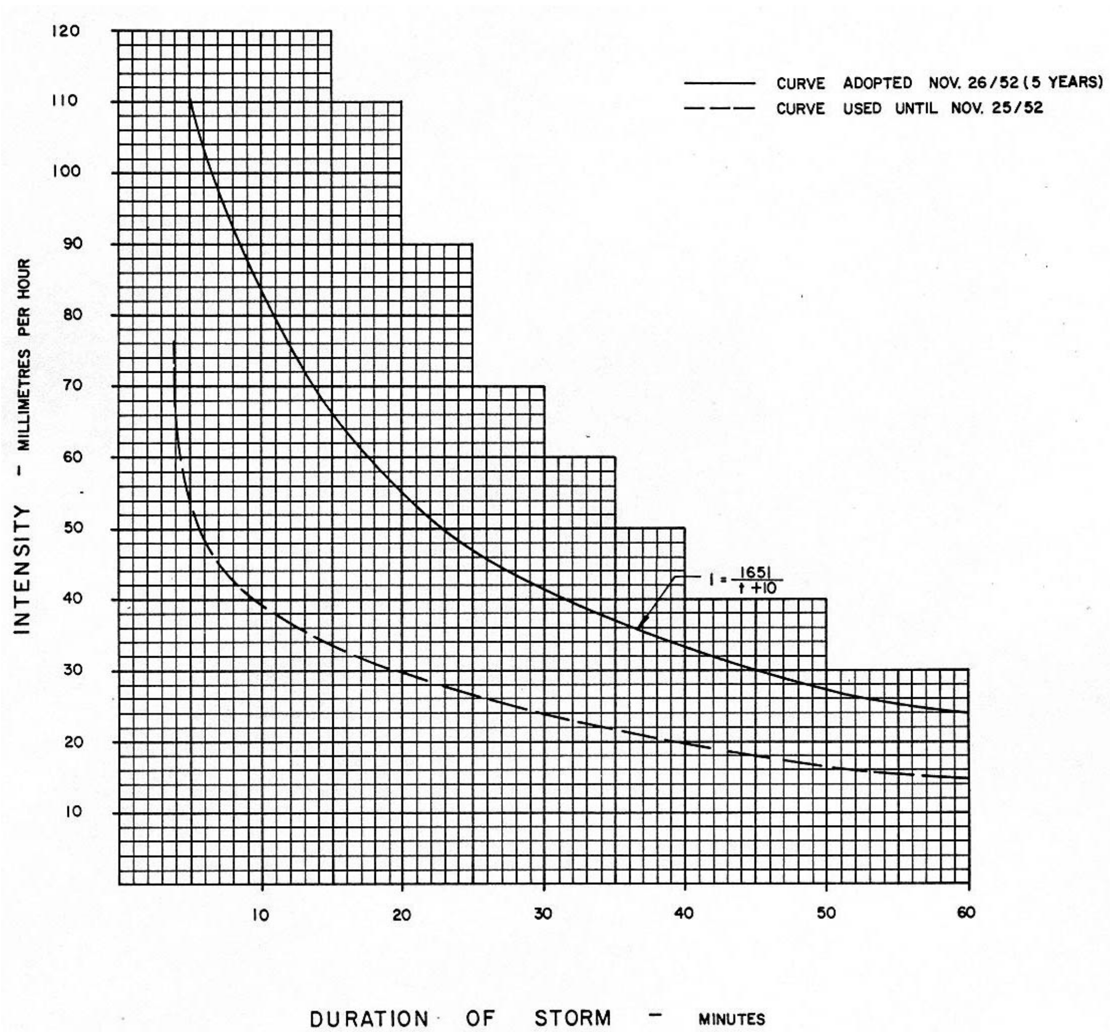
where:
- Q = peak runoff rate (L/s)
- 2.78 = constant
- C = runoff coefficient
- i = intensity of the rainfall (mm/hr) for a storm duration equal to t_c
- A = area of the drainage basin (ha)
- t_c = Time of Concentration for the basin (min) = Inlet Time + Flow Time
  Note: Inlet Time $\geq$ 10 minutes.

The intensity (i) is obtained from an Intensity-Duration-Frequency (IDF) curve derived from rainfall records for Calgary. The 1:5 year intensity curve (refer to ***Figure 3-2***) is derived using the following formula:

Equation 3-5: 1:5 Year Design Intensity

$$i = 1651/(t_c + 10) \text{ (mm/hr)}$$

Figure 3-2: Storm Sewer Design Curve for Rational Method



Refer to ***3.2.5.1 Runoff Coefficient (C)*** for more information regarding runoff coefficients.

3.1.2.6 Storm Sewer Design Table

A sewer design table or calculation sheet like ***Table 3-1*** or ***Table 3-2*** can be used to size the sewer pipe.

Table 3-1: Storm Sewer Design Table

Storm Sewer Design Table - Unit Area Release Rate Approach

Subdivision Name
Phase
Designed by
Date

Manhole Number		Area Number	Incremental Area	Cumulative Area	Unit Area Release Rate	Incremental Flow	Cumulative Flow	Invert Elevation - Upstream	Invert Elevation - Downstream	Pipe Length	Pipe Slope	Pipe Diameter	Pipe Roughness (Manning's n)	Pipe Capacity	Spare Capacity
From	To		(ha)	(ha)	(L/s/ha)	(L/s)	(L/s)	(m)	(m)	(m)	(%)	(m)	(-)	(L/s)	(L/s)

Table 3-2:Storm Sewer Design Table

Storm Sewer Design Table - Rational Method Approach

Subdivision Name
Phase
Designed by
Date

Manhole Number		Area Number	Incremental Area	Cumulative Area	Runoff Factor	Equivalent Area	Travel Time	Time of Concentration	1:5 Year Intensity	Incremental Flow	Cumulative Flow	Invert Elevation - Upstream	Invert Elevation - Downstream	Pipe Length	Pipe Slope	Pipe Diameter	Pipe Roughness (Manning's n)	Pipe Velocity	Pipe Capacity	Spare Capacity
From	To		(ha)	(ha)	(-)	(ha)	(min)	(min)	(mm/hr)	(L/s)	(L/s)	(m)	(m)	(m)	(%)	(m)	(-)	(m/s)	(L/s)	(L/s)

3.1.3 Major System

The major stormwater drainage system conveys runoff from extreme rainfall events that exceed the capacity of the minor underground system. Components of the major system typically include:

• Gutters and roof leaders.

• Lot drainage.

• Roads.

• Swales.

• Trap lows.

• Escape routes.

• Storage facilities (i.e., stormwater ponds).

• Culverts.

• Outfalls.

• Receiving waters.

Note: Some components, such as gutters, roof leaders, and bioswales, are classified as both minor and major system components, since they are considered in the design of each type of system.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage. Therefore, it is important to examine grading plans to ensure there is an overland route with adequate capacity as per the level of service described in ***3.1.3.2 Level of Service***.

3.1.3.1 General Requirements

i) The major system must be designed as an overland system.

ii) A continuous escape route must be provided for the overland flows. Adjacent properties must be protected from flooding by these flows.

iii) The major system is to be sized according to the level of service stipulated in ***3.1.3.2 Level of Service***.

3.1.3.2 Level of Service

In Calgary, the major system must be designed for the 1:100 year storm event to provide a reasonable level of flood protection. This includes all stormwater and evaporation ponds. Refer to ***3.2.4 Design Storm*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for more information. Stormwater pond volumes must be calculated using the approved Unit Area Release Rate(s) as identified in the relevant MDP(s).

3.1.4 Runoff Volume

With the increasing awareness that increased stormwater runoff can cause erosion, increase pollutant loadings, degrade receiving water body quality, and adversely impact aquatic habitat, **the need to control both runoff rate and volume** has been identified. Overall targets have been set for the Nose Creek, West Nose Creek, and Pine Creek watersheds.

While the Water Management Plans (WMPs) for these watersheds[8] provide the overall weighted targets for a large area, the designer must use the actual site-specific targets for the proposed land uses, subdivisions, and/or private sites from preceding MDPs, SMDPs, and/or Stormwater Management Reports (SWMRs). Contact Water Resources to verify that the runoff volume targets are applicable.

8. In case of the Pine Creek watershed, see also Dillon Consulting, 2009.

3.2 Runoff Analysis

3.2.1 General

The stormwater runoff process involves the interaction of a number of phenomena. This includes assessment of the precipitation event, interception and depression storage, evaporation, and infiltration. Although there are different methods to estimate runoff flows and volumes, care should be taken with the application of the analysis, considering the complexity of the runoff process. The analysis requires a thorough understanding of the runoff process and the methodology used to model that process.

Several estimation methods are available to determine runoff. They include:

- Rational Method (refer to ***3.1.2.5 Rational Method***.)
- SCS Method (refer to ***3.2.5.3.2 Soil Conservation Service (SCS) Method***).
- Horton Method (refer to ***3.2.5.3.1 Horton Method***).
- Deterministic Methods.

These methods are described further in *Stormwater Management Guidelines for the Province of Alberta (1999)*.

3.2.2 Computer Models

Numerous computer models have been developed that can perform both hydrological and/or hydraulic analyses. Models that can be applied to a wide variety of design situations tend to require extensive input data and a considerable level of expertise to ensure proper program usage. It is important to recognize that computer models are design tools, and should not be solely relied upon for their analytical results. As computer models evolve, some of the older models such as OTTHYMO/INTERHYMO, OTTSWMM, and QUALHYMO may no longer be supported or accepted.

3.2.2.1 General

Computer modelling is required for derivation of the 1:100 year flow rates and volumes, unless specified otherwise. When choosing a computer model, it is important to consider the data and model limitations. The selection and proper application of a computer model is primarily the responsibility of the developers and their consultants. The models must be approved by Water Resources.

In general, DDSWMM, SWMHYMO, EPA SWMM, and XP-SWMM are recommended for use in the design of dual (minor and major) drainage systems. The hydraulics mode of the SWMM models is recommended for surcharge analysis and special hydraulic situations.

QUALHYMO, QHM, EPA SWMM, and XP-SWMM are the models recommended for use in stormwater pond design for water quality and storage volume. Storage volumes also require the use of SWMHYMO, or associated model derivatives for comparison purposes. Refer to ***3.2.3 Single Event Modelling vs. Continuous Modelling*****,** ***7.5 Water Quality Modelling***, and ***7.6 Pond and BMP Sizing (Water Quality Perspective Only)*** for more information.

3.2.2.2 SWMHYMO

SWMHYMO is an evolution of the older OTTHYMO model. SWMHYMO is a complex hydrologic model that is used for the simulation and management of stormwater runoff in large and small urban and rural areas. In 1994, SWMHYMO was created by Mr. J.F. Sabourin to respond to increasing stormwater management needs and improved computer systems.

One of the main improvements of the program is the ability to multi-task through the Windows environment. Online help is available along with pull-down menus for creating data input files, default value files, output files, and storm and hydrograph files. Also included is an integrated printing utility for printing enhancements.

Unlike OTTHYMO, SWMHYMO is able to undertake limited continuous rainfall simulations, as well as single rainfall event simulations, through the incorporation of new commands. Improvements were also made to the ROUTE RESERVOIR command to allow overflow diversions. The new COMPUTE DUALHYD command allows flow to be split into major and minor systems, and the effects of surface storage at street trap lows to be determined.

As SWMHYMO has limited flow routing capabilities (i.e., pipes, swales, ditches, and streams), a more sophisticated pipe routing model is needed to evaluate complex storm sewer systems. One such tool is the Hydraulics Layer of SWMM (formerly known as EXTRAN). It allows for the simulation of backwater conditions, looped pipe systems, flow reversals, and surcharged flow conditions using the complete St. Venant (dynamic flow) equations.

3.2.2.3 EPA SWMM

The Stormwater Management Model (SWMM), was first developed by United States Environmental Protection Agency (USEPA) in 1971. Since its first version, the model has been continually maintained and updated.

SWMM is widely used for single event or long-term (continuous) simulation of runoff quantity and quality from urban areas. The hydrologic processes of SWMM operate on a collection of subcatchment areas containing both pervious and impervious sub-areas. The routing or hydraulic portion can transport runoff or overland flow through sub areas, subcatchments, drainage conveyance systems (pipes or channels), storage/treatment units, and diversion structures. Flow rate, flow depth, and water quality can be tracked during a simulation period consisting of multiple fixed or variable time steps.

Water quality constituents can be simulated at selected storage nodes from subcatchments through a hydraulic network with optional first order decay and linked pollutant removal through use of BMPs and Low Impact Development (LID). Furthermore, the model provides a user friendly graphical environment for editing watershed input data, running hydrologic, hydraulic, real time control and water quality simulations, and viewing the results in a variety of graphical formats.

3.2.2.4 DDSWMM

There are a number of models that are modified versions of EPA SWMM. The Dual Drainage Storm Water Management Model (DDSWMM), first released in 1996, is one such model. It is a new and improved release of the 1985 University of Ottawa Storm Water Management Model (OTTSWMM), a discrete model that was developed for the analysis of dual drainage systems. As with OTTSWMM, DDSWMM runoff is computed and routed through both the minor system and major system.

An important feature of the DDSWMM model is its ability to model the hydraulic capacity of storm inlets. It is capable of analyzing dual drainage systems by utilizing four sub-models (surface runoff, inlet, minor system, and major system) and the storage sub-models. DDSWMM was designed to interface with EPA SWMM and XP-SWMM.

The flow routing methodology in DDSWMM has also been improved. Although the basic routing algorithm is the same as OTTSWMM, a more elaborate procedure is used in analyzing the network. A kinematic wave model is used in the routing procedure; as such, more sophisticated routing models than DDSWMM are needed for the analysis of drainage systems subject to backwater conditions.

3.2.2.5 PCSWMM

PC SWMM is a spatial decision support system for EPA SWMM's stormwater management, wastewater, and watershed modelling system. It incorporates a modern, powerful GIS engine that works seamlessly with the latest GIS data formats, and provides intelligent tools for streamlining model development, optimization, and analysis in a comprehensive range of applications.

Integrating the full EPA SWMM engine, PC SWMM accounts for various hydrologic processes including:

- Precipitation.
- Evaporation
- Snow accumulation and melting.
- Infiltration into unsaturated soil layers and percolation of this infiltrated water into groundwater layers.
- Interflow.
- Non-linear reservoir routing of overland flow.

Handling networks of unlimited size, it contains a flexible set of hydraulic modelling capabilities, including:

- A wide variety of standard closed and open conduit shapes.
- Natural channels.

- Special elements such as culverts, storage/treatment units, flow dividers, pumps, weirs and orifices.
- Kinematic wave or full dynamic wave flow routing methods.
- Various flow regimes, including backwater and surcharge conditions, reverse flows, and surface ponding.

With respect to water quality, it represents pollutant build-up and wash-off, as well as the reduction of contaminant loadings through treatment in BMPs.

3.2.2.6 XP-SWMM

XP-SWMM is a state-of-the-art hydrologic and hydraulic tool for modelling stormwater flows and pollutants. XP-SWMM also models flows and pollutant transport in natural systems including rivers, lakes, and floodplains with groundwater interaction. Floodplain flow can be modelled in two dimensions or in an integrated 1D-2D linked configuration. The model is an enhanced version of EPA SWMM with a Graphical User Interface for data entry, runtime graphics, and results in graphical form, allowing CAD and GIS integration and animation of flows and water levels in the drainage system. The model has an optional Real Time Control module that allows for the control of gates, valves, flow regulators, moveable weirs, and telemetry-controlled pumps.

XP-SWMM's Hydraulics engine solves the complete St. Venant (dynamic flow) equations for gradually varied, one dimensional, unsteady flow throughout the drainage network. The calculation models backwater effects, flow reversal, surcharging, pressure flow, tidal outfalls, and interconnected ponds. The model allows for looped networks, allows for multiple outfalls, and accounts for storage in conduits. Flow can also be routed using EPA SWMM's hydraulic flow routing methods including the kinematic wave, diffusion wave, and fully dynamic wave methods.

XP-SWMM allows for the representation of dual drainage systems and has various options to represent the interception of flow by CBs, including reduced interception in case of extreme surcharge conditions in the storm sewer system.

XP-SWMM can simulate point and non-point pollution, including the build-up and wash-off of contaminants in catchments, transport through collection and conveyance systems, and treatment of stormwater by natural processes, BMPs, and LID.

3.2.2.7 QUALHYMO

QUALHYMO is a planning level model that simulates water quality and quantity. The model was developed in 1983 at the University of Ottawa with a grant funded by the Ontario Ministry of Environment. The model was originally designed to be a simple seasonal continuous water quality/quantity simulation model for lumped applications in urbanizing Ontario river basins. The intent was to supplement existing models with a flexible and economical model that had a reasonable scope of simulation. The model is capable of both continuous and single event simulations.

The basic structure of QUALHYMO is based on the HYMO and OTTHYMO models. A number of alternate commands were incorporated to expand the scope of the model, and to make QUALHYMO distinct in its ability to simulate the generation and routing of pollutants, snowmelt, and instream erosion potential. QUALHYMO is one of the simpler simulation models available.

A new version of QUALHYMO is under development. Contact Water Resources prior to using this new version, since both the operational commands and units of input parameters are understood to have changed.

3.2.2.8 QHM

QHM is a Windows-based watershed quantity and quality simulation model that is intended for watershed management and stormwater design. QHM was derived from the QUALHYMO model, and therefore has similar features to QUALHYMO. QHM is capable of simulating rainfall-runoff, soil, and groundwater effects on baseflow, evapo-transpiration, snowmelt and snow removal/disposal, soil erosion, and urban runoff quality (pollutants). Although QHM is primarily used for continuous simulation, single event simulation is also possible.

3.2.2.9 Runoff Volume Analysis Tools

With the acceptance of runoff volume control targets for the Nose Creek and Pine Creek watersheds, appropriate runoff volume analysis tools are needed. Single event models are not appropriate, since they cannot represent the full, long-term balance of soil moisture or runoff accumulated in cisterns, stormwater ponds, and wetlands. The need for runoff volume analyses puts an additional onus on the modeller to ensure that the modelling results are reasonable; most urban drainage was developed for extreme, single event analysis purposes, where the consequences of discrepancies in infiltration and/or evaporation data were limited. These components of the hydrologic cycle have gained more prominence as part of runoff volume analysis, because it is largely governed by the response of the drainage system to smaller storm events (with a rainfall depth of 5 to 15 mm per event).

Potential tools include QHM, EPA SWMM, XP-SWMM, and the new Water Balance Model *Powered by QUALHYMO*. Various spreadsheet approaches have been developed, as well. An interim spreadsheet tool that has a better representation of soil moisture conditions, allows for reduced infiltration during the winter months, and allows for seasonal re-use patterns (i.e., irrigation purposes) can be downloaded from the *Development Approvals Submissions* page on The City of Calgary's website. Where typical modelling tools such as QHM, EPA SWMM, and/or XP-SWMM are used for runoff volume computations, the modeller must explain in the relevant report how the following conditions have been met by the model:

- Provision of thicker topsoil layers in case of absorbent landscaping.
- Re-direction of flows from hard surfaces into permeable landscaping, absorbent landscaping or bioretention / bioswale media.

- Seasonal variation of water re-use from rainwater harvesting or stormwater re-use facilities.
- Replenishment of soil moisture due to irrigation.
- Reduced infiltration during the winter months.
- Reduced infiltration due to clogging over time.

Where relevant, the above conditions need to be met when carrying out runoff volume computations. Contact Water Resources for more information on appropriate tools for runoff volume analysis.

3.2.2.10 Other Models

Historically, the majority of the computer models used and accepted in Calgary have been based on the HYMO and SWMM families of models. However, computer modelling technology is evolving and new models have (and may continue to) become available.

Examples of other models include:

i) Water Balance Model *Powered by QUALHYMO* and spreadsheet-based water balance type analyses for runoff volume and evaporation pond analysis.

ii) SUSTAIN, WinSLAMM, MUSIC and RECARGA for the design and analysis of BMPs and LID.

iii) Watershed and receiving water quality models such as BASINS, HSPF, QUAL2K, and WASP.

iv) Hydrodynamic models such as EFDC, NCCHE and CFD (Computational Fluid Dynamics) to simulate flow and velocity patterns, sedimentation patterns and other water quality constituents in ponds and aquatic systems in multiple dimensions.

While Water Resources is open to considering modelling tools other than the accepted HYMO and SWMM models listed in the sections above, they must have clear benefits over the currently used tools and fit within Water Resources' long-term analysis objectives. Any tools to be considered must be commercially available and/or be made available to Water Resources at no cost for evaluation and future use. **Contact Water Resources for approval before using computer models other than the accepted HYMO and SWMM ones**. Typically, application would only be on a one-time trial basis and would not denote future acceptance. The proponent would have to work with Water Resources and allow for one or multiple workshops, at no cost to Water Resources, to evaluate the proposed model.

3.2.2.11 Calibration

Model calibration and verification is important to ensure the accuracy of model outputs. Unfortunately, when there is a lack of measured data, verification becomes more difficult. Water Resources is considering studies to obtain calibrated modelling parameters that would aid in the appropriate application of the models. In the interim, care should be taken in the selection of modelling parameter values. Some recommendations are made in the following sections.

3.2.3 Single Event Modelling vs. Continuous Modelling

Stormwater computer models can be used to model a drainage system for either single or continuous rainfall events. A single event model is defined as a simulation of a short duration storm event (i.e., hours to days) with subjective start-up conditions, while a continuous model is a simulation that models both dry and wet hydrology processes using a long-term continuous record of atmospheric data (i.e., months to years).

In single event modeling, a design single storm event (synthetic or historical), often with a 1 hour to 24 hour duration, is applied to determine the response of a drainage system. The storm event modelled usually has a 1:5 year or a 1:100 year return frequency. Single event models typically used include SWMHYMO, EPA-SWMM, DDSWMM, PCSWMM, and XP-SWMM.

For continuous modelling, runoff for a drainage area is modelled for a prescribed period of time, typically several years. A precipitation file, normally generated by Meteorological Service of Canada, is incorporated into the continuous model. The precipitation file typically includes hourly rainfall amounts that have been collected over the years. Temperature files can also be used to model snowmelt.

EPA-SWMM, PCSWMM, XP-SWMM, QUALHYMO and QHM are the most frequently used continuous models. With continuous models, water quality and quantity can both be modelled. Continuous models also have the advantage of being able to simulate and account for dry weather processes such as pollutant build-up and wash-off, evapo-transpiration, storage depletion, moisture conditions, and processes associated with the winter seasons.

The following considerations apply to the use of single event and continuous simulation models:

i) Single event simulation must be used to model the performance of dual drainage systems.

ii) Continuous simulation must be used to model water quality (sediment removal) and quantity for all stormwater ponds and to analyze annual runoff volumes. Refer to ***CHAPTER 7: WATER QUALITY*** for more information.

iii) Single event simulation must also be used to model water quantity for all stormwater ponds. A comparison must be made to the continuous simulation, and the most conservative volume must be used for water quantity control. Refer to ***6.1.2 Level of Service*** for more information.

iv) A combination of single-event and continuous simulation techniques can be used for the sizing of BMPs and LID provisions. Refer to ***3.2.4.5 Storm Duration and Time Interval*** for more information.

v) Water Resources intends to make climate data files available in the near future. Check the *Development Approvals Submissions* page on The City of Calgary's website or contact Water Resources for more information.

3.2.4 Design Storm

3.2.4.1 General

Single event computer modelling requires the input of a design storm, which is then used to generate runoff hydrographs to determine how a drainage area and system will respond and perform. In Calgary, the Intensity-Duration-Frequency (IDF) curve is derived from Meteorological Service of Canada (formerly known as Atmospheric Environment Services) rainfall data taken from the Calgary International Airport. A Chicago distribution is then often applied to formulate the synthetic design storm. The IDF curves and design storm are summarized below. A 1:100 year storm event is used in the design of the major system.

3.2.4.2 IDF Curve and Parameters

An IDF curve is a statistical description of the maximum potential rainfall intensity for a given duration and storm frequency. In Calgary, the IDF curve is derived from Meteorological Service of Canada (MSC) rainfall data taken from the International Airport. Rainfall, which has been collected from 1947 to 1998 (48 years), has been analyzed using Gumbel distribution.

3.2.4.2.1 MSC IDF Curve

Table 3-3: Design Storm Amount (mm)

Time		Return Frequency					
Minutes	Hours	2 yr	5 yr	10 yr	25yr	50 yr	100 yr
5	0.083	4.9	7.3	8.9	11.0	12.5	14.0
10	0.167	7.3	11.2	13.8	17.1	19.5	22.0
15	0.250	9.0	13.8	16.9	21.0	23.9	26.9
30	0.500	11.0	16.9	20.8	25.7	29.4	33.0
60	1	13.7	19.4	23.2	28.0	31.6	35.1
120	2	16.7	22.7	26.6	31.6	35.2	38.9
360	6	24.5	31.3	35.8	41.5	45.7	49.9
720	12	31.1	42.0	49.1	58.2	64.9	71.6
1440	24	37.2	51.2	60.4	72.1	80.8	89.4

Table 3-4: IDF Parameters - Calgary International Airport

Parameters	Return Frequency					
	2 yr	5 yr	10 yr	25yr	50 yr	100 yr
a	261.578	425.978	536.909	628.381	787.053	894.425
b	3.004	3.004	3.004	3.006	3.003	3.004
c	0.705	0.735	0.747	0.758	0.764	0.769

Parameters are derived for the formula:

Equation 3-6: Rainfall Intensity for IDF Curve

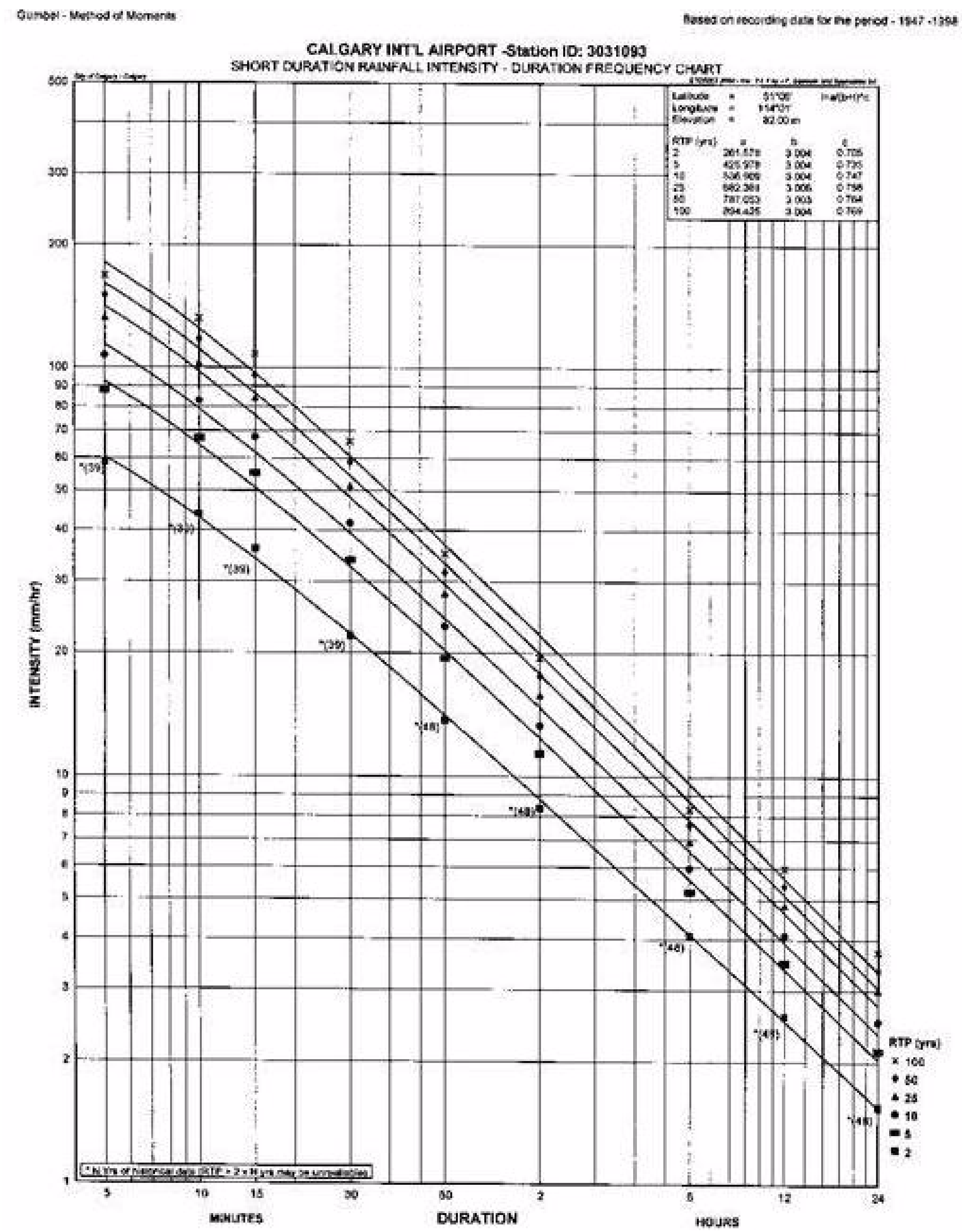
$$I = a/(b + t)^c$$

where: I = intensity (mm/hr)

t = time (minutes)

a,b,c = constants

Figure 3-3: MSC IDF Curve for Calgary



The curves in ***Figure 3-3*** were generated using the MSC hyetograph (***Table 3-3***) and the best fit IDF parameters (a, b, and c) derived from ***Table 3-4***.

3.2.4.2.2 Adjusted MSC IDF Curve and Parameters

Not all of the points fit the best-fit curves on ***Figure 3-3***. In terms of design, the following durations are important for stormwater design (trap lows and stormwater ponds) in Calgary: 5 minute, 1 hour, 12 hour, and 24 hour. Further analysis was undertaken to fine-tune the curves to these durations. **These adjusted values should be used for computer modelling purposes (refer to *Table 3-5* and *Table 3-6*)**.

Table 3-5: Adjusted IDF Curve-Intensity Summary (mm/hr)

Time		Return Frequency					
Minutes	Hours	2 yr	5 yr	10 yr	25yr	50 yr	100 yr
5	0.083	58.80	87.60	106.80	132	150	168
60	1	13.70	19.40	23.20	28	31.60	35.10
720	12	2.59	3.50	4.09	4.85	5.41	5.97
1440	24	1.55	2.13	2.52	3.00	3.37	3.73

Table 3-6: Adjusted IDF Parameters

Parameters	Return Frequency					
	2 yr	5 yr	10 yr	25yr	50 yr	100 yr
a	243	353.5	429.1	522.6	594.9	663.1
b	2.710	2.290	2.160	1.960	1.940	1.870
c	0.695	0.703	0.707	0.709	0.711	0.712

a, b, c = constants (refer to <Xrefs Table>Equation 3-6).

There are times (i.e., in the absence of emergency overland escape routes or as part of dam safety assessments) when there is a need to analyze the performance of a drainage systems for very severe weather conditions. ***Table 3-7*** and ***Table 3-8*** provide the precipitation depths and IDF parameters for the 1:200, 1:500 and 1:1000 year storm events.

Table 3-7: Rainfall Depths for Extreme Events

Time		Rainfall Depths (mm) for Extreme Events		
Minutes	Hours	200 yr	500 yr	1000 yr
5	0.083	15.7	17.8	19.4
30	0.500	37.1	42.3	46.1
1440	24	99.2	111.3	120.5

Table 3-8: IDF Parameters for Extreme Events

Parameters	Return Period		
	2 00 yr	500 yr	1000 yr
a	1220.4	1415.9	1564.6
b	5.90	6.06	6.16
c	0.782	0.786	0.789

a, b, c = constants (refer to <Xrefs Table>Equation 3-6).

3.2.4.3 Chicago Distribution

Generally, IDF curves cannot be used directly for complex hydrograph computations. However, the Chicago Hydrograph Method can be used to create a rainfall distribution curve (or design storm) from the **adjusted** MSC IDF curve. The resulting design storm can then be used for hydrograph routing computations.

Using ***Table 3-6*** and a time to peak (r) equal to 0.30, the Chicago distribution is used to generate the design storm for Calgary. The resulting hyetographs, with durations of 1 and 24 hours, are presented in tabular form in ***APPENDIX K: Calgary Design Storm Tables*** for the 1:2, 1:5, 1:10, 1:25, 1:50, 1:100, 1:200, 1:500, and 1:1000 year storm events. For other durations, select that portion of the 24 hour hyetograph that yields the highest rainfall depth for the duration of interest.

3.2.4.4 Water Quality Design Event

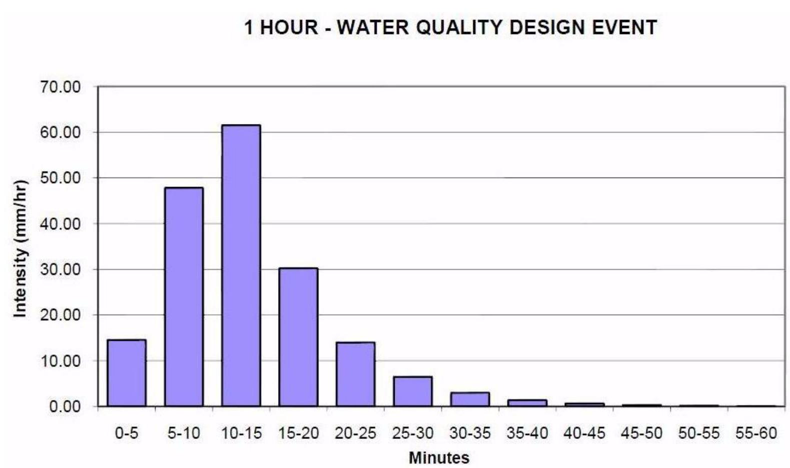
When designing treatment-type SCPs or BMPs (such as bioretention areas, bioswales, and permeable pavement), controlling and treating the runoff from extreme events (such as a 1:100 year event) is not necessarily needed to achieve the desired water quality enhancement of the runoff. Rather, by controlling and treating all runoff generated by the more frequent events, represented by the water quality design event, the desired objectives should be achievable.

Key considerations pertaining to the analysis and design of SCPs include the following:

i) For Calgary, the Water Quality Design Event has a rainfall depth of 15 mm.

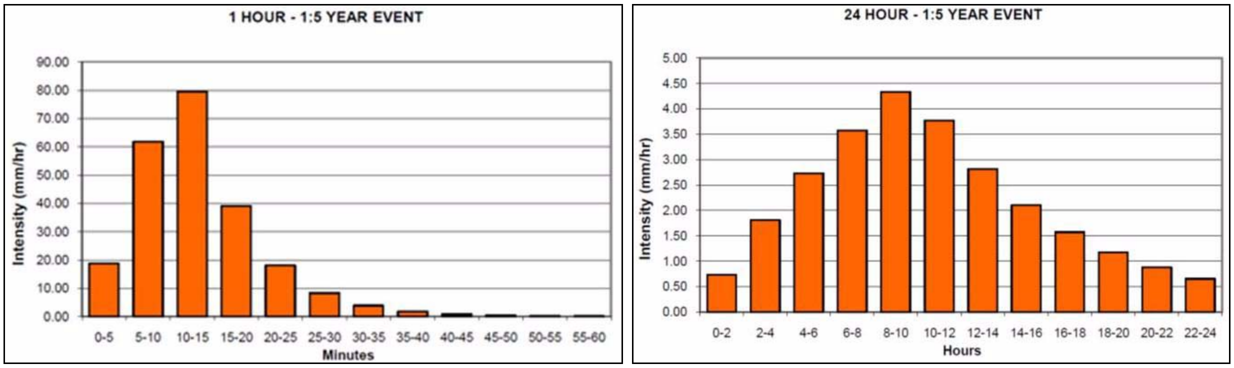
ii) Typically, a duration of 1 hour is used to examine the operation of SCPs, such as bioretention areas, bioswales, and permeable pavement. The hyetograph in ***Figure 3-4*** should be used for this analysis (this figure is displayed in tabular form in ***APPENDIX K: Calgary Design Storm Tables***).

Figure 3-4: Hyetograph for Water Quality Design Event



iii) A 1:5 year event must be used to quantify any benefits of these SCPs with respect to potential downsizing of downstream stormwater infrastructure. The hyetographs in ***Figure 3-5*** should be used for this analysis (this figure is displayed in tabular form in ***APPENDIX K: Calgary Design Storm Tables***). Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** for more information on the design of SCPs.

Figure 3-5: Hyetographs for 1:5 Year Event



iv) In the case of small sites (smaller than 2.0 ha), single event analysis is permitted for the sizing of single treatment-type BMPs and SCPs that have negligible long-term storage, such as bioretention, bioswales and permeable pavement. These BMPs and SCPs are assumed to have adequate removal of sediments provided that:

a) **All** runoff for the Water Quality Design Event is directed through the treatment unit, **without spillover.**

b) The emptying time is less than 6 hours.

c) The treatment unit has been designed according to ***CHAPTER 8: BEST MANAGEMENT PRACTICES***.

3.2.4.5 Storm Duration and Time Interval

It is important that the critical storm duration be identified properly:

i) The storm duration should be greater than twice the basin's time of concentration ($\geq 2t_c$). In general, a storm duration of 1 hour is suitable for most small urban areas. However, this should be confirmed at the time of modelling. Longer durations should be considered where there are backwater conditions from stormwater ponds.

ii) For the design of **trap low storage** in subdivisions or small areas, the following minima are recommended:

- A 1 hour duration for areas designed with a Unit Area Release Rate for the minor system greater than 45 L/s/ha, resulting in an emptying time of 30 minutes or less.
- A 4 hour duration for retro-fit areas, or as directed by Water Resources.
- A 24 hour duration if the minor system is subjected to backwater conditions from stormwater ponds.

iii) For the design of **storage volumes for stormwater ponds**, the following is recommended:

- 24 hour duration.
- A minimum of 7 days for (industrial) storm ponds if all runoff is to be collected, tested, and, if necessary, treated prior to release as per Alberta Environment stipulations. Refer to ***APPENDIX K: Calgary Design Storm Tables*** for the 1 day to 30 day precipitation depths for the Calgary International Airport. When using a SWMHYMO computation to compute storage requirements, the soil must be assumed to be fully saturated after the first day unless absorbent landscaping is provided.

Note: Continuous modelling must also be used to determine the most conservative of the volume established by means of single-event modelling versus the volume established by means of continuous simulation modelling.

iv) The hyetograph time interval must be 5 minutes for the single-event analysis of trap lows and peak flow rates. A longer duration interval may be considered for the single-event analysis of stormwater ponds. An hourly time interval is typically used for continuous simulation.

v) For the analysis of **runoff volumes for stormwater source controls practices and BMPs**, the following is recommended:

- A combination of single-event and continuous simulation techniques can be used for the sizing of BMPs and LID provisions.
- A single-event analysis for 1:5 and 1:100 year design events will be needed at all times to verify that the drainage system meets the performance criteria of ***3.3 Minor System Component Design*** and ***3.4 Major System Component Design***.
- Continuous simulation is required for:
  a) Runoff volume analysis purposes.
  b) BMPs and SCPs that utilize long-term storage, such as absorbent landscaping and rainwater harvesting, stormwater capture, and re-use systems, storm ponds, and wetlands.
  c) Water quality analysis purposes for sites where BMPs in series are implemented.

Water Resources intends to make various design graphs and tables available for the design of single BMPs and LID provisions within small sites (i.e. single bioretention area within a site smaller than 2 ha). Please contact Water Resources for more information.

3.2.5 Parameters

The amount and timing of runoff from a watershed is a function of several phenomena, which have varying degrees of importance. The runoff process includes the estimation of losses due to interception, infiltration, depression storage, abstraction, and evaporation. Some of these losses, and other modelling parameters, can have a significant impact on the amount of runoff if inappropriate values are used.

There are four popular methods used to determine runoff by taking into account hydrologic abstractions, soil types and antecedent moisture conditions. These include the Rational Method, the Soil Conservation Service (SCS) Method[9], the Horton Method, and the Green Ampt Method. The SCS Method combines initial abstraction and infiltration for losses, while the Horton and Green Ampt Methods combine depression storage with infiltration. The Rational Method assumes that all of the abstractions are represented by a single coefficient (C).

Water Resources has initiated a sensitivity analysis of some of the modelling parameters as part of a calibration study. In the interim, care should be taken when choosing modelling parameter values. Recommendations are made below:

3.2.5.1 Runoff Coefficient (C)

The runoff coefficient, C, is used in the Rational Method and is defined as the ratio of the average rate of rainfall on an area to the maximum rate of runoff. The runoff coefficient incorporates all of the hydrologic abstractions, soil types, and antecedent moisture conditions. It is important to note that the “appropriate” value of C depends on the magnitude of the storm; higher values may be required for extreme storm events.

Where runoff coefficients are required, The City of Calgary has generally used the following:

Table 3-9: The City of Calgary Runoff Coefficients

Description	Runoff Coefficient C
Residential	0.30
Industrial	0.40 to 0.75
Commercial, Downtown & Roadways	0.50 to 0.90

Note: An average weighted value of C should be used according to the size and type of area tributary to a given inlet.

For Development Site Servicing Plans (DSSPs), refer to ***4.2.2.3 Rational Method*** for required runoff coefficients.

With higher return period storms, the value of the runoff coefficient increases. ***Table 3-10*** illustrates the changes to C.

9. The Soil Conservation Service is now known as the Natural Resources Conservation Service (NRCS).

Table 3-10: Typical Urban Runoff Coefficients for 1:5 to 1:10 Year Storm Events

Description		Runoff Coefficient		
		Minimum	**Mean**	**Maximum**
Pavement (Asphalt or Concrete)		0.70	0.83	0.95
Roofs		0.70	0.83	0.95
Business	Downtown	0.70	0.83	0.95
	Neighbourhood	0.50	0.60	0.70
	Light	0.50	0.65	0.80
	Heavy	0.60	0.75	0.90
	Single family urban	0.30	0.40	0.50
	Multiple, detached	0.40	0.50	0.60
	Multiple, attached	0.60	0.68	0.75
	Suburban	0.25	0.33	0.40
Apartments		0.50	0.60	0.70
Parks, Cemeteries		0.10	0.18	0.25
Playgrounds		0.20	0.28	0.35
Railroad Yards		0.20	0.28	0.35
Unimproved		0.10	0.20	0.30

Notes: a) Values within the range given depend on the soil type if the watershed is significantly unpaved (sand is minimum, clay is maximum), slope, and on the nature of the development.

b) For storms having return periods of more than 10 years, increase the listed values as follows, up to a maximum coefficient of 0.95:

- 25 year - add 10 percent
- 50 year - add 20 percent
- 100 year - add 25 percent

c) The coefficients listed are for unfrozen ground. Taken from RTAC (1982).

3.2.5.2 Depression Storage

If the intensity of the rainfall reaching the ground exceeds the infiltration capacity of the ground, the excess will begin to fill the small depressions on the ground surface. For impervious surfaces, this will occur almost immediately. Once these tiny depressions have filled, overland flow will start and contribute to the runoff. ***Table 3-11*** lists suggested values for depression storage.

For Calgary, the following depression storage values are recommended:

- Pervious Areas: 3.2 mm.
- Impervious Areas: 1.6 mm.

Table 3-11: Suggested Depression Storage Losses[10]

Land Cover	Depression Storage (mm)	
	Range	Recommended
Impervious:		
Large paved areas	1.3 - 3.8	2.5
Roofs, flat	2.5 - 7.5	2.5
Roofs, sloped	1.2 - 2.5	1.2
Pervious:		
Lawn grass	2.0 - 12.5	7.5
Wooded areas	5.0 - 15.0	To be assessed.

3.2.5.3 Infiltration

Rainfall that reaches pervious ground surfaces will initially infiltrate into the upper layer of the soil. With periods of dry weather, the infiltration capacity of the soil can be quite large. However, this capacity will diminish gradually after the start of a rainstorm. The Horton Method, SCS Method, and Green-Ampt are three methods that are used to account for infiltration losses.

3.2.5.3.1 Horton Method

The Horton infiltration equation defines the infiltration capacity of the soil by using an initial infiltration rate that changes to a lower rate.

Equation 3-7: Horton Equation

$$f = f_c + (f_o - f_c)e^{-k(t)}$$

where: f = infiltration rate at time t (mm/hr)

f_c = final infiltration rate (mm/hr)

f_o = initial infiltration rate at the start of the storm (mm/hr)

k = decay rate (t^{-1})

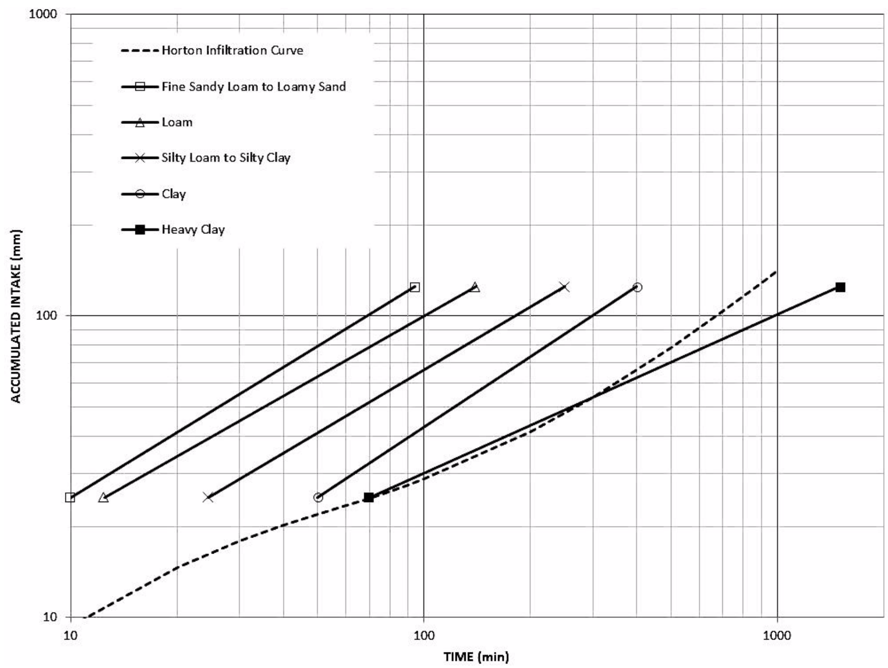
For Calgary, the following maximum Horton infiltration parameters are recommended:

- f_o = 75.0 mm/hr
- f_c = 7.5 mm/hr
- $k = 0.00115\ s^{-1}$ ($4.14\ hr^{-1}$)
- t = time since initial infiltration rate

Horton parameters applicable to specific areas are difficult to find. ***Figure 3-6*** illustrates the Horton infiltration curve based on the soil intake data for Alberta soils and the recommended parameter values for f_o, f_c, and k. Based on these values, these parameters provide infiltration results similar to clay soil. Much of the soil in Calgary is clay based.

10. Source: Scheaffer et al 1982.

Figure 3-6: Horton Infiltration Curve using Alberta Soils and Recommended Values[11]



3.2.5.3.2 Soil Conservation Service (SCS) Method

This method was originally developed by the U.S. Department of Agriculture's Soil Conservation Service to estimate agricultural runoff. Subsequently, the method has been widely applied to all types of hydrology problems, including urban drainage.

Runoff is calculated using the total depth of rainfall, initial abstraction, and curve number (CN) (refer to ***Equation 3-8***). CN can range from 0 (i.e., produces no runoff) to 100 (i.e., produces 100% runoff) for a rainfall event. The runoff hydrograph is then generated by the unit hydrograph methodology.

Equation 3-8: SCS Equation

$$Q = \frac{(P - I_a)^2}{P + S - I_a}$$

where: P = total depth of rainfall (mm)

I_a = initial abstraction (mm)

S = soil storage

Initial abstraction (I_a) is the interception, infiltration, and depression storage prior to runoff. As part of the original SCS Method, I_a is typically assumed to be equal to 0.2S based on an Antecedent Moisture Condition (AMC) II. With the modified SCS Method used in SWMHYMO, where I_a is provided by the user, the value for the Curve Number (CN) needs to be modified

11. Source: Stantec Consulting Ltd. 1996 (page 10).

Soil storage (S) is equal to:

Equation 3-9: Soil Storage

S = [25400/CN) - 25400]

where: CN = curve number, as described in <Xrefs Table>3.2.5.4 Curve Number (CN).

3.2.5.3.3 Green-Ampt Method

Infiltration can also be described by the Green-Ampt equation. The integral form of the Green-Ampt equation is:

Equation 3-10: Green-Ampt

$$F(t) = K_{sat}t + (\psi + h_0)\Delta\theta \ln\left[1 + \frac{F(t)}{(\psi + h_0)\Delta\theta}\right]$$

where: $F(t)$ = cumulative volume infiltrated up to time t

K_{sat} = saturated hydraulic conductivity

h_0 = ponding depth on the soil surface

ψ = capillary suction head (or negative matric potential) at the wetting front

$\theta\Delta$ = initial moisture deficit

The initial moisture deficit is defined as the maximum water content of the soil (often assumed equal to the porosity (n)), less the initial soil moisture content(θ_i), which would usually be a value intermediate between saturated and completely dry conditions. The suction head is highest when the soils are dry at the beginning of the event, declining to zero under saturated conditions.

Equation 3-10 : Green-Ampt is solved iteratively to determine the value of F(t), given K_{sat}, Ψ, and the time (t). The infiltration rate is computed as:

Equation 3-11: Infiltration Rate

$$f(t) = K_{sat}\left[1 + \frac{(\psi + h_0)\Delta\theta}{F(t)}\right]$$

where: $f(t)$ = infiltration rate at time t

Equation 3-11 can be used for LID controls that receive direct runoff because there will be surface ponding to a depth of h_0. For other LID controls, such as absorbent landscaping, for which there is no ponded water initially, a two-step process is assumed to apply. The first step describes the process of saturation of the surface when rainfall begins at intensity i, and f(t)=i. The soil becomes saturated and ponding begins when the infiltrated volume is equal to:

Equation 3-12: Cumulative Infiltrated Volume

$$F_p = \frac{K_{sat}\psi\Delta\theta}{i - K_{sat}}$$

where: F_p = cumulative infiltrated volume at time t_p

t_p = time when ponding starts

i = rainfall intensity'

Equation 3-13: Time when Ponding Starts

$$t_p = \frac{F_p}{i}$$

where: F_p = cumulative infiltrated volume at time t_p

t_p = time when ponding starts

i = rainfall intensity'

This condition only occurs if $i > K_{sat}$. Otherwise, all of the rain is infiltrated and ponding never occurs. After the surface becomes saturated, F(t) < i and needs to be determined. The infiltrated volume F(t) is computed iteratively using the following equation:

Equation 3-14: Infiltrated Volume at Time t

$$F(t) - F_p - \psi\Delta\theta \ln\left[\frac{\psi\Delta\theta + F(t)}{\psi\Delta\theta + F_p}\right] = K_{sat}(t - t_p)$$

Then ***Equation 3-11*** is used to compute the infiltration rate F(t). A ponded depth can be included in ***Equation 3-14*** but it is usually negligible compared to the suction head for LID controls, such as absorbent landscaping, that are not designed to allow ponding. However, in bioretention systems the effect of ponding included in ***Equation 3-11*** can be significant.

Typical values for the Green-Ampt equation are presented in ***Table 3-12***.

Table 3-12: Green-Ampt Values[12]

Soil Texture Class	Saturated Hydraulic Conductivity (K) mm/hr	Suction Head (ψ) mm	Porosity, Fraction (Φ)	Field Capacity, Fraction (FC)	Wilting Point, Fraction (WP)
Sand	120.396	49	0.437	0.062	0.024
Loamy Sand	29.972	61	0.437	0.105	0.047
Sandy Loam	10.922	110	3.450	0.190	0.085
Loam	3.302	88.9	0.463	0.232	0.116
Silt Loam	6.604	170	0.501	0.284	0.135
Sandy Clay Loam	1.524	220	0.398	0.244	0.136
Clay Loam	1.016	210	0.464	0.310	0.187
Silty Clay Loam	1.016	270	0.471	0.342	0.210
Sandy Clay	0.508	240	0.430	0.321	0.221
Silty Clay	0.508	290	0.479	0.371	0.251
Clay	0.254	320	0.475	0.378	0.265

3.2.5.4 Curve Number (CN)

Curve numbers (CN) are used in the SCS Method. The curve number is a function of soil type, ground cover, and antecedent moisture conditions (AMCs).

Four hydrological soil groups are defined:

i) Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravel. Soils have a high rate of water transmission (low runoff potential).

ii) Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep and moderately well to well-drained soils with moderately fine to moderately coarse texture. Soils have a moderate rate of water transmission.

iii) Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. Soils have a slow rate of water transmission.

iv) Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. Soils have a very slow rate of water transmission (high runoff potential) .

Table 3-13 provides general information on CN values. CN values can range from 0 (produces no runoff) to 100 (produces 100% runoff) for a rainfall event.

Recommended modified CN values for Calgary are 70 to 74 corresponding to Soil Group C. The average modified CN value to be used is 72. Use of lower modified CN values for urban modelling requires the approval of Water Resources.

12. Source: EPA 2004, adapted from Rawls, W.J. et al 1983.

Table 3-13: Traditional SCS Curve Numbers for Urban Areas[13]

Cover Type and Hydrologic Condition - Fully developed urban areas (vegetation established).	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Open space: (lawns, parks, golf courses, cemeteries)				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good Condition (grass cover >75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.	98	98	98	98
(excluding right-of-way)				
Streets and roads:				
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89

Note: Assumes AMC II and I_a=0.25

3.2.5.5 Imperviousness

Impermeable surfaces, such as pavement or rooftops, prevent the infiltration of water into the soil. Imperviousness is one of the most important parameters to consider in determining runoff. ***Table 3-14*** lists some typical values applicable to Calgary.

Where imperviousness values are not provided, imperviousness should be estimated using air photo maps and weighted averaging.

Table 3-14: Typical Imperviousness of Urban Catchments[14]

Description	**% Imperviousness**
Single Family Residential with No Lanes:	
Overall	55
Front Yards and Streets	76
Rear Yards	25
Single Family Residential with Lanes:	
Overall	55
Front Yards and Streets	55
Rear Yards	55
Multi-Family	65
Light Commercial and Industrial	85
Commercial Malls with Large Parking Areas	95
Paved Surfaces and Roofs	100
Gravelled Roads, Lanes and Parking Areas	50
Major Road Right-of-Way	70

13. Source: USDA. *Hydrology: Engineering Handbook*, 1968.
14. Source: Stantec Consulting Ltd. 1996 (page 9).

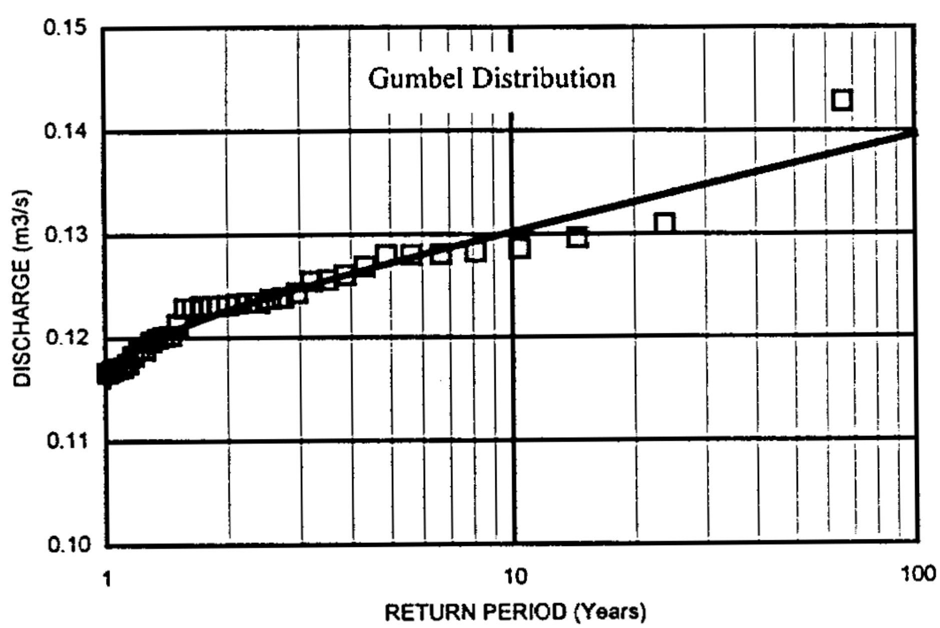
XIMP and TIMP are parameters used in the SWMHYMO model. XIMP is the ratio of the total area directly connected to the sewer system (i.e. roof drains that drain to driveways and then to the street). TIMP is the ratio of total impervious area within a catchment. For conventional design practice without LID, **it is recommended that XIMP = TIMP for modelling purposes for Calgary**. With LID implementation, a distinction between XIMP and TIMP is acceptable.

3.2.6 Statistical Analysis

Many hydrological processes are so complex that they can only be interpreted and explained in a probabilistic sense. Statistical analysis provides ways to reduce and summarize data, to determine underlying characteristics, or to make predictions.

Statistical (or frequency) analysis is required when determining storage volumes for stormwater ponds using continuous simulation. With continuous simulation, maximum yearly storage volumes are generated; **a statistical analysis must then be performed to determine the required 100 year volume**. Simply using the maximum storage volume generated over the time period is **not** correct.

Figure 3-7: Sample Frequency Curve



Different distributions can be used in the regression analysis, including Normal, Log-Normal, Person III, Log-Pearson III, Gumbel, and Weibull; the distribution with the best fit should be used. Best fit should be considered in terms of correlation and standard error.

3.3 Minor System Component Design

Typically, the minor system will quickly and efficiently remove rainstorm runoff below its design capacity. This section outlines the design criteria that apply to the components of the minor system for new developments.

3.3.1 Design Basis

i) The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary. Combined systems are not permitted.

ii) In general, the storm sewer must be designed to convey design flows when flowing full with the HGL at or below the obvert of the pipe. Sewer pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.2 m below surface to avoid compromising catchbasin interception.** Also, proper aeration and venting should be considered as per ***5.5.2 Design***.

iii) The minor system is to be designed according to the level of service stipulated in ***3.1.2.2 Level of Service***. All new developments should be designed using the Unit Area Release Rate Method.

3.3.2 Pipes

For more information, refer to The City of Calgary's *Design Guidelines for Subdivision Servicing* and *Standard Specifications Sewer Construction*.

3.3.2.1 Design Flow

i) The design flow of the minor system must be determined according to the level of service stipulated in ***3.1.2.2 Level of Service***. All new developments should be designed using the Unit Area Release Rate Method.

ii) Where the Rational Method is permitted, the inlet time at the most upstream manhole of a storm sewer line is 10 minutes, resulting in a minimum Time of Concentration (t_c) of 10 minutes.

3.3.2.2 Capacity & Size

i) Manning's Formula must be used to determine the gravity flow (capacity) and size of pipe required. Assume that the pipe is flowing full.

Equation 3-15: Manning's Formula

$$Q = \frac{1.0\ A\ R^{2/3}\ S_f^{1/2}}{n}$$

where:
Q =discharge (capacity) (m^3/s)
R = hydraulic radius (A/P) (m)
A = cross-sectional area of pipe (m^2)
P = wetted perimeter (m)
S_f = friction gradient (or slope of pipe)
n = Manning's roughness coefficient

ii) Manning's Roughness Coefficient (n)

- Concrete Pipe: n = 0.013
- PVC, Polyethylene (PE): n = 0.011
- Ultrarib: n = 0.011[b]
- Corrugated Metal Pipe (std): n = 0.017-0.030[b]
- Steel Pipe: n = 0.010-0.017[b]

Notes: a) PHDPE Pipe is not currently approved for use. Refer to the Approved Products List in the City of Calgary's *Standard Specifications Sewer Construction* or contact Water Resources for more information.)

b) Values of Manning's n can vary. Approval from Water Resources is required if values deviate from those listed above.

iii) Minimum Size

Minimum storm sewer diameters are as follows:

- residential areas: 300 mm.
- commercial/industriall:375 mm.
- roof drains:100 mm.
- weeping tile drains (main):150 mm
- weeping tile drains (service connection): 75 mm.

Refer to ***3.3.6.3 Size & Slope*** for more information on weeping tile drains.

3.3.2.3 Flow Velocities and Minimum Slope

i) The following **minimum** slopes must be used:

Table 3-15:Minimum Pipe Sizes

Size	Concrete Pipe n=0.013	PVC, PE Pipe n=0.011
	Minimum Slope (%)	Minimum Slope (%)
100 mm*	2.00	2.00
150 mm*	1.00	1.00
200 mm	0.80	0.60
250 mm	0.56	0.40
300 mm	0.44	0.32
375 mm	0.32	0.24
450 mm	0.26	0.18
525 mm	0.22	0.16
600 mm	0.18	0.12
675 mm	0.15	0.11
750 mm	0.13	0.10
$\geq$ 900 mm	0.10	0.10

* where permitted and approved by Water Resources (DSSPs)

ii) Storm sewers must be designed so that the actual velocity corresponding to the design flow is greater than 0.90 m/s.

iii) Where design velocities in excess of 3.0 m/s are proposed, provisions must be made to protect against displacement of sewers by sudden jarring or movement. Supercritical flow should not occur unless provisions are made in the design to address structural stability and durability concerns. In general, anchors are required on pipes where pipe slope is greater than, or equal to, 33%, or as requested by Water Resources.

3.3.2.4 Cover

For public storm sewers, the **minimum** depth of cover from pipe obvert to finished road grade is 1.20 m. A cover depth greater than 1.20 m is preferable.

For private property connections (DSSPs), the **minimum** depth of cover from pipe obvert to finished grade is 1.00 m. A greater cover depth is preferable for frost protection.

3.3.2.5 Pipe Material, Strength & Bedding

i) All pipe must conform to and be installed as per City of Calgary *Standard Specifications Sewer Construction*.

ii) All concrete pipes and appurtenances must be manufactured using Type HS cement (formerly Type 50 alkali resistant cement). Concrete pipes over 300 mm in diameter must be reinforced concrete pipe.

iii) All pipe joints are to be rubber gasketed, except when approved by Water Resources.

iv) PVC DR35 may be used for pipe diameters smaller than or equal to 1050 mm; otherwise, concrete pipe must be used (refer to City of Calgary's *Standard Specifications Sewer Construction*). Use of other pipe materials and/or sizes require the approval of Water Resources prior to installation.

v) Typically, PVC DR35 is used for storm connections for DSSPs, but Ultrarib may also be used. Use of any other plastic pipe materials must be approved by Plumbing Services and Water Resources. The designer/consultant is responsible for ensuring the proper class of pipe and bedding is installed. Refer to City of Calgary's *Standard Specifications Sewer Construction* for more information.

vi) For DSSPs, cast iron or an approved equivalent is required under buildings, ramps, overhangs and underdrives.

vii) All pipe design, bedding and installation must be in accordance with The City of Calgary's *Standard Specifications Sewer Construction*, *Standard Practice for the Design and Construction of Flexible Plastic Pipe*, and/or *Standard Practice for the Design and Installation of Rigid Gravity Sewer Pipe*.

3.3.2.6 Concrete/Steel Encasement

For flexible pipe:

i) Concrete encasement is generally **not** required or desired for flexible pipe. Steel encasement may be required in cases where minimum cover cannot be met or where the pipe goes through a utility right-of-way that is narrow or on a private site.

ii) The length of encasement is site-specific and must be approved by Water Resources. Generally, only the affected pipe length would require encasement, not necessarily from manhole to manhole.

For concrete pipe:

i) Concrete encasement is required for maintenance purposes where access is limited.

ii) Concrete encasement is not required in a Public Utility Lot (PUL), a large open area, or where a wide easement is provided.

iii) The length of encasement is site-specific and must be approved by Water Resources. Generally, only the affected pipe length would require encasement, not necessarily from manhole to manhole.

3.3.2.7 Drainage Length

Drainage length is the surface distance that overland flow (surface runoff) must travel to the nearest interceptor (typically a CB or inlet), measured from the high point to the first interceptor.

i) The maximum drainage length of surface runoff on **streets** before the first interceptor must be 150 m. Where grades exceed 2%, this distance may be extended to a maximum length of 300 m. Invert crossings (crossfalls) are not permitted.

ii) The length of drainage in a lane should be minimized. Any drainage length over 175 m is subject to review by Water Resources.

iii) The **maximum** allowable cumulative drainage length to any one CB in lanes and streets is 300 m.

Figure 3-8: Drainage Length

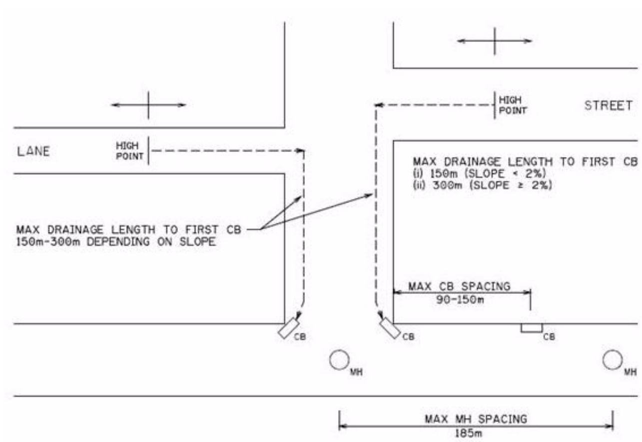
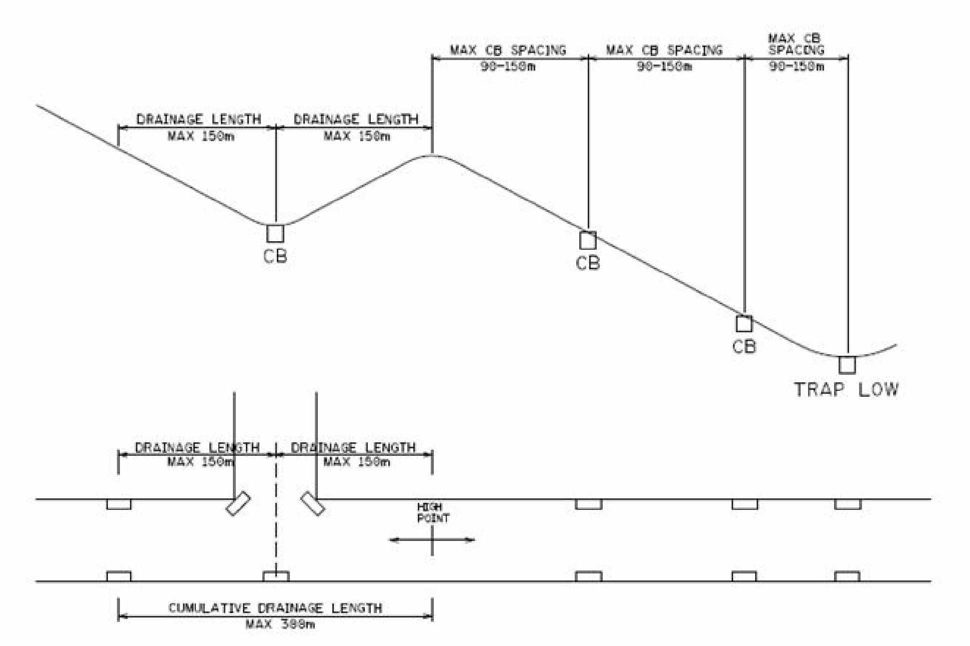


Figure 3-9: Catchbasin Spacing



3.3.2.8 Curved Sewers

Curved (radiused) sewers and bends are permitted to conform to curved street layouts and to offer hydraulic improvement. The required minimum grade for sewers on a curve must be 50% greater than the minimum grade required for a straight run of sewer. Refer to the City of Calgary's *Design Guidelines for Subdivision Servicing* for minimum radii of curvature and permitted joint deflections.

3.3.2.9 Oversize

Any storm system or part of a system must be designed to serve the area within the subdivision development boundary **plus** any area tributary to the system, as outlined in the storm catchment maps. When oversizing is required to service upstream areas, the oversize information must be provided on the preliminary construction drawings and must be approved by Water Resources prior to release of underground construction permission.

When The City of Calgary requires a storm sewer to be larger than necessary to serve an additional area not owned or controlled by the developer, the City will pay the developer the additional cost of oversize. Refer to The City of Calgary's *Design Guidelines for Subdivision Servicing* for more information.

3.3.2.10 City-Funded Storm Conveyance Infrastructure

The City of Calgary typically finances and pays for storm conveyance infrastructure consisting of storm sewer trunks that meet all of the following three conditions:

i) They are 900 mm in diameter and greater.

ii) They are downstream of a storm pond.

iii) They serve the lands owned by more than one landowner/developer.

In the event that a developer is permitted to build infrastructure that would normally be built and financed by The City of Calgary, a Construction and Financing Agreement (CFA) must be executed prior to construction. If construction of this infrastructure is commenced prior to the execution of the CFA, the developer will not be able to recover the costs of this infrastructure from The City of Calgary, nor will this infrastructure be eligible for cost recovery from the Oversize Fund.

3.3.2.11 Hydraulics

Hydraulics requirements include the following:

i) In general, the storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the obvert of the pipe. Sewer Pipes should not surcharge for design or 100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year Hydraulic Grade Line must be at least 1.20 m below surface to avoid compromising CB interception.** Also, proper aeration and venting should be considered as per ***CHAPTER 5: HYDRAULIC DESIGN***. Inlet Control Devices are often used to control flows into the pipe system. Refer to ***3.3.5 Inlet Control Devices (ICDs)*** for more information.

ii) The storm sewer must be designed to account for hydraulic losses due to bends, junctions, transitions, etc. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

iii) HGL calculations are required where surcharge conditions might occur due to backwater affects from stormwater ponds or where hydraulics present a potential problem, or as requested by Water Resources. Refer to ***3.1.2.1 General Requirements*** for more information.

iv) To minimize settlement of solids in the pipes upstream of a stormwater pond, the length of pipe with **standing** water (i.e. pipe invert lower than NWL) must be limited to 100 m.

3.3.2.12 Alignment & Easements

Refer to The City of Calgary's *Design Guidelines for Subdivision Servicing* for alignment and easement requirements. Deeper pipe may require a wider easement for installation and maintenance purposes.

3.3.2.13 Service Connections

Refer to City of Calgary's *Design Guidelines for Subdivision Servicing*, *Standard Specifications Sewer Construction*, and *Design Guidelines for Development Permits, Development Site Servicing Plans and Waste & Recycling Services for Commercial/Industrial Applications* for service connection and alignment requirements. Refer to ***4.5.1 Service Connections*** for more information about Development Site Servicing Plans.

3.3.3 Manholes (MHs)

For more information, refer to The City of Calgary's *Standard Specifications Sewer Construction*.

3.3.3.1 Location

Transitions in size, grade or direction of sewer pipes are to be accomplished by means of MHs, except in the case of curved sewers.

3.3.3.2 Types

i) For two pipes 600 mm in diameter or smaller, use a Type 5A MH, except where a 3 or 4-way junction occurs. Where a 3 or 4-way junction occurs, a Type 1 or 1-S MH may be required depending on pipe sizes and the vertical separation.

ii) For pipe 675 mm in diameter of larger, use a Type 1 MH, or a Type 1-S MH.

iii) Pre-cast T-riser MHs will be accepted for 1050 mm diameter or larger trunks where there is no change in pipe size, grade, or direction. T-riser MHs may be required at pre-fabricated bends.

3.3.3.3 Material

i) All MHs must conform to and be installed as per City of Calgary *Standard Specifications Sewer Construction*.

ii) All MHs and appurtenances must be manufactured using Type HS cement (formerly Type 50 alkali resistant cement).

3.3.3.4 Spacing

The maximum distance between MHs must be 185 m. In all cases, a MH is required at the upper end of a sewer for maintenance purposes.

Modifications to MH spacing may be required where sewers are curved.

3.3.3.5 Drops

i) At MHs where the downstream pipe has a larger diameter than upstream ones, the drop must be equal to or greater than the difference in pipe diameter. If the drop is equal to the difference in pipe diameter, the elevation of the obverts should be kept continuous to maintain the energy gradient.

ii) Where no change in pipe diameter occurs, a minimum drop of 30 mm is required in a through MH.

iii) Where no change in pipe diameter occurs, a minimum drop of 60 mm is required in a bend.

iv) In general, large drops are discouraged due to hydraulic considerations. For drops greater than 1.0 m, a specially designed drop MH might be required to address hydraulic requirements due to the elevation change.

3.3.3.6 Benching

Refer to The City of Calgary's *Standard Specifications Sewer Construction* for benching requirements (file 452-1003-007) and ***CHAPTER 5: HYDRAULIC DESIGN***. Where benching is required for hydraulic concerns, details must be shown on the construction drawings.

3.3.3.7 Junctions and Bends

i) When connecting laterals to large trunks, it may be advantageous to build a MH on the lateral immediately adjacent to the trunk with a direct connection from the MH to the trunk.

ii) Where 2 large diameter (greater than 750 mm diameter) incoming laterals enter a MH, the MH must be hydraulically designed. Refer to ***CHAPTER 5: HYDRAULIC DESIGN***. The use of bends and curved pipe or other appropriate measures. should also be considered.

iii) Bends should be 90^{o} or less. A bend is defined as a deflection of the horizontal alignment between incoming and outgoing sewers.

3.3.3.8 Hydraulics

Notwithstanding ***3.3.3.5 Drops***, sufficient change in sewer invert elevation must be provided across MHs and at junctions and bends to account for energy losses due to flow transitions, turbulence, and impingement. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

3.3.3.9 Service Connections

Refer to The City of Calgary's *Design Guidelines for Subdivision Servicing* and *Standard Specifications Sewer Construction* for service connection requirements. Refer to ***4.5.1 Service Connections*** for requirements for DSSPs.

3.3.4 Catchbasins (CBs)

For more information, refer to The City of Calgary's *Standard Specifications Sewer Construction*.

3.3.4.1 Locations

i) CBs are to be installed to intercept all overland flows, including back lanes, gutters/swales, and overflow from LID BMPs.

ii) The number of CB installations in lanes must be kept to a minimum.

iii) CBs are required at trap lows or sags in the road. The location of catchbasins in parks (MRs, ERs, etc.) is at the discretion of Parks.

iv) For roadway intersections with a continuous grade around a corner, catchbasins might have to be located at the end of curve (EC) or beginning of curve (BC) of the curb radii on the uphill side of the curb return. The need for catchbasins will be assessed on a case-by-case basis by Water Resources and/or Roads. Catchbasins must not be located within the curb radii to avoid conflicts with wheelchair ramps and to minimize the potential for damage to catchbasins resulting from heavy vehicles. Special attention is required to ensure the grade is sufficient around the corner to convey the drainage. This also applies to cul-de-sacs.

v) A CB must be installed at the curb upstream of locations where concentrated flows will cross any roadway (e.g., from one super-elevated curve crossing to another super-elevated curve).

3.3.4.2 Types

There are four types of approved CBs:

- Type C CBs with storm back (previously Type K). Configuration may be single or double.
- Type K2 CBs for rolled curb and gutter (typically twin grate configuration).
- Type K3 CBs (single type C without stormback).
- Grated Top manhole.

Refer to City of Calgary *Standard Specifications Sewer Construction* for more information. Use of other types of CBs, such as super CBs, requires prior approval by Water Resources.

Supporting hydraulic computations must be submitted.

i) CBs must be twinned (two CBs built side by side and interconnected) in trap lows where there is a large drainage area (>1.0 ha), or where a large amount of water may accumulate after bypassing upstream CBs situated on very long steep streets. Type C CBs with storm backs must be used.

ii) There must be a minimum of one Type C CB in a trap low; K2 CBs will be accepted for the other CB(s). The Type C CB should intercept flows from the largest sub-catchment draining to the trap low.

Where conflicts with driveways occur, the Type C CB can be changed to a K2 provided an additional Type C CB is installed on the curb just upstream of the driveway. The two CBs must be interconnected.

iii) Type K2 and/or C CBs may be used on continuous grades, depending on curb type.

iv) Interconnected single CBs may be used when capacity restrictions prevent the use of multiple CBs or CB leads. When interconnected CBs are used, the downstream CB typically (but may not) requires a double barrel. Use of interconnected CBs should be kept to a minimum. The interception by the CB must reflect the greater hydraulic head on the CB lead when double barrels are used.

v) A grated top MH at the upper end of a lateral may be required, plus a lane-type CB as per City Standards, for storm sewer laterals extended to drain low lanes.

vi) For Development Site Servicing Plans, grated top MHs should be used in place of CBs when:
- The depth from the rim to the pipe invert exceeds 2.50 m.
- The total sum of incoming pipe diameters is > 600 mm.
- A 3 or 4-way junction occurs.

In all three conditions, the use of a MH is required instead of a CB barrel.

3.3.4.3 Material

i) All CBs must conform to and be installed as per City of Calgary *Standard Specifications Sewer Construction*.

ii) All concrete pipes and appurtenances must be manufactured using Type HS cement (formerly Type 50 alkali resistant cement).

3.3.4.4 Capacity

Two conditions of flow occur with CBs: flows along a continuous grade and flows under ponding (trap low) conditions. CBs on a continuous grade, or flow-by conditions, will capture only a portion of the flow. The balance of flow will bypass the CB. Based on testing done by Townsend and Moss (1980) and Wilson (1983), Stantec Consulting Ltd. has developed capture curves for five types of City of Calgary CBs (K2, K3, C, Twin C, and GT) for flow-by and ponding conditions. The following information should be used to determine whether Inlet Control Devices (ICDs) might be required and to compute the capture into the pipe system. When required, the consultant is responsible for determining an adequate capture curve for grated top MHs.

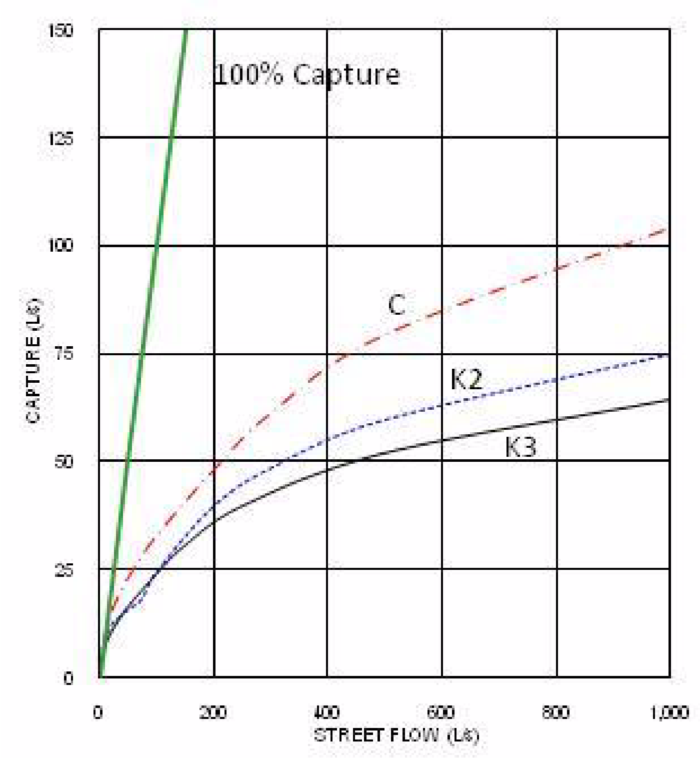
3.3.4.4.1 Flow-by Conditions

Table 3-16: Capture Rating Data for City of Calgary Catchbasins under Flow-by Conditions[15]

K2 CB		K3 CB		C CB	
Street Flow (L/s)	Capture (L/s)	Street Flow (L/s)	Capture (L/s)	Street Flow (L/s)	Capture (L/s)
0	0.00	0	0.0	0	0.0
8	8.00	6	6.0	9	9.0
15	10.6	10	7.6	15	12.7
25	12.8	25	10.8	25	16.5
50	15.7	50	15.5	50	23.0
75	18.2	75	19.6	75	28.2
100	24.4	100	23.5	100	32.8
200	39.6	200	35.2	200	48.0
300	48.4	300	42.2	300	61.1
500	59.6	500	51.0	500	79.3
1000	74.7	1000	63.0	1000	104.0

15. Source: Stantec Consulting Ltd. 1996 (page 15).

Figure 3-10: Capture Rating Curve for City of Calgary Catchbasins under Flow-by Conditions



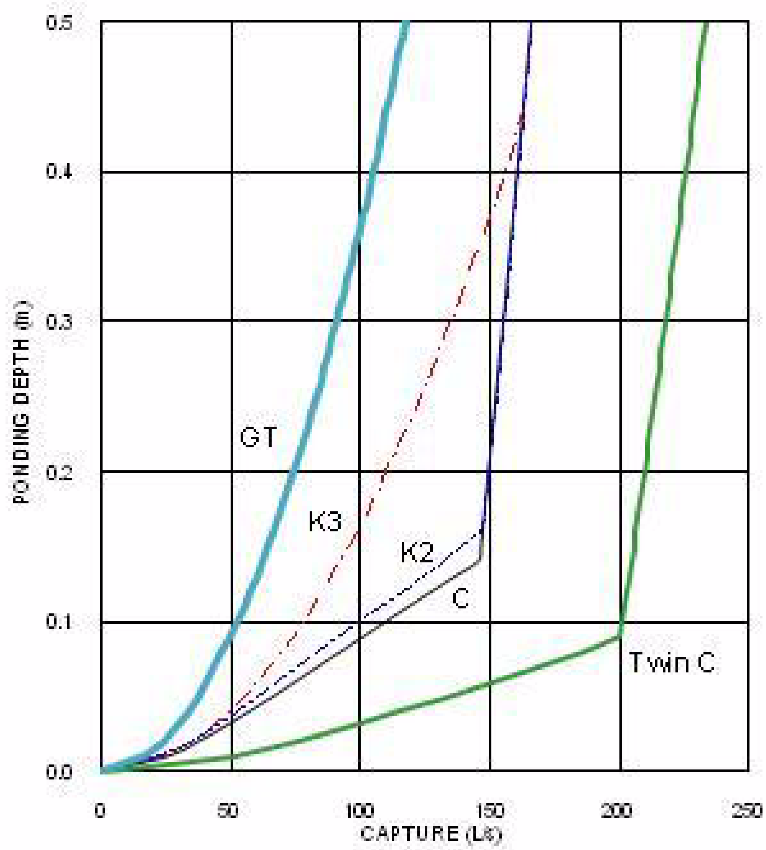
3.3.4.4.2 Ponding Conditions

Table 3-17:Capture Rating Data for City of Calgary Catchbasins under Ponding Conditions[16]

Ponding Depth (m)	Capture Rates (L/s)				
	K2 Inlet	GratedTop Manhole	K3 Inlet	C Inlet	Twin C Inlet
0	0.0	0.0	0.0	0.0	0.0
0.10	98.4	52.4	77.9	110.3	201.2
0.20	149.8	74.2	110.1	149.8	209.7
0.30	155.5	90.8	134.9	155.5	217.8
0.40	161.0	104.9	155.7	161.0	225.7
0.50	166.3	117.3	166.3	166.3	233.2

16. Source:Stantec Consulting Ltd. 1996 (page 19).

Figure 3-11: Capture Rating Curves for City of Calgary Catchbasins under Ponding Conditions



ICDs might be required in CBs to prevent surcharge of the pipe system during the design and 100 year flows. Refer to ***3.3.5 Inlet Control Devices (ICDs)*** for more information.

3.3.4.5 Spacing

i) CB spacing on a continuous grade must range from 90 m to 150 m, with closer spacing required for flat grades and at all corners where storm sewers exist, except in the case of a high corner (i.e. drainage away from corner in both directions). Refer to ***3.3.2.7 Drainage Length*** for more information about CBs in trap lows and additional CB spacing information. CB spacing up to 175 m may be approved on a case-by-case basis. Contact Water Resources for more information.

ii) Where CBs are located in lanes, it is necessary to compact utility trenches and pave 23.0 m upstream and 15.0 m downstream from the catch basin, as shown in The City of Calgary Roads' *Standard Specifications Roads Construction*, Drawing 454.1011.002. If the catchbasin is located in a trap low, it will be necessary to pave 23.0 m in both directions.Trap lows in lanes should be avoided where possible.

3.3.4.6 Lead Sizes & Slopes

i) All CBs must be connected to a MH, not directly to the main.

ii) Minimum lead sizes are as follows:
- Single CB - 250 mm lead
- Twin CB - 300 mm lead (one common lead)
- Interconnected CB - 300 mm lead (one common lead)

iii) The length of a CB lead should not exceed 30.0 m.

iv) A minimum slope of 2% is required on all leads.

v) For Development Site Servicing Plans, the **minimum** lead size for an area drain CB is 250 mm diameter. Exceptions are as follows:
- Where routes require cast iron or equivalent PVC pipe, smaller pipe sizes will be accepted,
- Where the pipe is directly involved in a stormwater retention system or is upstream of a retention system, a minimum size of 150 mm diameter is acceptable.
- Where the public mains are less than 525 mm diameter, pipe sizes from 150 mm to 250 mm diameter will be considered.

All lead sizes for DSSP area drains must be approved by Water Resources.

3.3.4.7 Hydraulics

Sewer pipes should not surcharge for design or 1:100 year flow rates unless previously approved by Water Resources. Inlet Control Devices (ICDs) are required in CBs to prevent surcharge of the pipe system during these rain events. Refer to ***3.3.5 Inlet Control Devices (ICDs)*** and ***3.3.1 Design Basis*** for more information.

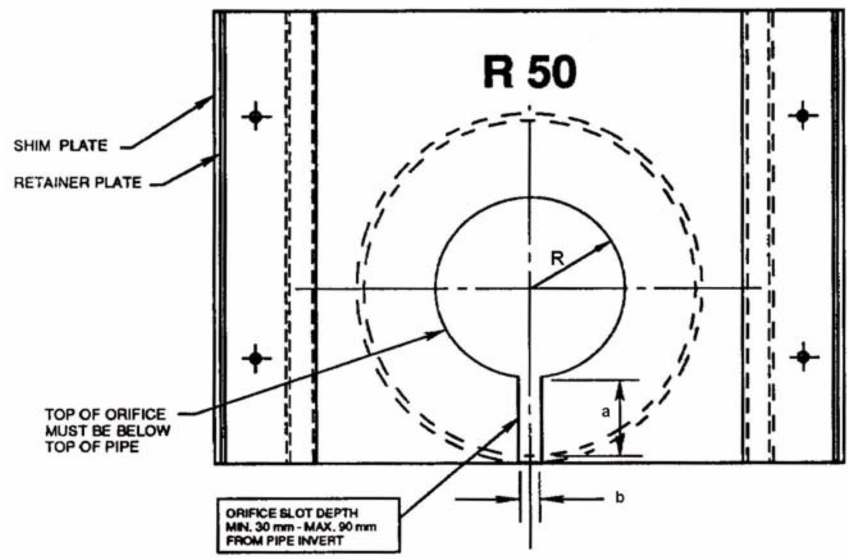
3.3.5 Inlet Control Devices (ICDs)

3.3.5.1 Types

ICDs are required to prevent surcharge of the pipe system during the design and 1:100 year flow rates. ICDs are plates installed inside the CB over the inlet of the lead.

The City of Calgary has four standard ICDs that should be used to control flows into the storm sewer: R30, R50, R70 and R100. Refer to City of Calgary *Standard Specifications Sewer Construction* for more information.

Figure 3-12: ICD Configuration



3.3.5.2 Discharge

ICD discharge (L/s) is determined for each size based on The City of Calgary's *ICD Testing Results* study[17]. The orifice equation was utilized along with slot dimensions a = 30 mm and b = 30 mm.

- R30: $Q=17.10\ H^{0.5}$
- R50: $Q=30.05\ H^{0.5}$
- R70: $Q=49.40\ H^{0.5}$
- R100: $Q=89.80\ H^{0.5}$

For trap lows, rating curves for the ICDs were developed using the following equation:

Equation 3-16: Computation of Head on ICD

H = z + Depth of Ponding on Road - 0.5 x CB lead diameter

where: z = depth from invert of orifice to top of the CB at surface.

A value for z equal to 1.213 m (based on the height of one CB barrel) was used in the following table.

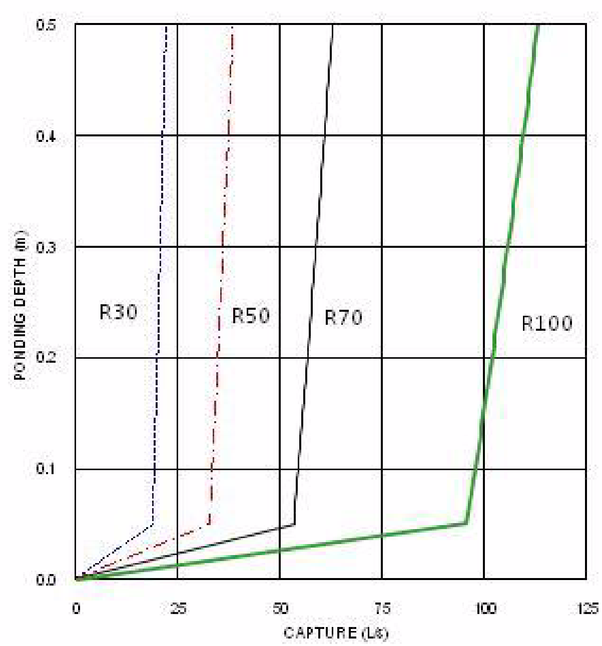
17. The City of Calgary 1995.

Table 3-18: Capture Rating Data for Standard City of Calgary Inlet Control Devices

Ponding Depth (m)	Capture Rates (L/s)			
	R30	R50	R70	R100
0	0.0	0.0	0.0	0.0
0.10	19.1	33.4	54.4	97.7
0.20	19.9	34.7	46.6	101.7
0.30	20.6	36.0	58.7	105.6
0.40	21.3	37.2	60.8	109.4
0.50	22.0	38.4	62.7	113.0

Note: The lowest interception rate from ***Table 3-17*** and ***Table 3-18*** governs.

Figure 3-13: Capture Rating Curves for Standard City of Calgary Inlet Control Devices



The consultant should minimize the use of R30 ICDs where possible to reduce the potential for plugging. The provision of interconnected CBs controlled by one single ICD should be considered in cases where the target design interception rate for the CBs is small.

3.3.6 Weeping Tile Drains (Foundation Drain)

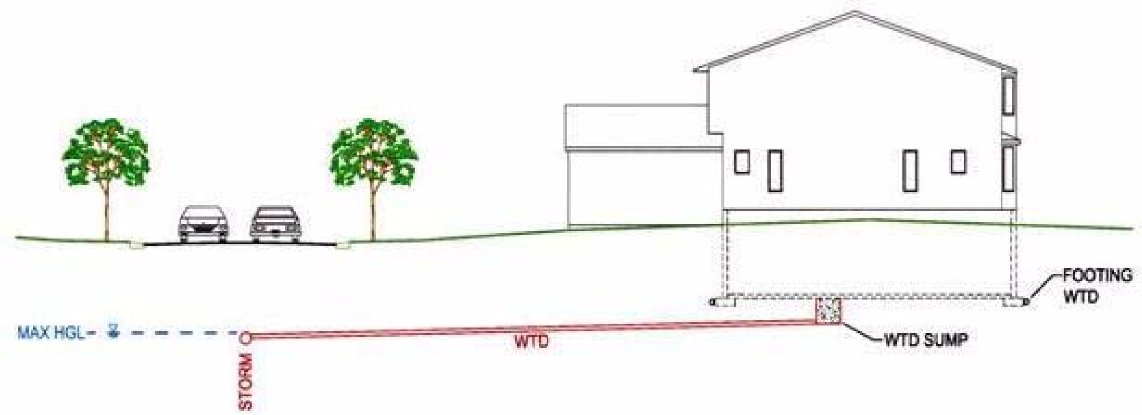
Weeping tile drains, or foundation drains, are typically used to provide protection of foundations due to high water tables and/or inadvertent seepage along the foundation wall. Three types of systems are available: direct connection to the storm sewer, sump pump, and a three pipe system. In accordance with Drainage Bylaw 37M2005, surface drainage is not permitted to drain to a weeping tile drainage system by any means other than infiltration from the surface, Window wells, roof leaders and area drains must not have a direct connection to the weeping tile drainage system.

3.3.6.1 Types

3.3.6.1.1 Storm Connection

All weeping tile drains (WTDs) are required to tie to the storm sewer by gravity (refer to ***Figure 3-14***). Connection to the sanitary sewer is not permitted.

Figure 3-14: Conventional Storm and WTD



3.3.6.1.2 Sump Pump

There are some circumstances where connection to the storm sewer is not possible or recommended:

- Infill housing where storm sewer is available, but footing elevations must be set low to conform to grades of adjacent developments, therefore making gravity drainage impossible (refer to ***Figure 3-16***).
- Infill housing where storm sewer is unavailable (refer to ***Figure 3-17***.
- Existing lots that experience storm sewer backup.
- Lots where the hydraulic grade line (HGL) is sufficiently high to cause potential storm sewer backup. This includes lots or areas in a floodplain.

In these situations, pumping water from a sump (i.e., sump pump) is allowed. If a public storm sewer system is available, a connection to this storm sewer system is required. The top of the goose neck in the discharge pipe of the sump pump must be above ground or above the spillover elevation of adjacent trap lows, whichever is higher. Discharge to ground is only permitted if there is no public storm sewer system. If discharging to ground, to prevent icing, the discharge should be into absorbent landscaping or bioretention areas, away from paved or impervious surfaces. Sump pumps are typically installed on a case-by-case basis, and require pre-approval from Water Resources.

In some cases, the weeping tile drain for a walkout basement cannot readily drain into the storm sewer by gravity. In that case, a sump pump that directs water from the walkout section of the weeping tile drainage system into the weeping tile drainage system servicing the balance of the building is permitted (refer to ***Figure 3-15***).

Figure 3-15: Weeping Tile Drain Arrangement for Walkout Basements

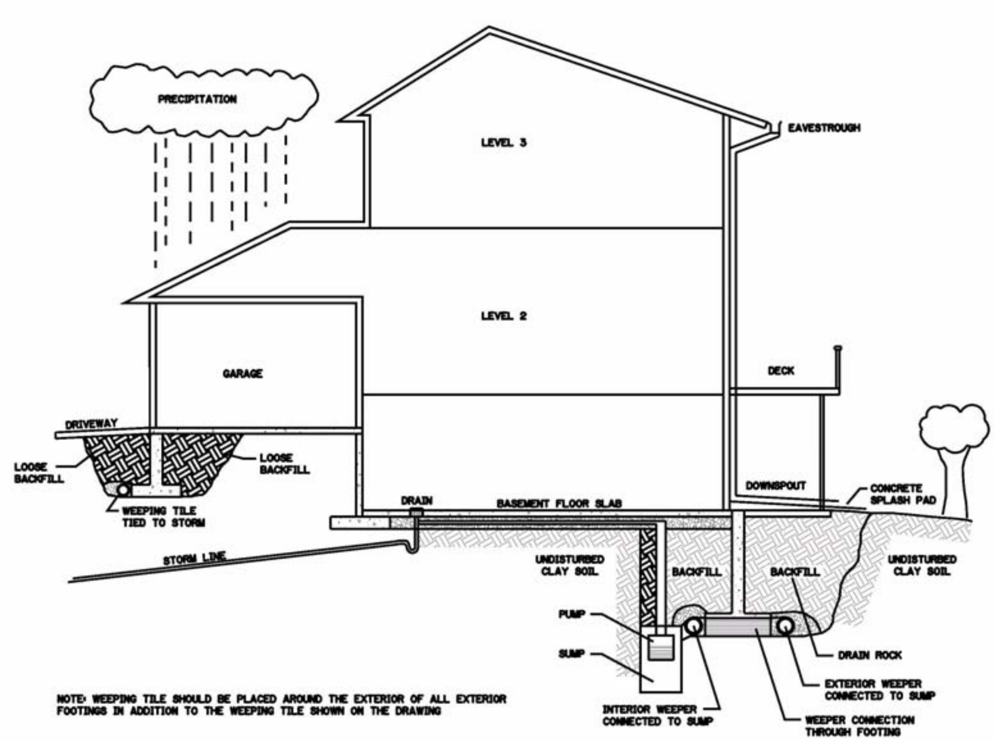


Figure 3-16: Conventional Storm and WTD

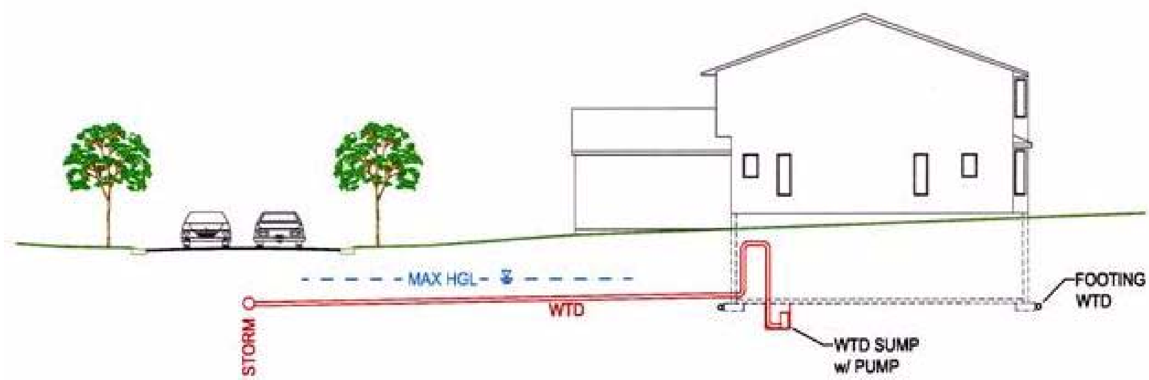
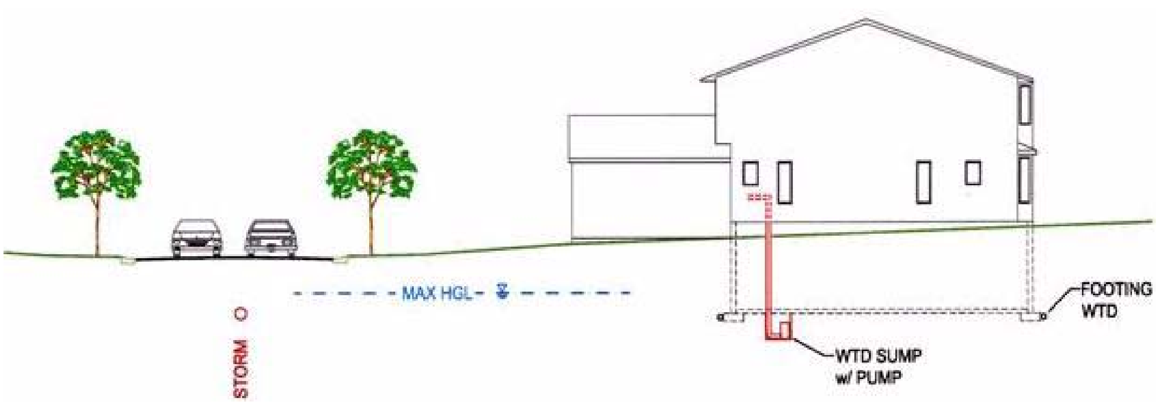


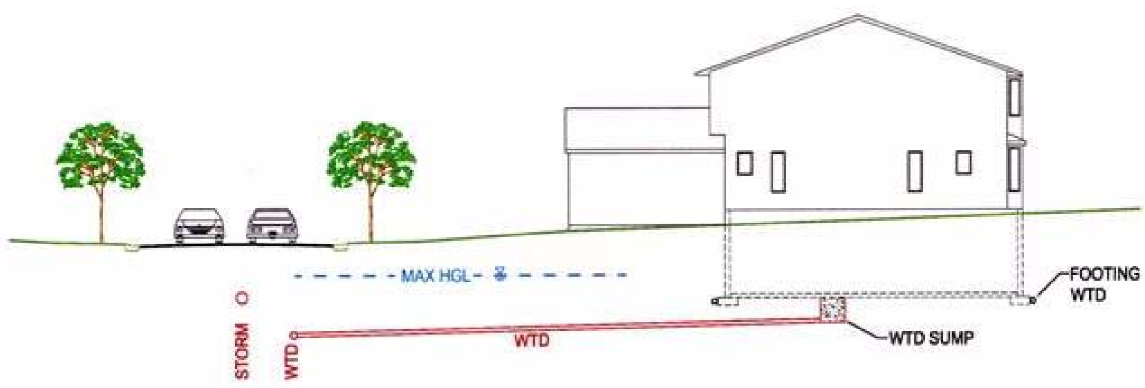
Figure 3-17: WTD Sump Pump to Surface



3.3.6.1.3 Three Pipe System

When the HGL is sufficiently high and **the impact affects a significant area**, then a separate pipe system (third pipe) that carries only foundation drainage should be considered. Water Resources should be contacted. Although this is not necessarily the recommended solution, the three pipe system provides good and virtually fool-proof drainage to basements and allows the storm sewer to surcharge with virtually no consequences. However, due to the additional pipe system, there is the added potential for cross connections between the sanitary, storm and foundation drain systems. Refer to ***Figure 3-18***.

Figure 3-18: Three Pipe System with Separate WTD Main



3.3.6.2 Requirements

3.3.6.2.1 Residential (R1, R2, R2A) and Multi-Family

i) All weeping tile drains are to be connected to the storm sewer; connection to the sanitary sewer is not permitted.

ii) A weeping tile drain is required on lots that meet one or more of the following criteria:
- Where the lowest top of footing (LTF) is l**ess than 2.50 m** above the seasonally adjusted water table (refer to ***3.3.6.8 Water Table Requirements***).
- On fill of 2.00 m or greater.
- Requiring bearing certificates

iii) Where a weeping tile drain is required for walkout basement lots, the weeping tile drain must be designed and installed to provide total basement seepage protection.

3.3.6.2.2 Infill Housing

i) Where storm sewer is available:
- A weeping tile drain is required to tie to the storm sewer; connection to the sanitary sewer is not permitted.
- A weeping tile drain is required unless a professional Geotechnical Engineer has determined otherwise. The consultant must use the criteria set out in ***3.3.6.8 Water Table Requirements***. A letter with the appropriate elevations (in metric geodetic) and information will be required by Water Resources.

- A sump pump is required to collect weeping tile flow and discharge it to a storm sewer by gravity when normal weeping tile drainage by gravity is not possible. This may occur where the footing must be set low to conform to grades of adjacent developments.
- The gravel blanket below the footing and basement slab is **NOT** considered a substitute for weeping tile drains around the building footing.

ii) Where storm sewer is NOT available:

- A weeping tile drain is required unless a professional Geotechnical Engineer has determined otherwise. The consultant must use the criteria set out in ***3.3.6.8 Water Table Requirements***. A letter with the appropriate elevations (in metric geodetic) and information will be required by Water Resources.
- If the consultant concludes that a weeping tile drain is required, then the weeping tile drain must be connected to a sump pump that discharges the flow onto the lot such that it drains away from the house. To prevent icing, the discharge should be into absorbent landscaping or bioretention areas, away from paved or impervious surfaces.

iii) Floodplain areas:

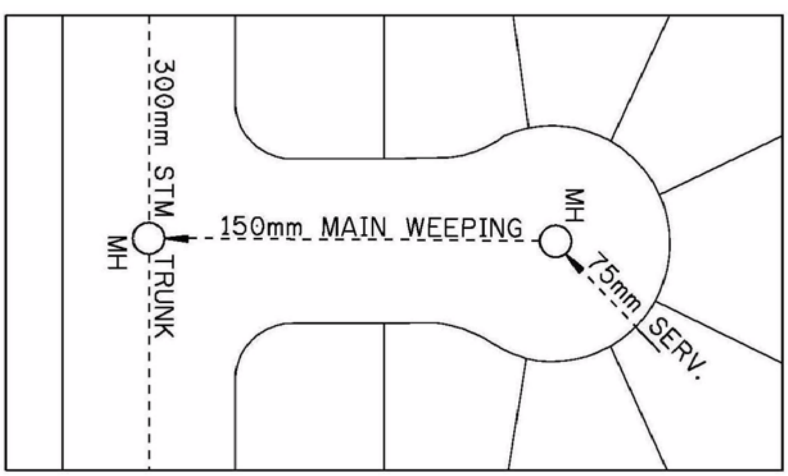
All developments within a designated floodplain area require a weeping tile drain in conjunction with a sump pump that discharges the flow to surface, whether storm sewer is available or not. Refer to ***3.5 Floodplain Requirements*** for more information.

3.3.6.3 Size & Slope

The **minimum** diameter for weeping tile service connections is 75 mm. The minimum diameter for the weeping tile main (where individual weeping tile service connections tie into) is 150 mm diameter. In three pipe systems, the weeping tile drainage system must be properly designed and sized with input by a professional Geotechnical Engineer with respect to the expected flow rates.

Weeping tile drains must be designed to provide a **minimum** velocity of 0.60 m/s when flowing full.

Figure 3-19: Weeping Tile Connections



3.3.6.4 Cover

Adequate cover is required for frost protection. This should be 1.20 m where possible.

3.3.6.5 Backwater Valves

Backwater valves, or backflow prevention devices, are required on all weeping tile drainage systems to minimize backup of stormwater and must be installed according to *National Plumbing Code of Canada*. P traps are required to minimize backup of sewer gas.

Fiodrains, or any other similar devices, are not permitted where a plumbing arrangement may introduce groundwater to a sanitary sewer system.

3.3.6.6 Hydraulics

Weeping tile drains must **not** surcharge.

Where storm sewer surcharge conditions may occur, the lowest top of footing (LTF) elevation must be a minimum of 0.30 m above the HGL for the 1:100 year event or stipulated design event. This applies to retrofit and re-development projects in established communities as well. In these cases, the HGL elevations must be shown on the Building Grade Plan, at the approximate MH location, or on the lot information.

3.3.6.7 Service Connections

Refer to City of Calgary *Design Guidelines for Subdivision Servicing* and *Standard Specifications Sewer Construction* for service connection requirements.

3.3.6.8 Water Table Requirements

Groundwater elevations are required to determine the need for a weeping tile drain. If no water table readings are included, a weeping tile drain must be installed. Requirements are as follows:

i) The highest anticipated groundwater table elevation for an area must be determined by adequate test wells.

ii) Test well holes are to be spaced on an approximate 150 m grid, with modifications as required to suit the particular subdivision. A set of test hole logs should accompany the plan, listing soil sulphate content and water level readings. **Subdivisions require successive readings for a period of 6 months at one month intervals. Infill lots require a minimum of two test hole readings obtained one month apart.**

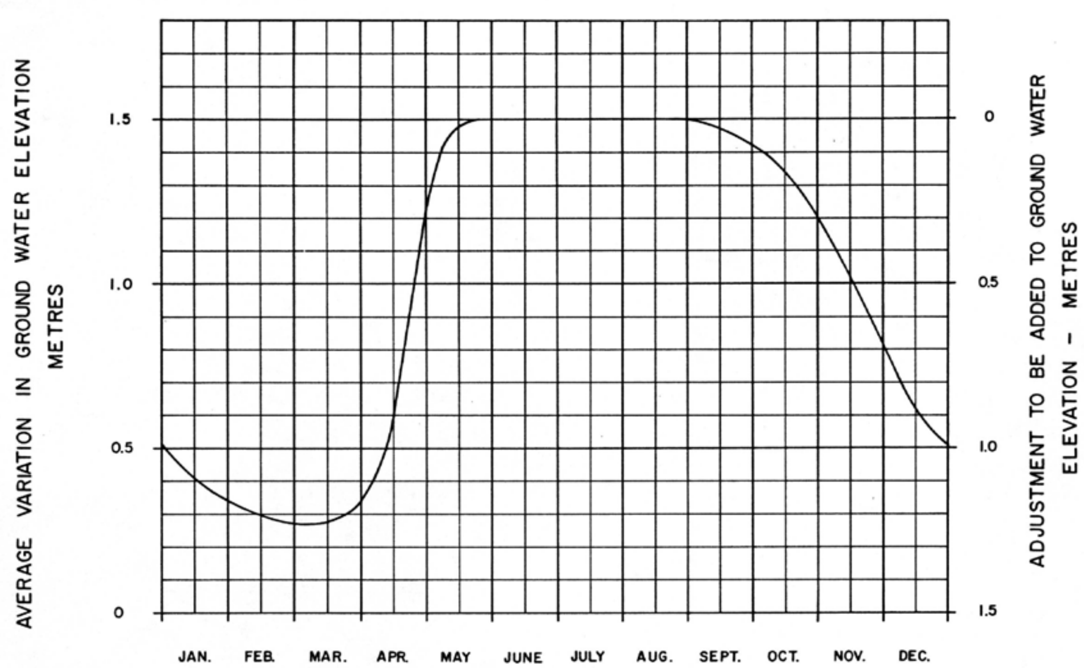
Table 3-19: Test Hole Data.

TEST HOLE NO.	SOIL SULPHATE CONTENT %	GROUND ELEV. AT HOLE	BOTTOM OF HOLE ELEVATION	WATER LEVEL READINGS													TEST HOLE NO.
				DATE													
				CORRECTION													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													
				AS READ / COR-RECTED													

NOTE: HIGHEST CORRECTED WATER LEVEL SHOULD BE CIRCLED FOR EACH TEST HOLE

iii) Water table readings must be seasonally adjusted using the following curve:

Figure 3-20: Groundwater Adjustments.



iv) A weeping tile drain is required where the lowest top of footing (LTF) is **less than 2.50 m** above the seasonally adjusted water table.

v) For SCPs utilizing percolation, potential impacts on the groundwater table must be determined by a qualified professional hydrogeologist.

vi) Subdivision construction drawings must include the following information:
- Location of test holes.
- Test hole information and readings.
- Contours of the highest seasonally adjusted water table.
- Proposed LTF of each lot.
- Identification of lots requiring a weeping tile drain.

3.3.7 Outfalls

3.3.7.1 General Requirements

i) Structural and hydraulic details of storm outfalls are to be submitted to Water Resources for approval. Details should include design and analysis as detailed in Alberta Environment's *Code of Practice for Outfall Structures on Water Bodies*.

ii) Provincial registrations, notifications, and possibly dispositions are required for all outfalls that discharge into watercourses (i.e. Bow River, Elbow River, Nose Creek, Fish Creek, etc.). Refer to ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES*** for more information.

iii) A Development Permit might be required for structures in the floodway. The design of the outfall should minimize incremental floodway obstruction.

iv) All outfalls and appurtenances must be manufactured using Type HS cement (formerly Type 50 alkali resistant cement).

v) The minimum distance from the point of discharge to the nearest dwelling must be 150 m if discharge is to an open ditch.

vi) River flood backflow prevention valves should be incorporated for any outfall servicing catchment areas with ground or basement elevations below the local designated river flood level (1:100 year design event). Contact Water Resources for outfall valve design guidance.

vii) Outfalls must be constructed with adequate erosion protection. The outfall apron should also drain properly. The design of the outfall structure should account for potential long-term scour of the receiving water body's bed and banks, to the satisfaction of Water Resources.

viii) For receiving water bodies that are braided or contain abandoned channel scrolls, locate the outfall as far from the main channel as practical to prevent failure and scour of the sewer and outfall under flood conditions.

ix) The structural design for outfall structures should account for groundwater rise and fall associated with flood conditions on receiving water bodies, including seepage, subsurface drainage and structure foundation considerations.

x) Local bank protection incorporating riprap, cobble, or other earthworks-based erosion protection features should yield slopes preferably flatter than 3H:1V and **always** flatter than 2.5H:1V. Protection must be appropriate to local site conditions, including bank stability and habitat considerations.

xi) Erosion protection design should account for the local ice regime and potential bank scour by ice.

3.3.7.2 Hydraulics

i) In order to minimize erosion, outfalls are to extend to the bottom of drainage courses or to the edge of streams. This includes back-yard drainage into ravines. **Concentrated discharges onto steep slopes, without appropriate erosion protection, will not be accepted.**

ii) Hydraulic and stability requirements of the outfall must be considered. Exit velocities must not damage or erode watercourses. Suitable baffles, aprons, rip-rap, or energy dissipation features must be considered. Hydraulic losses must be taken into account.

On smaller creeks and rivers, where the bankfull width of the receiving stream is less than six times the outfall diameter, an outfall discharge at 90 degrees (or perpendicular) to the opposite bank should be avoided or mitigated to the satisfaction of Water Resources. Alignment angled towards the downstream flow in the receiving water body is preferred; the configuration and angle will be subject to the approval of Water Resources.

iii) Where appropriate, bioengineering treatments should be incorporated into the protection of the shoreline of the receiving water body.

iv) Hydraulic analyses of the outfall and receiving water body should include consideration of outfall performance at a range of receiving water levels, including open water season low quartile level and mean open water season level, as well as the 1:2, 1:5, 1:20, and 1:100 year flood levels. Erosion protection should be incorporated for the most conservative scenario.[18]

v) Outfalls and storm sewers should be configured to avoid hydraulic jumps within the pipes or conduits directly upstream of the outfall. Appropriate energy dissipation structures with proper venting and aeration should be included where supercritical flows could develop.

vi) Outfalls should typically have invert elevations above the 1:5 year level of the receiving stream. For receiving water bodies susceptible to winter ice build up, ice affected receiving water elevations should be considered.

18. Flood levels for the Bow River, the Elbow River, Nose Creek, West Nose Creek, and Pine Creek are available from the *1983 Calgary Floodplain Study* (Alberta Environment, 1983 and 1996 (including model updates)) and the *2010 Bow and Elbow River Updated Model Project* (City of Calgary, 2010) for the Bow and Elbow Rivers, the *2006 Nose Creek Flood Risk Mapping Study* (Alberta Environment, 2006) for Nose Creek and West Nose Creek, and the *2007 Pine Creek Drainage Study* (City of Calgary, 2007) for Pine Creek. In addition, Water Survey Canada publishes quartiles and other flow statistics that can be downloaded from their website at no cost.

3.3.7.3 Maintenance

i) Access to the top of the outfall or adjacent bank must be provided for maintenance purposes. Walking access to outfalls in environmentally sensitive areas may be considered, however all other outfalls must be accessible by vehicle for inspection and maintenance.

Particular care in design of the roadway surface is required; it should be integrated with the adjacent landscape. A 4.0 m wide drivable surface (capable of handling a 23 tonne vacuum truck) is preferred; narrower widths are subject to approval by Water Resources. Additional consideration for width at turns and bends is required. Sharp turns must be avoided; the minimum turning radius is 12.0 m.

A turnaround might need to be provided at the outfall if it is situated more than 30.0 m from the adjacent roadway. The slope of the access route to the outfall should preferably be less than 5%, with a maximum slope of 8%. The entrance must be gated with a bollard or equivalent (at any location where a public vehicle could access the outfall site) to prevent unauthorized access. The subgrade must conform to a “Lane” road standard as per The City of Calgary Roads’ *Standard Specifications Roads Construction*. Alternatives will be considered by, and are subject to the approval of, Water Resources.

ii) A skimming MH, or approved equivalent, must be provided upstream of the outfall to remove oil and chemical spills. The skimming MH must be easily accessible for tandem axle maintenance vehicles. A skimming MH will not be required if the discharge to an outfall is directly from a stormwater wet pond, wetland, or approved oil/grit separator.

iii) Outfalls should be clearly signed. Water Resources/Water Services is responsible for providing and installing the signs.

iv) Inclusion of valves should be considered at all outfalls to allow for isolation of potential spills from reaching the receiving water body. Alternately, anchor points for sorbent booms should be incorporated into the structure.

v) Valve actuation points should have appropriate signage or markings so that they are readily accessible, even under 1.0 m of snow cover.

vi) Operation and maintenance procedures, including winter closure considerations, must be provided as part of outfall designs. For large flood or isolation gates, provisions for automated or mechanically assisted actuation should be considered as per Water Resources.

vii) Designs that include provisions that accommodate future monitoring or sampling will be favoured.

viii) An Operating and Maintenance (O&M) manual must be provided for all outfalls that are equipped with backflow protection valves or have water quality appurtenances.

3.3.7.4 Safety & Aesthetics

i) All outfalls must be constructed with safety provisions to prevent the entrance of children or other unauthorized persons. A grate with vertical bars must be installed with means for locking. Provision must be made for opening or removing the grate for cleaning purposes. Break-away grating with vertically oriented bars and shear pins is required on outfalls larger than 600 mm diameter.

ii) Fall protection, including corrosion-resistant guardrails or approved equivalent, must be incorporated for any outfall structures where the grading is steeper than 3H:1V or where the drop is greater than 0.60 m.

iii) Outfalls, which are often located in parks, ravines, or along the river banks, should be made as safe and attractive as possible. Aesthetic treatment or concealment is to be part of the overall design. Bushhammered, exposed aggregate concrete, or finishes that blend into the natural surroundings are recommended.

3.3.8 Culverts

All culverts are to be approved by Water Resources. Submission of hydraulic design calculations to identify design flow conditions and inlet and outlet head conditions is required. Energy dissipation and erosion control measures should be considered in the design. Clay plugs or other geotechnical measures might be required (as determined by a professional geotechnical engineer) to ensure adequate earth fill drainage, groundwater management, and structural stability. For culvert design references refer to ***5.3 Special Structures***.

3.3.8.1 Major Culverts

i) Major culverts, with diameter greater than 900 mm, are typically located in named water courses or ravines in MRs or ERs.

ii) The capacity of the culvert is dictated by the level of service required for the roadway, as established by the City of Calgary. Typically, the culvert should have adequate capacity to convey the 1:100 year peak discharge with 300 mm freeboard from the obvert at the inlet. Exceptions must be approved by Water Resources.

iii) Culvert design and regulatory submissions must meet Alberta Environment's *Code of Practice for Watercourse Crossings,* as well as Transport Canada (*Navigable Waters*), Environment Canada, and Fisheries and Oceans Canada regulatory requirements, where applicable.

iv) Hydraulic design calculations must be submitted that identify design flow conditions and inlet and outlet head conditions.

v) Where possible, both the culvert inlet and outlet should be depressed at least 150 mm below the downstream channel invert.

vi) Culvert design should consider winter ice conditions and the potential for ice accumulation.

vii) Energy dissipation and erosion control measures should be considered in the design. The design should preclude damage up to the 1:100 year peak discharge rate with a minimum factor of safety of 1.2 on shear stresses incorporated in the erosion protection design. In general, downstream energy dissipation should be placed for a distance of at least 3 to 6 times the bankfull width of the channel downstream of the outlet.

viii) The alignment of the culvert should be parallel to the stream channel, avoiding skewed crossings. Avoid locating culverts within a distance of 6 times the bankfull width of the channel from bends in the stream channel alignment.

ix) The design should be configured to prevent supercritical flow in the culvert.

x) Designs incorporating bevelled corrugated steel pipe (CSP) conduits projecting from fill should be avoided. Collars or headwall designs might be required to prevent uplift associated with differential head.

xi) Where culverts cross fish-bearing streams, design must yield hydraulic conditions that meet or exceed provincial fish passage requirements. In general, natural bed or baffled designs are preferred.

xii) Perched/elevated culvert outlets with free drop onto splash pads should be avoided.

xiii) Where seepage considerations warrant, clay plugs or other geotechnical measures might be required.

xiv) Minimum cover as recommended by the Engineer.

3.3.8.2 Minor Culverts

i) Minor culverts, with diameter smaller than or equal to 900 mm, typically convey runoff from swales and ditches and are located in road right-of-ways or in parks.

ii) The minimum diameter must be 450 mm. The preferred longitudinal slope of the culvert must be a minimum of 2% to prevent icing during winter. If smaller slopes are requested, the minimum culvert size might need to be increased to compensate for icing and snow deposition in the culvert.

iii) The minimum capacity of the culvert is dictated by the level of service required for the crossing. Typically, the culvert should have adequate capacity to convey the 1:100 year peak discharge without overtopping the road or driveway. Exceptions must be approved by Water Resources.

iv) Hydraulic design calculations of the culverts and upstream and downstream swales and/or ditches must be submitted. Design flow conditions and inlet and outlet head conditions must be identified.

v) Where feasible, overflow or bypass earthworks on one or both embankment approaches to a culvert should be included to preclude overtopping failure of the culvert itself.

vi) In case the roadway or driveway is overtopped, appropriate erosion protection must be provided to prevent wash-out.

vii) Culvert design should consider winter ice conditions and potential for ice accumulation.

viii) Erosion control measures should be considered in the design. The design should preclude damage up to the 1:100 year peak discharge rate with a minimum factor of safety of 1.2 on shear stresses incorporated into the erosion protection design. Erosion protection other than rip rap is preferred.

ix) Where possible, the design should be configured to prevent supercritical flow in the culvert.

x) Culverts should have flared ends on both ends of the pipe to integrate with embankment side slopes. Designs incorporating bevelled CSP conduits projecting from fill should be avoided.

xi) Minimum cover should be equal to the diameter or height of the culvert, or as recommended by the Engineer.

xii) Culverts in park areas (ER and MR) are to conform to Parks Standards Specifications and will be reviewed and approved by Water Resources and Parks. Refer to the City of Calgary's *Development Guidelines and Standard Specifications for Landscape Construction* for more information.

3.3.9 Pumping and Lift Stations

In general, stormwater pumping is not acceptable; storm systems must drain by gravity unless otherwise approved by Water Resources. Contact Water Resources for more information.

Where a storm lift station has been approved, designs must be submitted to Water Resources for review and approval. Submission should include, but is not

limited to:

- Sizing information, including dynamic system curve.
- Control philosophy, including operating procedures.
- Pump and force main failure scenario and backup.
- SCADA set up sensors and alarms including monitoring equipment for metering of flows, pressures and levels.
- Maintenance procedures for wet wells and force mains.

An O&M manual must be included. Refer to ***10.2.4 Pumping Facilities***.

3.4 Major System Component Design

The major drainage system conveys runoff from the extreme rainfall events that are in excess of the capacity of the minor underground system. In Calgary, the major system must be designed for the 1:100 year storm event. Components of the major system facilitate the safe conveyance of these overland flows to appropriate safe points of escape or storage. This section outlines the design criteria that apply to the components of the major system. Overland flows are also regulated by *Drainage Bylaw 37M2005*.

3.4.1 Roof Leaders

The most common means of accommodating roof drainage is to direct it to ground that is graded away from the building. Discharge of roof leaders should be onto grassed or pervious areas, or absorbent landscaping to help reduce the volume of runoff. Direct connection of roof leaders to a weeping tile drain, storm sewer, or sanitary sewer is prohibited (refer to *Drainage Bylaw 37M2005* and *Sewer Service Bylaw 24M96*). Drainage of runoff via downspouts, eavestroughing, piping, or other means must not discharge within 2.0 m of a street (refer to *Drainage Bylaw 37M2005*). Directing roof leaders to driveway surfaces is not recommended due to icing problems in the winter. Surface drainage is not permitted to drain to a weeping tile drainage system by any means other than infiltration from the surface. Window wells, roof leaders, and area drains must not have a direct connection to the weeping tile drainage system.

3.4.2 Lot Grading & Drainage

Carefully designed and controlled lot grading is an important component of the Major System and good stormwater management. All lot grading must be in compliance with the *Lot Grading Bylaw 32M2004*.

3.4.2.1 Types

There are typically three types of lots: split drainage, back-to-front, and front-to-back. Split drainage is the most frequent type of lot drainage in Calgary, and is the preferable drainage arrangement. Front-to-back drainage is not recommended.

3.4.2.2 Requirements

The finished grade elevations at buildings and on the property should be established in compliance with the *Lot Grading Bylaw 32M2004 and* the following requirements:

i) All property elevations must be shown on the Building Grade Plan (BGP).

ii) Grades adjacent to new buildings should be sufficient to allow for settlement of fill and maintenance of positive drainage away from the building.

iii) An overall minimum slope of 2% should be established on all lots to provide positive drainage away from buildings. The minimum grade should normally be exceeded if topography allows.

iv) Side yard elevations for lots adjacent to trap lows must be set a **minimum** of 0.20 m above the spill elevation or 1:100 year elevation, whichever is greater.

v) For DSSP lots, all pertinent grading must be shown. This includes berms, trap low ponding areas, ponds, and overland escape routes. All buildings on the lot must be protected from flooding.

vi) Down-ramp driveways and/or garages should be avoided.

3.4.2.3 MGs,/TOSs, and Restrictive Covenants (RMGs)

Requirements include:

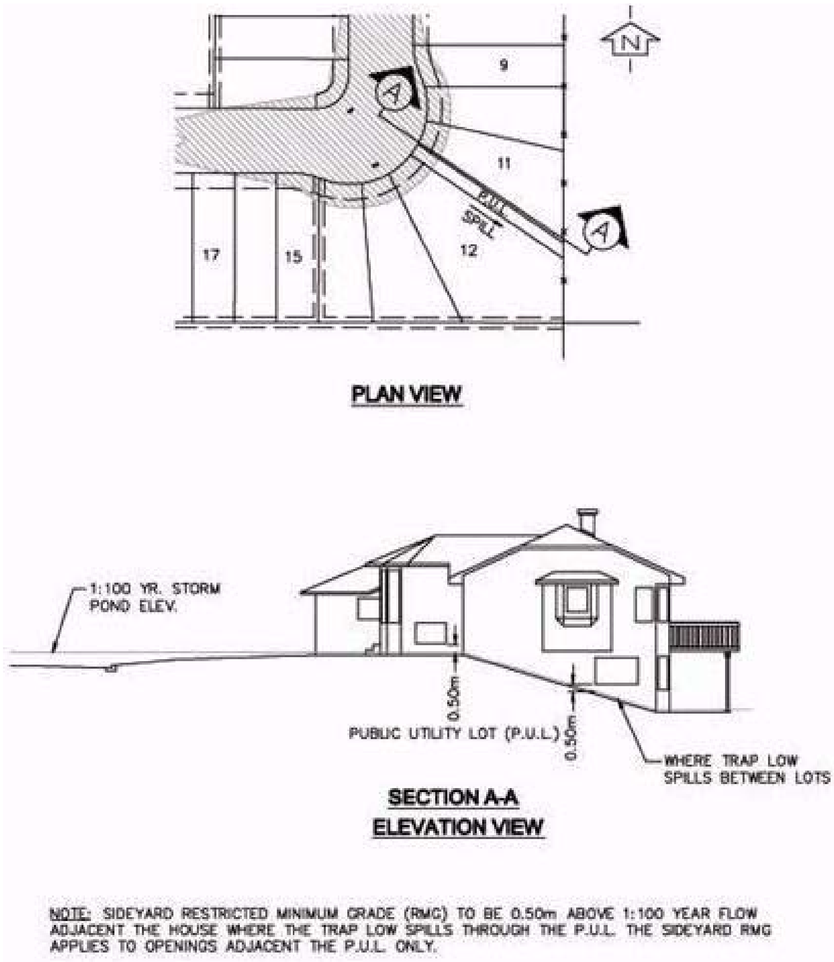
i) Minimum building opening elevations (MGs) must be specified for all lots adjacent to trap lows and stormwater ponds. Building openings refer to window wells, garage doors, and door entrances. These elevations are to be specified on the BGP for all affected lots. Refer to ***6.1.3 Overland Drainage and Escape Routes*** for more information about MG elevations at stormwater ponds.

Note: In the future, MGs may be required for lots adjacent to specific BMPs or SCPs.

ii) Where the overland escape route is via a **public road**, MGs are to be set a **minimum** of 0.30 m above the spill elevation ($Elev_{spill}$) or the 100 year elevation ($Elev_{100}$), whichever is higher. It is preferable that MGs be set 0.40 m above the spill elevation or the 100 year elevation; this permits flexibility in the design should upstream trap low ponding conditions change. Trap lows in lanes must adhere to the same minimum opening elevations. Main roadways are the preferred option for the overland emergency escape route; the use of lanes for this purpose is discouraged.

iii) **Where the overland escape route is via a PUL, MR, or utility right-of-way (RoW)** (which includes pathways, regardless of zoning), front and side MGs are to be set a **minimum** of 0.50 m above the corresponding adjacent maximum spill elevation ($Elev_{spill}$) or 100 year elevation ($Elev_{100}$), whichever is higher. Trap lows in lanes must adhere to the same minimum opening elevations. Deviations due to extenuating circumstances require the approval of Water Resources.

Figure 3-21: Minimum Openings - Lot Adjacent to a PUL.



iv) For Development Site Servicing Plans, top of slab (TOS) elevations for buildings are to be set a **minimum** of 0.30 m above the spill elevation ($Elev_{spill}$) or the 100 year elevation ($Elev_{100}$), whichever is higher.

v) Additional designations of “f” (front), “s” (side), “r” (rear), and “g” (garage) should be added to the opening elevations shown when there is more than one trap low adjacent to a lot.

vi) In all cases, the spill elevation ($Elev_{spill}$) must be based on the **highest** spillover elevation, whether it is located in the phase or site itself, or further downstream in adjacent lands.

vii) For instances without a practical emergency escape route, refer to ***3.4.8 Escape Routes***.

viii) Restrictive covenants are required when the spill depth of the trap low is greater than 0.30 m. Restrictive covenants require the registering of a drainage easement on affected lots.

ix) When a restrictive covenant is required, the minimum opening elevation must be identified as “RMG”. R designates the requirement for a restrictive covenant.

3.4.3 Roads

Overland flows will likely fill local roads during the 100 year event. The following criteria should be followed:

i) There must be continuity of overland flows between adjacent developments. Unless overland spill has been specifically designed in a downstream development, overland flow must be stored within the subdivision phase boundary. Approval from Water Resources is required where overland flows spill from development to development. MDP or SMDP reports should indicate the acceptability of, and the degree of, permitted overland flows.

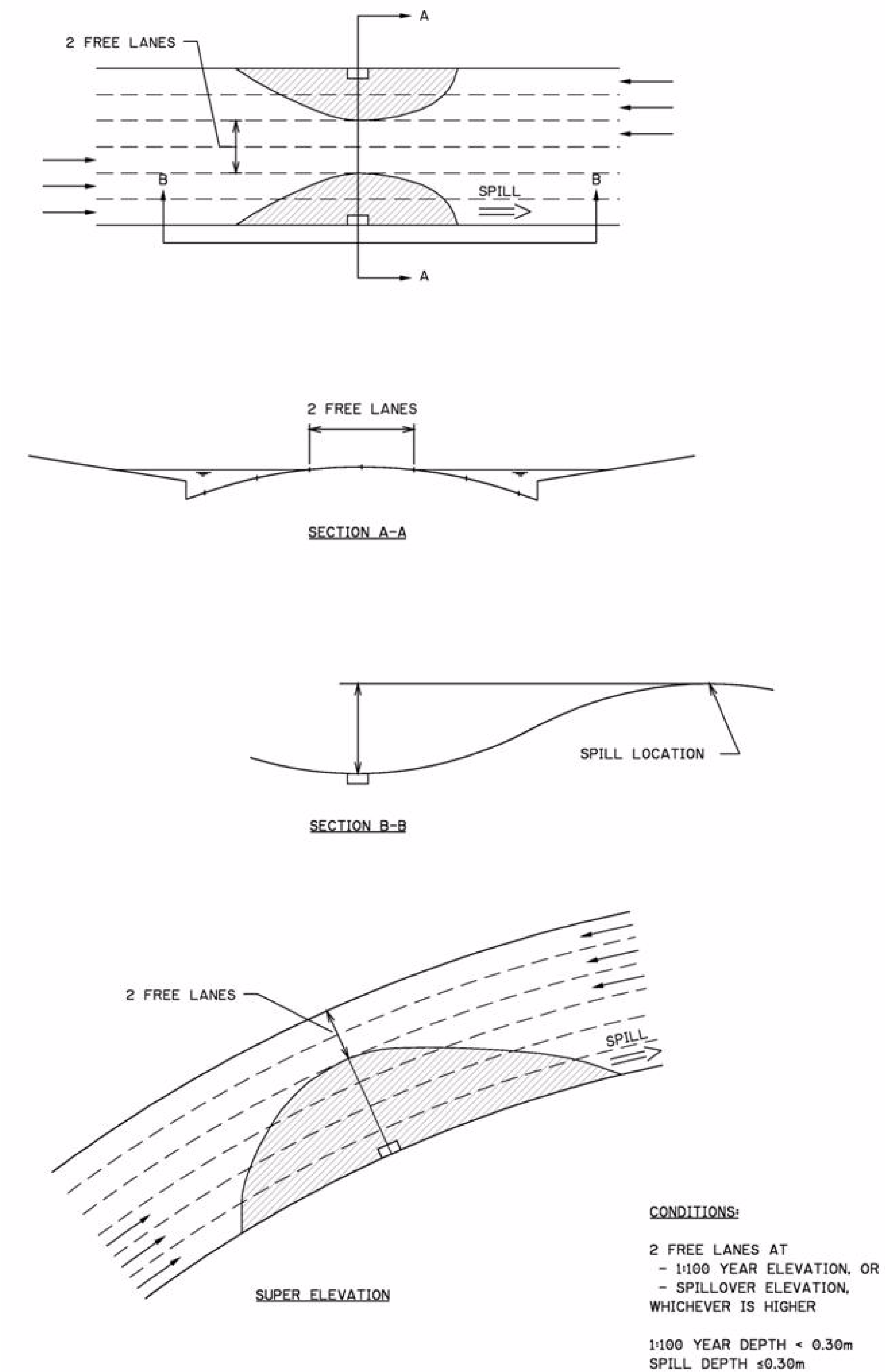
ii) Arterial and major roads must have at least two lanes that are not inundated with overland flow. Ponding on arterial and major roads should be avoided. The maximum trap low depth is 0.30 m and the maximum spill depth is 0.30 m (refer to ***Figure 3-22***). Where overland flow crosses an arterial or major road, the depth of flow should be less than 0.05 m. Minimum spacing required from vertical point of intersection (VPI) to VPI is 200 m.Refer to ***Figure 3-22*** for more information.

iii) Collector roads must have at least one lane which is not inundated with overland flow. The maximum trap low depth is 0.30 m and the maximum spill depth is 0.50 m. Where overland flow crosses a collector road, the depth of flow should be less than 0.10 m.

iv) The maximum depth of flow at the curbside gutter should be no more than 0.30 m. Depths less than 0.20 m are preferable (just above or at curb height).

v) **Standing water at all other low points (trap lows) should not exceed 0.50 m in depth. Where feasible, the maximum depth of ponding in trap lows should be 0.30 m.** Ponding on arterial and major roads should be avoided where possible; approval for ponding is required by Water Resources in these situations. Ponding on collector roads should be kept to a minimum where possible.

Figure 3-22: Inundation Requirements for Trap Lows along Arterial and Major Roads

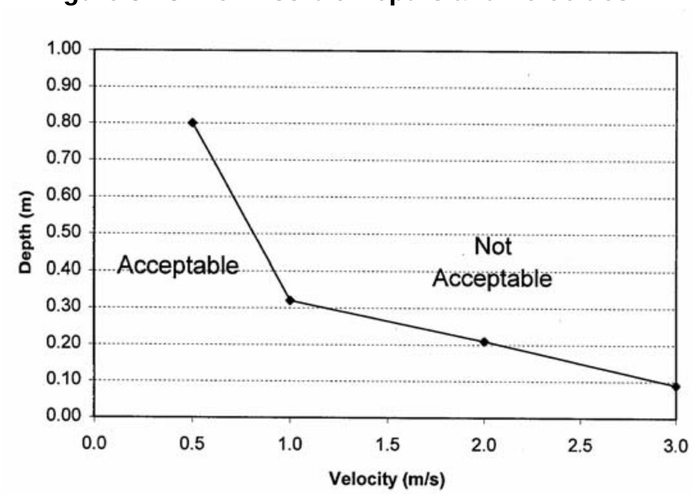


vi) The velocities and depths of flow for the major drainage system should not exceed the values outlined in ***Table 3-20***. Values outside of these limits must be approved by Water Resources.

Table 3-20: Permissible Depths for Submerged Objects

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09
Note: Based on 20-kg child and concrete-lined channels. Larger persons may be able to withstand deeper flows.	

Figure 3-23: Permissible Depths and Velocities.



vii) The combination of the flow rate, velocity, and depth of flow (Q, v, and d) must be indicated for all critical locations (into trap lows, out of trap lows, concrete swales with large drainage areas, etc.) to ensure depth-velocity requirements are met. Modelled flows may be pro-rated on an aerial basis.

viii) For roadway intersections with a continuous grade around a corner, special attention is required to ensure that the grade is sufficient around the corner to convey the drainage.

3.4.4 Trap Lows (Surface Ponding)

Trap lows are sags or depressions that are located along roads or in parks. Trap lows are part of the major overland system and provide stormwater storage areas local to the area where the flows are generated. Temporary storage is created during major rainfall events through the selection of specific types of CBs and/or the use of ICDs. Trap lows are a vital component of the major system in that they minimize the cascading of overland flows from one development to another, and therefore reduce the potential for property flooding.

3.4.4.1 Requirements

Trap low requirements are as follows:

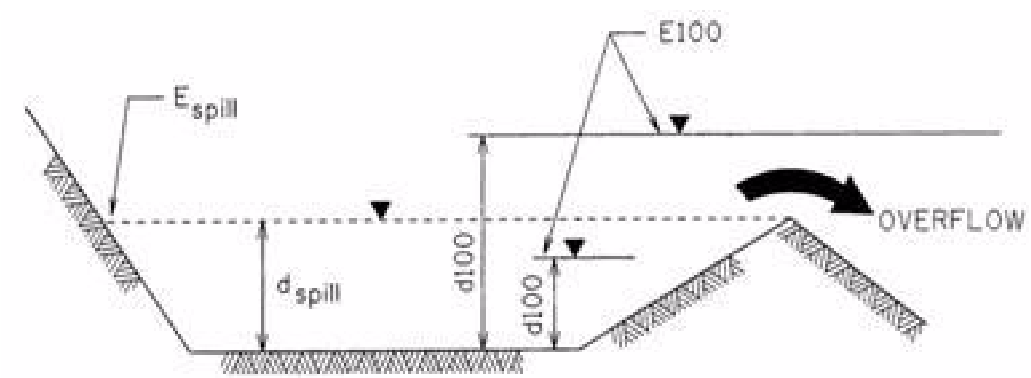
i) All trap lows must have a defined escape route. This escape route should be continuous through the development and any downstream areas. Escape routes should be shown on the applicable drawings and reports. Refer to ***11.6.2 Underground Utilities and Lift Stations, Surface Drainage Facilities, and Surface Improvements*** for required as-built information.

ii) **Standing water at trap lows should not exceed 0.50 m in depth. Where feasible, the maximum depth of ponding in trap lows should be 0.30 m.** Ponding on arterial and major roads should be avoided where possible; approval for ponding is required by Water Resources in these situations. Ponding on collector roads should be kept to a minimum where possible.

iii) Where possible, trap lows should be designed to contain all the flows generated from the 1:100 year event. Spillover is permitted on a limited basis, when the downstream system is designed to accommodate spillover flows and depth/velocity criteria are adhered to, as approved by Water Resources.

iv) Required storage volumes must be determined through stormwater modelling. Trap low information should include depths, elevations, and volumes for the 1:100 year requirement and the spill condition. Refer to ***Figure 3-24*** and ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information.

Figure 3-24: Trap Low Definition.



v) Trap low depths and elevations will affect the MG required for properties adjacent to the trap low. Restrictive covenants (RMGs) may also be required. Refer to ***3.4.2 Lot Grading & Drainage***.

vi) The number of trap lows in lanes should be kept to a minimum due to space restrictions that might impact garage grades and driveways. For trap lows in lanes, it is necessary to pave 23.0 m in both directions.

vii) Where possible, consideration should be given to locating trap lows away from arterial, major, and collector roads, entrances to residential or local roads, and major intersections. These locations should be kept clear for emergency vehicle use.

viii) Where trap lows on major and collector roads can only be drained by pumping (i.e. underpasses), the area tributary to the trap low should be minimized. In cases where back-up power supply and back-up pumps are not feasible, adequate (underground) storage capacity must be provided to completely store the entire runoff from a 24 hr, 1:100 year event without the ponding exceeding 0.30 m depth in the trap low.

ix) For DSSPs, driveway entrances should be located away from trap lows located on public roads or property. It is the designer/consultant's responsibility to identify locations of trap lows in the adjacent public area.

x) Where pumping is provided to drain a trap low or on-site storage unit on private sites, the storage capacity must accommodate the entire runoff volume from a 24 hour, 1:100 year event. In addition, a freeboard of 0.50 m must be provided above the elevation corresponding to the entire runoff volume from the 24 hour, 1:100 year event to minimize the potential of damage to property or spillage into adjacent properties.

3.4.4.2 Manhole (MH) Seals

Where possible, sanitary sewer MHs should be located outside of trap lows. For any sanitary sewer MHs located in trap lows, sanitary seals are required to reduce infiltration. One of the following approved MH sealing methods must be used:

- Plastic or rubber plugs inserted into the holes of the MH lid. One hole should be left open for access purposes.
- One-hole MH lid.

The one-hole MH lid is the preferred option for sealing. In certain circumstances, sealing around the MH lid may also be permitted. MH seals are also required on weeping tile MHs located in trap lows for designs that employ the three pipe system. **Parson inserts are not permitted.**

3.4.5 Roof-Top Storage

Commercial, industrial, and multi-family sites may use roof-top storage as part of the on-site storage requirements. Refer to ***CHAPTER 4: DEVELOPMENT SITE SERVICING PLANS (DSSPs)*** for more information.

3.4.6 Underground

When surface storage is not sufficient to provide all of the storage requirements, alternative storage methods such as underground storage should be considered. Approval for all underground storage designs is at the discretion of Water Resources.

Typically, the design loading for the underground storage chambers should be H20. For installations under pavement or other hard surfaces designated as fire vehicle access, H25 design loading must be used. Refer to *CSA B184 Series-11* for the design of polymeric subsurface stormwater management structures.

Underground storage designs and structures must be included in SWMR and/or DSSP submissions to Water Resources, Development Approvals. Submissions should also include (but are not limited to) the following:

- Sizing information.
- Overflow conditions.
- Operating and maintenance procedures (O&M manual).
- The need for pre-treatment and post-treatment, sediment build-up and storage capacity.
- Inspection and maintenance access.
- Anticipated life span.

Infiltration and/or percolation into the subsoils are not permitted if the runoff is contaminated with highly mobile constituents as assessed by an environmental specialist from The City of Calgary's Environmental & Safety Management business unit. Any infiltration and/or percolation provisions must be designed by a professional Geotechnical Engineer. Any proponent that proposes to utilize deep infiltration and/or percolation as an avenue to meet runoff volume targets must:

i) Assess the impact on the ground water table.

ii) Demonstrate that the assumed percolation rates are sustainable in the long run on a local and regional level.

iii) Demonstrate that the percolating runoff will have no detrimental impact on the adjacent road base or any downstream structures.

iv) Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

3.4.7 Swales

Vegetated swales, concrete swales, and bioswales are used to convey overland flows during minor and major rainfall events. In minor events, the swales are typically used to convey flows to CBs and/or allow the flow to infiltrate into the bioswale media. In major events, higher velocities and depths of flow will be conveyed. Velocities and depths of flow should be carefully controlled. The combination of the flow rate, velocity, and depth of flow (Q, v and d) should be indicated on the appropriate reports and drawings.

Velocities and depths of flow for vegetated swales, concrete swales, and bioswales should not exceed the values outlined in ***3.4.3 Roads (v)***, ***Table 3-20*** and ***Figure 3-23***. Values outside of these limits must be approved by Water Resources. While this criterion includes roadside ditches and swales, it does not apply to natural or naturalized drainage systems or larger conveyance systems such as the Shepard Ditch. Regardless, appropriate precautions such as the provision of signage or fencing should be considered at any locations where the public might access drainage courses and hence public safety might be impacted. Contact Water Resources for more information.

Special design consideration is required when swales discharge onto sidewalks and streets. In certain situations the potential exists for ice to build up in areas that are north-facing, that are in shade, or where the street has a low slope.

3.4.7.1 Vegetated Swales

The use of grass or vegetated swales must be carefully considered in terms of design. Requirements are as follows:

i) Velocities in grass swales must be controlled so that erosion does not occur. In general, the maximum permissible velocity for easily eroded soils should be maintained between 0.80 m/s and 1.80 m/s, depending on the vegetation cover and slope. For erosion resistant soils, the maximum permissible velocity should be maintained between 1.10 m/s and 2.40 m/s, depending on the vegetation cover and slope.[19] Alternate sources of information may be used for reference. Permissible velocities should be verified.

ii) Longitudinal slopes must ensure proper drainage and conveyance of flows. A minimum slope of 2% is recommended where possible. Grass swales in parks (MRs, ERs) require approval from both Water Resources and Parks.

    Longitudinal slopes flatter than 2% may be considered on a case-by-case basis if the grassed swale is equipped with a subdrain. Refer to The City of Calgary's *Development Guidelines and Standard Specification Landscape Construction* for more information on swales in parks.

iii) All flows, up to and including the 1:100 year flow, must be contained in the swale.

iv) For bioswales, refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES***.

3.4.7.2 Concrete Swales

Concrete swales, or gutters, are typically used to convey flow from back of lot drainage. **They are not intended to be used as overland escape routes.**

There are different types of concrete swales available. Refer to The City of Calgary's *Standard Specifications Sewer Construction* for more information.

- **Standard** concrete swales are to be used when possible. Overland flows, up to and including the 1:100 year event, should be contained in the gutter. For gutters on a supercritical slope, the full energy head must be contained in the gutter to prevent the flow from jumping out of the gutter at bends or misaligned joints.
- **Deep** concrete swales are required when overland flows cannot be contained within a standard gutter.
- **Highback** concrete swales are required at points where the swale changes direction. The highback should extend far enough downstream to ensure that the flow does not jump out of the swale as the flow bounces from side to side. Where possible, turns should have an adequate radius to facilitate flow conveyance.
- **Overland Escape Route** concrete swales are required at locations where the overland escape route is not along a roadway or paved pathway. This typically

19. Source: USDA 1966.

includes escape routes via Utility RoWs (where accepted), and could include PULs and MRs as well (at the discretion of Water Resources). In general, the Overland Escape Route swale is 1.00 m wide, with a minimum 1.80 m easement (refer to The City of Calgary's *Standard Specifications Sewer Construction* and ***3.4.7 Swales***). However, each situation must be evaluated separately to ensure that the swale has adequate cross-sectional area to convey the anticipated flows.

Concrete swale requirements are as follows:

i) The minimum slope for concrete swales is 0.60%.

ii) Use of the drainage easement to convey overland flows should be avoided; approval from Water Resources is required if drainage easements are proposed. **Overtopping of the concrete swale is not permitted.**

    It is recommended that the operation of concrete drainage gutters be evaluated as early as possible during the layout phase of a subdivision (i.e., at the time of the preparation of the Outline Plan and SMDP), if even only in a preliminary fashion.

iii) Swale hydraulics should be considered along with the effect of turns on critical and supercritical flows and keeping the flow within the swale. Highback and special design swales may be required to overcome these problems.

iv) Rear yard and side yard concrete swales should not be used as overland escape routes. Where a side or rear yard overland escape route has been approved by Water Resources, the appropriate type of swale must be used (Overland Escape Route Swale, Highback or Standard).

i) Details regarding lengths and type of swale required must be shown on the construction drawings. City of Calgary specifications can be referenced as required.

ii) The number of lots draining to swales should be minimized. Swales were originally designed for grade control, not flow conveyance.

iii) Fences crossing concrete swales must be kept a minimum of 150 mm above the top of the swale to facilitate flows. **Blockage of the swale is not permitted.** Refer to *Drainage Bylaw 37M2005*.

3.4.8 Escape Routes

There must be **continuity** of overland flows between adjacent developments.

A continuous overland escape route is required with the conveyance of overland flows to appropriate safe points of escape or storage. Overland escape routes will always exist, whether one is planned or not. However, an unplanned escape route could lead to flooding or erosion. Therefore, it is important that an overland escape route be properly **planned, designed, and controlled**. Overland escape routes should be planned at the MDP and Outline Plan (OP) levels. Specific details should be shown at the subdivision and DSSP levels.

Escape routes should always be via public roadways where possible. When an escape route cannot be accommodated via a roadway, it should preferably be through a PUL utilizing a paved pathway, a paved walkway or a designated overland escape route swale (or approved equivalent). An escape route between two homes through a MR may be considered on a case-by-case basis (see ***3.4.2 Lot Grading & Drainage*** for lot grading requirements). Proper design of these areas as escape routes is required, and is subject to approval by Water Resources. Use of utility RoWs as overland escape routes is generally not acceptable; both an overland easement and a utility RoW are required. Site-specific situations should be discussed with Water Resources. The use of downhill cul-de-sacs is discouraged. Escape routes through private properties by use of overland easement is also discouraged; site-specific situations require the approval of Water Resources.

Concrete swales and vegetated swales may only be used to convey overland flows from back of lot drainage. They are not intended to serve as overland escape routes. Fences or other obstacles must not impede overland flows; a drainage route free of obstacles is required. A clearance of 150 mm is required for fences, more if the flows are more significant.

Spillover elevations that determine escape routes must be carefully constructed to prevent changes in the escape route, which could result in negative impacts to downstream areas and cause potential flooding. These spillover elevations must be included in the as-built information. Refer to ***11.6.2 Underground Utilities and Lift Stations, Surface Drainage Facilities, and Surface Improvements***.

In the absence of a demonstrated practical overland emergency escape route at a trap low (i.e., infill development, redevelopment in existing communities, or elevated adjacent phases), and subject to prior approval by Water Resources, the following options may be considered (listed in declining order of desirability):

i) Provision of a piped emergency escape route (i.e., a culvert that daylights downstream) with a diameter equal to or greater than 450 mm. The invert of this pipe must be at 0.50 m or lower above the CB rim. The CB should be a combination of a grated top MH and a storm back. MGs must be 1.00 m above the CB rim, or 0.50 m above the 1:100 year elevation ($Elev_{100}$), whichever is higher.

ii) Increase the interception capacity of the CB to 150 L/s/ha (providing capacity is available) with a CB lead greater than or equal to 450 mm in diameter and no ICDs. The CB should be a combination of a grated top MH and a storm back. MGs must be 1.00 m above the CB rim, or 0.50 m above the 1:100 year elevation ($Elev_{100}$), whichever is greater.

iii) For infill or retrofit situations where no changes can be made to existing grades or the storm sewer system, the MGs must be 1.00 m above the CB rim, or 0.30 m above the 1:500 year elevation ($Elev_{500}$), whichever is greater. In addition, a second Type C CB must be provided at a higher elevation to provide relief in case the grate is clogged.

Refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for more information about escape routes from stormwater ponds.

3.4.9 Receiving Waters

It is important to recognize that receiving waters form an integral part of both the major and minor drainage systems. Drainage does not end at the boundary of the development or site being designed. Stormwater management, along with erosion, flooding, and water quality must be taken into consideration.

3.4.10 Outfall Channels

The use of open channels in Calgary has generally been minimal. When outfall channels are used, safety, aesthetics, and maintenance costs must be considered. Approval from Water Resources is required; approval from Parks might also be required.

3.4.11 Stormwater Ponds

Stormwater ponds are the most commonly used forms for controlling runoff. They are an important component of the major system. In general, stormwater ponds consist of dry ponds, wet ponds, wetlands, and any hybrid ponds. Design criteria are outlined in ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***.

3.4.12 Best Management Practices (BMPs)

BMPs and other SCPs are activities or practices, or a combination of practices, that are designed to reduce runoff volume and/or prevent or reduce the release of pollutants to receiving waters or streams. The selection and design of stormwater BMPs must incorporate both water quantity and water quality concerns. Current stormwater quality criteria for the City of Calgary requires the removal of a minimum of 85% Total Suspended Solids (TSS) for particle sizes greater than, or equal to, 50 µm. Care should be made in selecting the appropriate BMP or combination of BMPs.

The design of all BMPs requires the approval of Water Resources. As well, all BMPs must be inspected and maintained on a regular basis as per *Drainage Bylaw 37M2005*; records should be kept to demonstrate this.

Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** for more information and details.

3.5 Floodplain Requirements

Developments in floodplains and floodway areas are subject to the regulations described in *Land Use Bylaw 1P2007*.

In general, all landowners or developers proposing construction within the 1:100 year floodplain of the Bow River, Elbow River, and Nose Creek drainage basins are required to follow *Land Use Bylaw 1P2007*. Floodplain maps are available at the Planning Policy/Building Regulations sales counter (Municipal Building).

Floodplain requirements are as follows:

i) No new buildings or other new structures will be allowed except for the replacement of existing single family, semi-detached, duplex dwellings and/or accessory buildings on the same locations.

ii) No replacement of, external alterations to, or additions to existing buildings will be allowed that might increase the obstruction to floodwaters on that site, or have a detrimental effect on the hydrological system or water quality.

iii) Where development or redevelopment is permitted, the appropriate requirements will be made by Water Resources. The main requirements are as follows (but are not limited to these):

- The minimum first floor elevation must be constructed at or above the relevant designated flood level. All electrical and mechanical equipment must be located at or above this elevation.
- A sump pump should be provided in the basement with the outflow pipe looped and discharging above the designated flood level. Cut-off valves must be installed on the sewer lines or gravity flow basement drains must be eliminated.

3.6 Technical Requirements

Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information on required reports and construction drawings.

CHAPTER 4: DEVELOPMENT SITE SERVICING PLANS (DSSPs)

4.1 General

In many respects, stormwater design of commercial, industrial, and multi-family lots is similar to or the same as stormwater design of subdivisions. Therefore, reference to other sections in this manual are required. Overall, for minor system and major system component design, refer to ***CHAPTER 3: STORMWATER DESIGN***. For sanitary design, refer to The City of Calgary's *Design Guidelines for Development Permits, Development Site Servicing Plans and Waste & Recycling Services for Commercial/Industrial Applications*.

Development Site Servicing Plans (DSSPs) will generally be circulated through the Development Permit (DP) review process. Refer to The City of Calgary's *Design Guidelines for Development Permits, Development Site Servicing Plans and Waste & Recycling Services for Commercial/Industrial Applications* for requirements and process review information. **All DSSPs must be designed and prepared by qualified consultants.** Qualified consultants for drainage and sewer servicing typically include civil or municipal engineering companies.

Submission of a Stormwater Management Report (SWMR) is required for:

- All sites greater than 2 ha.
- Sites smaller than or equal to 2 ha, and without servicing by a storm sewer system.
- Sites smaller than or equal to 2 ha, and where Best Management Practices (BMPs) and Source Control Practices (SCPs) are proposed to reduce on-site storage requirements, control runoff volume, and/or enhance water quality.
- Re-development of sites smaller than or equal to 2 ha that are part of a larger private site.

4.2 Minor System

The **minor** system provides a basic level of service by conveying flows from the more common (i.e., low intensity, more frequent) rainstorm events. The system consists of the underground network of pipes and associated structures. Components of the minor system typically include:

- Gutters and roof leaders.
- Weeping tile drains.
- Lot drainage.
- Source Control infrastructure, such as bioswales, catchbasins (CBs), inlets and leads.
- Underground pipe system.
- Manholes (MHs) and junctions.
- Outfalls.
- Receiving waters.

Note: Some components may be classified under both minor and major systems.

4.2.1 General Requirements

i) The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary. Combined systems are not permitted.

ii) In general, the public storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the obvert of the pipe. Sewer Pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface to avoid compromising CB interception.** Also, proper aeration and venting must be considered as per ***5.5.2 Design***.

Flow restrictions are often incorporated in conjunction with trap low storage capacity to ensure that the downstream storm sewer system does not surcharge in 1:100 year flow conditions. For some sites there may be a requirement for a three-pipe system in cases where the HGL is above the weeping tile drain.

iii) On private sites, surcharge due to back-up from the flow control from the private site to the public system is acceptable. However, the designer must ensure that the maximum 1:100 year water level is at least 0.30 m below slab elevations. This will also ensure that low-lying areas such as parkades are not negatively impacted by the backwater conditions.

iv) The minor system is to be designed according to the level of service stipulated in ***4.2.2 Level of Service***. The majority of sites will be designed using the Unit Area Release Rate Method.

v) Where the public storm sewer system is surcharged, the hydraulic analysis of the flow controls, HGL, and trap low storage requirements within the private site must be based on the HGL of the public storm sewer system.

4.2.2 Level of Service

A basic level of service is provided by the minor system. In Calgary, this has typically been sized for the 1:5 year storm event since 1952. Prior to 1952, the level of service was based on a 1:2 year storm event. In Calgary, sizing of the storm trunks was previously done using the Rational Method design.

The City of Calgary has now adopted the Unit Area Release Rate Method as the preferred approach to storm trunk design. This method uniformly distributes the storm trunk capacity, on a per hectare basis, for the area tributary to the storm trunk.

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha). In general, and in the absence of SCPs that could significantly reduce runoff volumes, the recommended minimum unit area release rate is 70 L/s/ha. On steeper terrain, where on-street storage is minimal, the design rate might need to be higher. **Permitted lot release rates are to be specified in the subdivision construction drawings when servicing is available. These release rates must be strictly adhered to.**

4.2.2.1 Unit Area Release Rate Method

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha). Refer to ***3.1.2.3 Unit Area Release Rate Method***.

Figure 4-3 should be used instead of ***Figure 3-1*** for determining storage requirements for DSSP lots. Refer to ***4.8.1.2 Unit Area Release Rate Method***.

4.2.2.2 Modified Unit Area Release Rate Method

Until such time as all drainage catchments are designed using the Unit Area Release Rate Method, a modified method may have to be used for design of the minor system. While the Modified Unit Area Release Rate Method is preferred, use of the Rational Method is allowed when the remaining drainage area in a catchment is less than 30 ha, there are no stormwater ponds, and where the storm trunk was originally designed using the Rational Method.

Refer to ***3.1.2.4 Modified Unit Area Release Rate Method***.

4.2.2.3 Rational Method

The Rational Method was originally used for the design of storm sewer systems in Calgary. It was replaced by the Unit Area Release Rate Method in the 1990s, except for **catchment areas** that were originally designed using this method, provided the remaining undeveloped area is smaller than or equal to 30 ha. Areas larger than 30 ha should be designed using the Unit Area Release Rate Method or the Modified Unit Area Release Rate Method. Use of the Rational Method should be limited where possible, even for areas smaller than 30 ha. Refer to ***3.1.2.5 Rational Method***.

For industrial, commercial, and multi-family lots, the following runoff coefficients (C) should be used for the Rational Method:

Service Type	**C**
Roof	1.00
Pavement	0.90
Gravel	0.50
Landscaping	0.30

Runoff Coefficients different than the above are subject to approval by Water Resources.

4.3 Major System

The **major** stormwater drainage system conveys runoff from extreme rainfall events that are in excess of the capacity of the minor underground system. Components of the major system typically include:

- Gutters and roof leaders.
- Lot drainage.
- Roads.
- Swales.
- Trap lows.
- Escape routes.
- Storage facilities (stormwater ponds),.
- Culverts, Outfalls.
- Receiving waters.

Note: Some components may be classified under both minor and major systems.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage. Therefore, it is important to examine grading plans to ensure there is an overland route that has reasonable capacity.

4.3.1 General Requirements

i) The major system must be designed as an overland system.

ii) A continuous escape route must be provided for the overland flows. Adjacent properties must be protected from flooding by these flows.

iii) The major system is to be sized according to the level of service stipulated in ***4.3.2 Level of Service***.

4.3.2 Level of Service

In Calgary, the major system must be designed for the 1:100 year storm. This includes all stormwater and evaporation ponds. This is to provide a reasonable level of flood protection. Development Site Servicing Plans must provide on-site retention to contain the runoff generated by a 1:100 year event.

The (landscaped) perimeter of private sites, including driveways and access roads, may drain onto the public roadway system if the corresponding area and imperviousness were accounted for in the drainage design and analysis of the public roadway. Boundaries and imperviousness ratios must match the preceding SWMR. Typically, this perimeter should only be a few metres wide. Parking lots and storage areas are not to be included in this perimeter.

4.4 Runoff Volume

With the increasing awareness that increased stormwater runoff can cause erosion, increase pollutant loadings, degrade receiving water body quality, and adversely impact aquatic habitat, **the need to control both the rate and the volume of runoff** has been identified.

Overall targets have been set for the Nose Creek, West Nose Creek, and Pine Creek watersheds. While the Water Management Plans (WMPs) for these watersheds provide the overall targets for a large area, for new developments the designer must use the actual site-specific targets for the proposed private sites from preceding Master Drainage Plans (MDPs), Staged Master Drainage Plans (SMDPs) and/or Stormwater Management Reports (SWMRs). For redevelopment or retrofit projects, a WMP might supersede older MDPs, SMDPs and/or SWMRs. Contact Water Resources to confirm runoff volume targets as needed.

4.5 Minor System Component Design

This section outlines the design criteria that apply to the components of the minor system for Development Site Servicing Plans. Refer to ***3.3 Minor System Component Design*** for information on the following components:

- ***3.3.2 Pipes***
- ***3.3.3 Manholes (MHs)***
- ***3.3.4 Catchbasins (CBs)***
- ***3.3.5 Inlet Control Devices (ICDs)***
- ***3.3.6 Weeping Tile Drains (Foundation Drain)***
- ***3.3.7 Outfalls***
- ***3.3.8 Culverts***
- ***3.3.9 Pumping and Lift Stations***

4.5.1 Service Connections

Service connections can be made to the public storm sewer and/or to the public ditches or bioswale, if applicable. The design of service connections must be reviewed and approved by Water Resources.

4.5.1.1 General

i) No portion of private sewer systems are permitted in bylawed setback areas, except for service connections.

ii) Extensive and/or complicated external sewer systems must be installed with the surveyor's grade sheets and batter boards. Where this is required, DSSPs will be stamped for inspection purposes.

iii) Comments regarding development permit requirements are provided to the applicant prior to circulation of the DSSP. It is the designer/consultant's responsibility to ensure that the drawings meet current stormwater design standards. Adjacent site conditions (i.e., trap lows, berms, etc.) should be identified and taken into account to ensure adequate site design.

4.5.1.2 Servicing

i) Servicing connections are to be made to the public storm sewer or to the public ditches or (bio)swale, if applicable.

ii) An existing service connection may be used if it has adequate capacity and is inspected and approved by Water Resources. Contact Water Resources for more information.

iii) Separate services are required for separate properties, whether or not the property or lot lines are existing or proposed.

iv) Only one sanitary connection and one storm connection are allowed to service an individual lot. In case a third pipe system is provided for weeping tile drainage, one weeping tile connection per lot is allowed as well. Additional connections (i.e., in the case of the consolidation of multiple lots with existing connections) require prior approval from Water Resources, and the applicant must demonstrate that the lot cannot be physically serviced by a single connection. Contact Water Resources for more information.

v) Force mains and private sewers are not permitted on City property.

vi) Designers/consultants must ensure that sump pumps are adequately sized.

4.5.1.3 Location

i) Service connection locations must be made at right angles to the City sewer main.

ii) Connection lines must be located relative to property lines.

iii) Sanitary sewer MHs and cleanouts will not be permitted within stormwater retention areas (trap lows, ponds, etc.). Water Resources might approve sanitary sewer MHs in trap lows, provided there are no other suitable locations, the sanitary sewer MH cover is sealed (rim and holes, refer to ***3.4.4.2 Manhole (MH) Seals***), and appropriate venting and aeration is provided.

4.5.1.4 Grades

Existing and proposed invert elevations, and the invert of the service lead at the property line, will be checked by the Building Grade Supervisor and indicated on the plan. Use the invert elevations given by the Building Grade Supervisor to revise the design as necessary at re-submission. In special cases, especially downtown areas, the sewer connection must be pre-installed at the site prior to on-site sewers being installed, due to possible conflicts with other utilities in the street.

For **private subdivisions**, grades at the property line should be set by adhering to *Lot Grading Bylaw 32M2004* and accounting for the following:

- Adding slope of pipe.
- Allowing for construction and datum error.
- Allowing more grade if there is a possible conflict with other utilities.
- Considering HGL elevations where surcharge conditions occur.

4.5.1.5 Manholes (MHs)

A MH is required on a main for a connection when:

i) The diameter of the connection line is greater than one half the diameter of the main.

ii) The length of the service connection from the building to the main is greater than 30.0 m.

Otherwise, direct connection to the main sewer is permitted. Refer to The City of Calgary Water Resources' *Standard Specifications Sewer Construction* for details. Where possible, a cover of 1.20 m over the storm pipe should be maintained for frost protection; if 1.20 m cover cannot be achieved then other means of frost protection may be required.

4.6 Major System Component Design

There are no separate design criteria that apply to the components of the major system for DSSPs. Refer to the following for information on the design of specific components:

- ***3.4.1 Roof Leaders***
- ***3.4.2 Lot Grading & Drainage***
- ***3.4.3 Roads***
- ***3.4.4 Trap Lows (Surface Ponding)***/
- ***3.4.7 Swales***
- ***3.4.8 Escape Routes***
- ***3.4.9 Receiving Waters***
- ***3.4.10 Outfall Channels***
- ***4.7 Servicing***
- ***4.9 Storage Options***
- ***4.9.1 Parking Lot Storage (Trap Lows)***
- ***4.9.2 Roof Top Storage***
- ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***

4.7 Servicing

4.7.1 Serviced Sites

Storm connection is required in areas where storm servicing is available. Connection locations are indicated in the standard development permit comments. Permitted release rates (L/s/ha) and volume control (mm, where applicable) targets should also be identified where possible. However, it is the designer/consultant's responsibility to determine permitted flow rates, based on the approved Stormwater Management Report (SWMR) and/or construction drawings. Areas where the HGL is a concern are also indicated on the approved construction drawings for the public storm sewer system.

It is important that the permitted design flow for the lot is not exceeded. To ensure the design flow to the public main is not exceeded, three methods are available. In order of preference, these methods are:

i) **Reducer Pipe:** The upstream section of the last pipe segment that ties into the public main system can be reduced to the appropriate size; the size and length of the reducer pipe is a function of the head conditions that exist. However, an alternate type of restriction should be considered for pipe sections smaller than 150 mm in diameter.

ii) **Reduced Pipe Size:** The entire length of the last pipe segment (MH to MH) that ties into the public main can be reduced to the appropriate size (based on any head conditions that exist). However, an alternate type of restriction should be considered for pipe sections smaller than 150 mm in diameter.

iii) **Bolted Inlet Control Device (ICD) Plates:** Bolted ICD plates will be considered for the last pipe segment that ties into the public main. The ICD must be installed in a MH on the outgoing pipe and bolted in place. **The owner is responsible for any downstream flood damage that may occur from removal of the bolted ICD; removal of any devices used to control flows is an offence under** *Drainage Bylaw 37M2005***.**

In some areas (such as Section 22-24-29-W4M in the South Foothills Industrial Park) servicing by gravity might not be practical or might be cost prohibitive. In these cases, pumping may be considered, at the discretion of Water Resources. Refer to ***3.3.9 Pumping and Lift Stations*** and ***10.2.4 Pumping Facilities*** for information on pumping systems.

In the absence of an overland emergency escape route, storage requirements will need to be increased to store the entire runoff volume from a 24 hour, 1:100 year storm event. In addition, a freeboard of 0.50 m must be provided above the elevation corresponding to the entire runoff volume from a 24 hour, 1:100 year event to minimize the potential of spillage into adjacent properties. Refer also to ***4.8 Storage Requirements and Methods*** and ***3.4 Major System Component Design***.

4.7.2 Non-Serviced Sites

In general, development is **not** permitted unless servicing is available. However, Water Resources will permit development in some areas provided certain conditions are met. At all times, an SWMR must be submitted that will address **both interim** (without servicing) **and ultimate** (with servicing) development conditions. Contact Water Resources for more information.

4.7.2.1 Dry Wells

When storm sewers are not available, a **temporary** dry well system may be considered by Water Resources. **Dry wells are only permitted until such time as servicing becomes available.** Dry wells will only be considered for small lots (less than 1 ha) where soil conditions allow for adequate drainage; dry wells located near slopes require geotechnical consideration. The percolation rate must be determined by a Geotechnical Engineer, and must incorporate appropriate safety factors to represent clogging over time.

Infiltration and/or percolation into the subsoil is not permitted if the runoff is contaminated with highly mobile constituents, as determined by an environmental specialist from The City of Calgary's Environmental & Safety Management business unit. Refer to The City of Calgary Water Resources' *Standard Specifications Sewer Construction* and/or ***4.9 Storage Options*** for more information.

In the downtown core (Bow River to 9th Avenue S and Elbow River to 14th Street W), dry wells will be permitted for gravel parking lots or gravel parking lots with paved lanes for a period not exceeding 5 years. If the lot is to be in service longer, a storm connection is required. Paved lots in the downtown core and all parking lots (paved or gravel) outside of the downtown core must have a storm connection.

4.7.2.2 Zero-Discharge Ponds

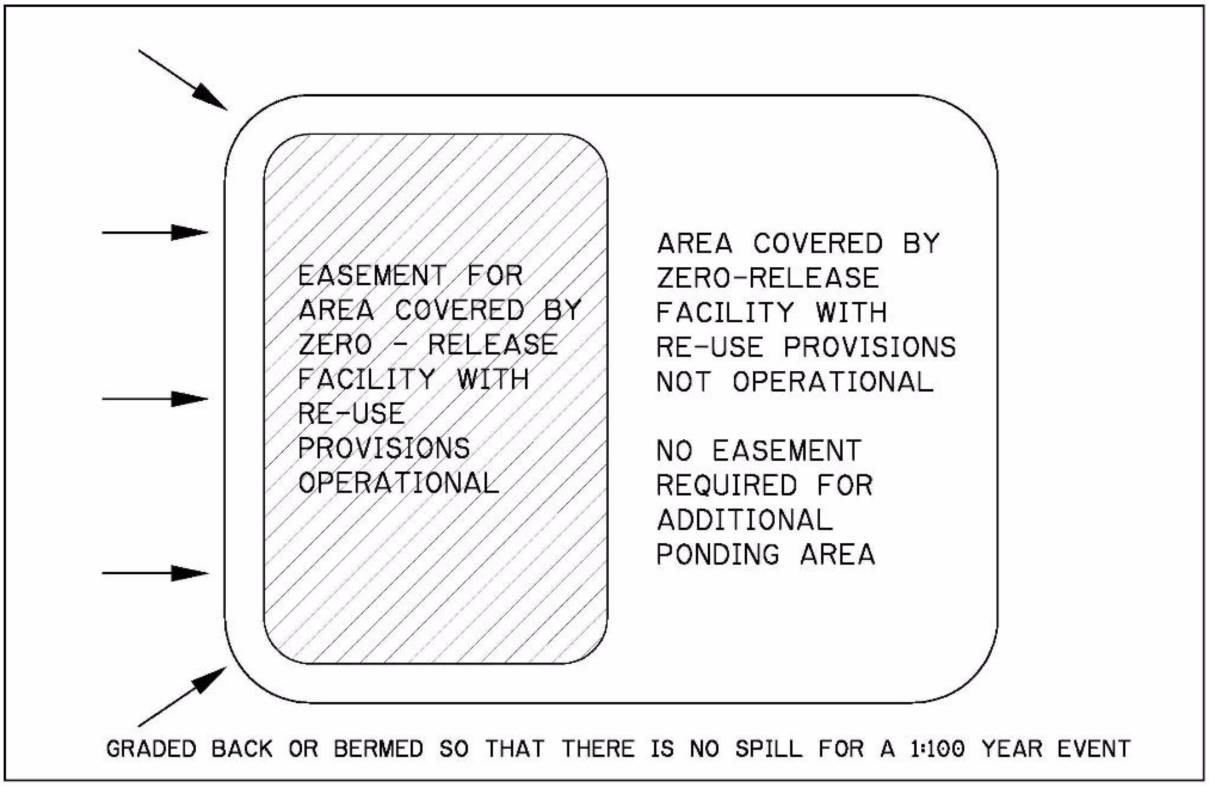
In some areas where off-site servicing is not available, zero-discharge facilities such as evaporation ponds may also be considered, at the discretion of Water Resources. Irrigation and/or other methods to reduce the footprint of these facilities can be taken into account when sizing these facilities, based on two conditions:

i) The long-term viability of the water re-use and/or runoff reduction techniques needs to be demonstrated to the satisfaction of Water Resources.

ii) A scenario in which only evaporation is used will be assessed; there must be no spillover into adjacent lands or onto public right-of-ways under this scenario.

Typically, an easement is provided for the area that will be covered by the zero-discharge facility, assuming that the water re-use provisions are operational. However, the grading of the property has to be such that no spillover into adjacent lands or onto public right-of-ways occurs up to a 1:100 year condition if the water re-use system fails or is not operational. An appropriate emergency overland escape route must be provided to accommodate the excess runoff in case of events in excess of a 1:100 year conditions. Refer to ***Figure 4-1*** for clarification of the grading and easements for zero-discharge facilities. Refer to ***4.8.4 Zero-Discharge Facilities*** for more information on how to establish the footprint and capacity of these facilities.

Figure 4-1: Grading and Easements for Zero-Discharge Ponds

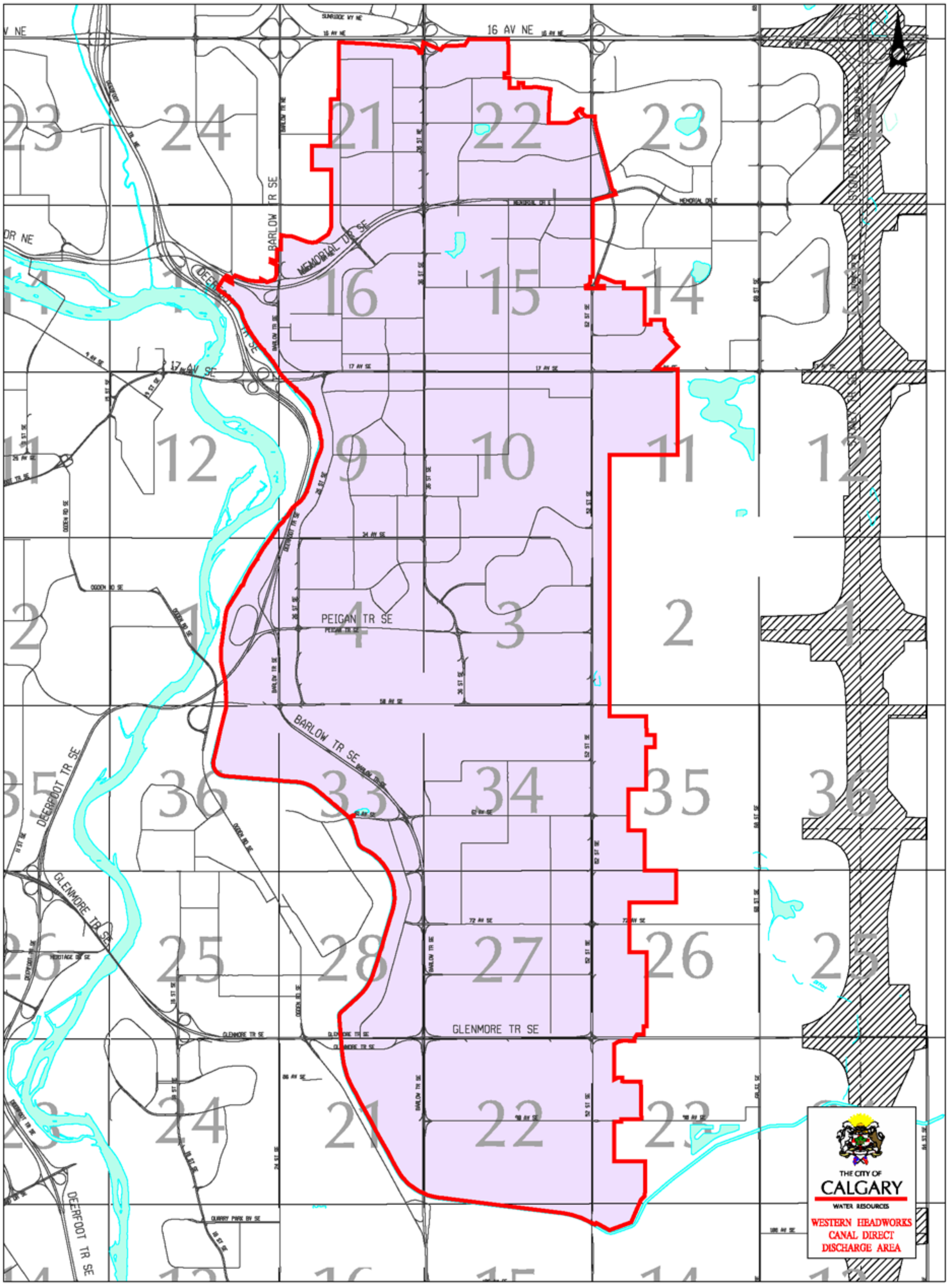


4.7.3 Servicing in Western Headworks Canal Catchment

Areas located within the shaded area on ***Figure 4-2*** drain directly into the Western Headworks (WH) Canal, and, as such, fall under the 1980 Moratorium of Stormwater Discharges into the WH Canal. Any future development and redevelopment within this catchment, which could result in an increase in imperviousness, is required to implement BMPs to yield, at a minimum, a net-zero increase in runoff rate, runoff volume, and pollutant loading to the WH Canal.

Where possible, proponents should reduce the runoff rate, runoff volume, and pollutant loadings below existing levels. The assessment of runoff rate must address both the 1:5 year and 1:100 year conditions. The assessment of pollutant loadings must address sediment (TSS), phosphorus, and nitrogen.

Figure 4-2: Servicing in Western Headworks Canal Catchment



4.8 Storage Requirements and Methods

The major system must be designed for the 1:100 year storm event. This is to provide a reasonable level of flood protection. DSSPs must provide on-site retention to contain the runoff for a 1:100 year event without spillover. Retention can be accomplished by means of roof top storage, trap low storage, underground storage, or stormwater ponds. Refer to ***4.9 Storage Options*** for more information.

4.8.1 Conventional Discharge Scenario - Manual Calculations/Graphs

For small sites (less than, or equal to, 2 ha) that have a gravity connection to the public storm sewer system, required 1:100 year storage volumes can be tabulated through manual calculations or graphs, as shown below.

4.8.1.1 Rational Method

For sites where servicing is available and the Rational Method is permitted, the method outlined in ***APPENDIX B: Storm Retention Calculations For DSSPs*** can be used to determine the required 1:100 year storage volume.

4.8.1.2 Unit Area Release Rate Method

For sites where servicing is available and the permitted release (or design discharge) is specified in L/s/ha, ***Figure 4-3*** and ***Equation 4-1*** may be used to determine the required 1:100 year storage volume:

i) Based on the release rate and overall site imperviousness, determine the required maximum storage volume (m^3/ha) from ***Figure 4-3***. Values may be interpolated if required.

ii) Determine required 1:100 year volume.

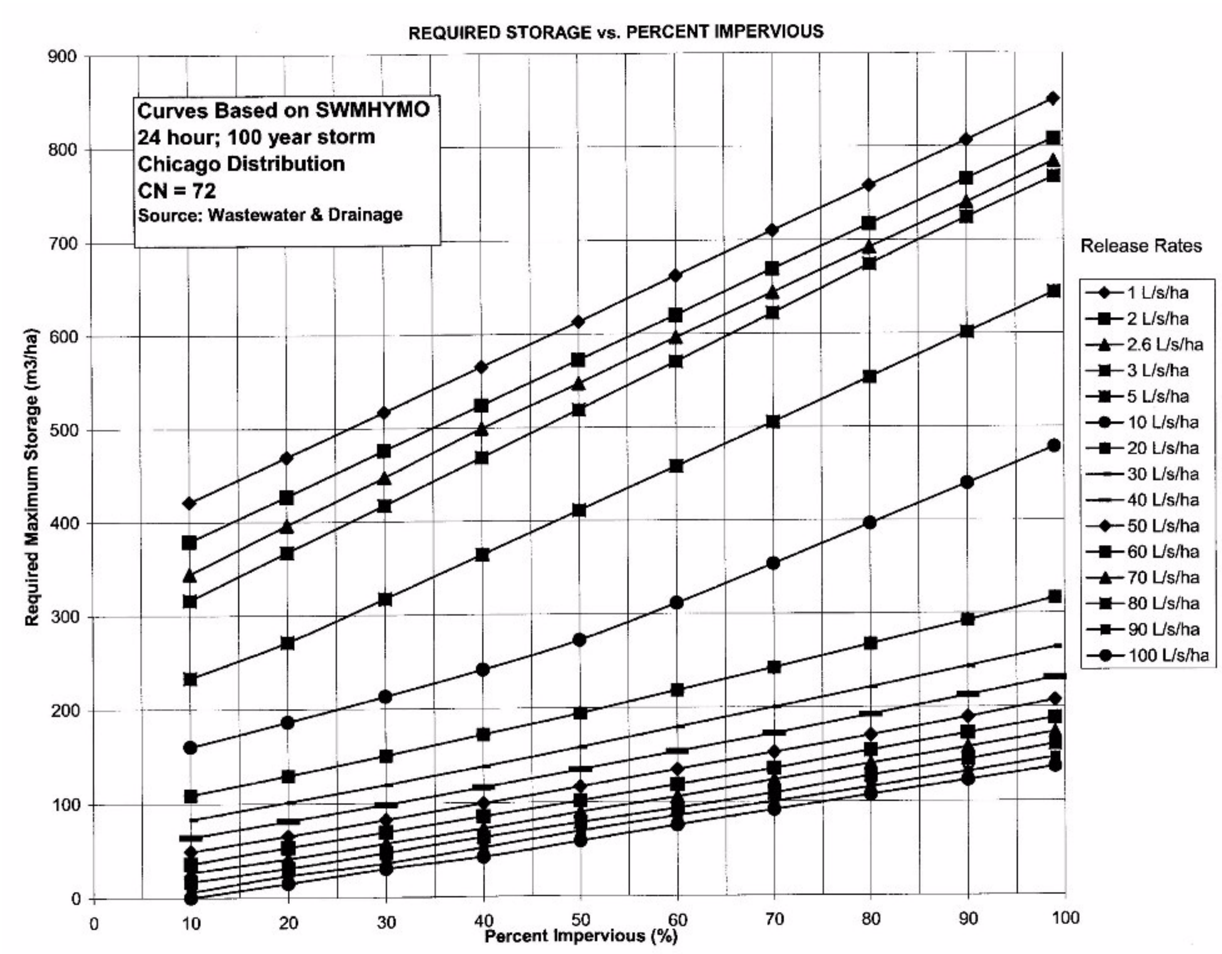
Equation 4-1: Computation of On-Site Storage Requirements

$$V100 = \text{Required Storage } (m^3/ha) \times A$$

where: V100 = volume required for 1:100 year event (m^3)

A = total area of site (ha)

Figure 4-3: Required Storage vs. Imperviousness for Unit Area Release Rate Method



4.8.2 Conventional Discharge Scenario - Computer Modelling

Computer modelling is required to determine the 1:100 year storage volume requirements for the following situations:

i) Serviced sites larger than 2 ha.

ii) Sites that require stormwater ponds.

iii) Non-serviced sites.

iv) Sites smaller than 2 ha with SCPs proposed to reduce on-site storage requirements.

v) Sites smaller than 2 ha with non-gravity service connection.

For computer modelling requirements, refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***4.9.6 Zero-Discharge Facilities***.

4.8.3 Batch Operation Scenario

Some stormwater ponds, such as provided at landfills or certain industrial facilities, operate under batch conditions, where all runoff is to be collected, tested, and, if necessary, treated prior to release, as per Alberta Environment stipulations. In that case, the storm pond must have adequate capacity to fully contain the runoff from a storm event with duration of a minimum of 7 days, for the return frequency of interest. The facility must also be assessed for a 1:100 year event. Refer to ***APPENDIX K: Calgary Design Storm Tables*** for the 1 day - 30 day precipitation depths for the Calgary International Airport. When using a SWMHYMO computation to compute storage requirements, the soil must be assumed to be fully saturated after the first day unless absorbent landscaping is provided.

4.8.4 Zero-Discharge Facilities

Regardless of the size of the site, a water balance analysis using models approved by Water Resources such as QUALHYMO, QHM, SWMM or a spreadsheet tool must be used to evaluate the long-term operation of zero-discharge facilities. The analysis must account for seasonal variations in water re-use. The climate database must include both rainfall and snowfall, covering the entire year, to account for the proper runoff volume; the database shall include the period 1960 through 2009. The analysis techniques must also account for frozen soil conditions during the winter months.

A statistical analysis must be performed of the annual maximum volumes to establish the 1:100 year capacity and surface area. In the case of evaporation facilities where the annual maxima are not independent but a function of the amount of water in the pond in preceding years, preferably, an auto-regression type statistical analysis should be carried out. Contact Water Resources to discuss the analysis technique.

A minimum 0.50 m freeboard must be provided above (a) the maximum water level established as part of the continuous simulation calculations, or (b) the 1:100 year water level from the statistical analysis of the annual maxima, whichever is higher. Some flexibility may be exercised in the freeboard allowance on a case-by-case basis, if it can be demonstrated that risks associated with a reduced freeboard are addressed to the satisfaction of Water Resources.

The continuous simulation of the water levels in the pond must utilize a starting water level that is greater than zero. A starting water level equal to the computed average water level over the period of record (typically iteratively determined) is acceptable. In the case of evaporation ponds, it must also be verified that the surface area of the evaporation is sufficiently large that the runoff from the catchment is balanced by the evaporation for an average year. Shallow-lake evaporation data as per ***Table 4-1*** should be used for this assessment.

Table 4-1: Shallow Lake Evaporation[20]

Month	Evaporation mm)
January	3.0
February	10.9
March	34.6
April	72.1
May	112.0
June	137.1
July	154.7
August	124.1
September	67.2
October	30.6
November	8.1
December	2.2

20. *Source:* Alberta Environment. *Evaporation and Evapotranspiration in Alberta,* 2001.

4.9 Storage Options

Storage can be accomplished through several methods, including surface storage, underground storage, stormwater ponds, and evaporation ponds. Servicing of the site and the permitted discharge or release rate will determine which methods of storage are viable.

4.9.1 Parking Lot Storage (Trap Lows)

Parking lot storage in the form of trap lows is the most common form of storage. Provided that the grades on the lot are not steep, **and** that the permitted release rate is reasonably high (≈50 L/s/ha or higher), no additional storage may be required. For design of trap lows, refer to ***3.4.4 Trap Lows (Surface Ponding)***.

4.9.2 Roof Top Storage

Where roof top storage is provided, the following information should be provided on the drawings or plans:

- Roof boundary and any drainage boundaries where the roof encompasses a large area.
- Roof top storage volume(s).
- Location of roof drain(s).
- Number and type of roof drains.
- Type of inlet control and flow per roof drain (L/s and L/s/ha).
- Total flow from drain (L/s and L/s/ha).
- Nature and elevation of emergency overflow drains and/or scuppers.

The unit area capacity (L/s/ha) of the roof drain(s) must be smaller than or equal to the unit area capacity (L/s/ha) of any downstream flow controls.

4.9.3 Dry Wells

A **temporary** dry well system may be considered for lots where storm sewers are not available. Approval is at the discretion of Water Resources. Dry wells will only be considered for small lots (less than 1 ha) where soil conditions allow for adequate drainage; dry wells located near slopes require geotechnical consideration. The percolation rate must be determined by a Geotechnical Engineer, and must incorporate appropriate safety factors to represent clogging over time. Gravel based soils usually allow for sufficient drainage. Refer to ***4.7.2 Non-Serviced Sites*** for more information.

Refer to The City of Calgary Water Resources' *Standard Specifications Sewer Construction* for details. The minimum number of dry wells must be determined by considering the flow generated from the site in relation to the intake capacity of the soil in the dry well structure. Sufficient temporary storage (i.e., trap lows) surrounding the dry well must be constructed to contain generated flows until such time as they infiltrate into the subsurface. The use of dry wells is not generally recommended where other storage options provide better protection and servicing.

4.9.4 Underground Storage

When surface storage is not sufficient to provide all of the storage requirements, alternative storage methods such as underground storage will be considered. All underground storage designs are at the discretion of Water Resources.

Typically, the design loading for the underground storage chambers should be H20. For installations under pavement or other hard surfaces designated as fire vehicle access, H25 design loading must be used. Refer to *CSA B184 Series-11* for the design of polymeric subsurface stormwater management structures.

As part of the Stormwater Management Report and/or DSSP submission to Water Resources, Development Approvals, underground storage designs and structures must be included for approval. The submission should also include, but is not limited to:

- Sizing information.
- Overflow conditions.
- Operating and maintenance (O&M) procedures.
- Need for pre-treatment and post-treatment.
- Sediment build-up and storage capacity.
- Inspection and maintenance access,.
- Anticipated life span.

An O&M manual and sample maintenance log must be provided to the owner of the underground storage system.

Infiltration and/or percolation into the subsoil is not permitted if the runoff is contaminated with highly mobile constituents, as assessed by an environmental specialist from The City of Calgary's Environmental & Safety Management business unit. Any infiltration and/or percolation provisions must be designed by a professional Geotechnical Engineer. Any proponent that proposes to use deep infiltration and/or percolation as an avenue to meet runoff volume targets must:

i) Assess the impact on the ground water table.

ii) Demonstrate that the assumed percolation rates are sustainable in the long run on a local and regional level.

iii) Demonstrate that the percolating runoff will have no detrimental impact on the adjacent road base or any downstream structures.

iv) Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

4.9.5 Stormwater Ponds

Stormwater ponds may be required for the following:

- Large sites (greater than 2 ha).
- Sites where the imperviousness is high.
- Sites where the permitted release rate is low.
- Sites requiring water quality improvement.
- Non-serviced sites.

When stormwater ponds are required, design should conform to the requirements listed in ***6.1 General***, ***6.2 Dry Ponds***, ***6.3 Wet Ponds***, and ***6.4 Wetlands***.

Since the stormwater ponds will be on private sites, monitoring equipment will not be required. The requirement for water quality monitoring for wet ponds and wetlands is at the discretion of Water Resources; normally water quality monitoring will not be required, except under special circumstances. Water Resources might also request fencing of the pond area if safety is an issue. All required pond details and design requirements must be included on the DSSP plans or drawings.

The design of non-serviced sites requiring evaporation ponds must take into account the general requirements for stormwater ponds, depending on the type of stormwater pond required (typically a wet pond or wetland). Specifically, attention must be paid to lot grading and safety. In view of the fact that many evaporation ponds are large and shallow, sections deeper than 0.30 m must be cordoned off and signed to prevent inadvertent access during high water conditions. Refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for design requirements and ***4.9.6 Zero-Discharge Facilities*** for storage volume requirements.

4.9.6 Zero-Discharge Facilities

In some areas where off-site servicing is not available, zero-discharge facilities such as evaporation ponds may be considered at the discretion of Water Resources. Evaporation ponds will typically occupy 30% to 50% of the total site area, and should be large and shallow to aid in the evaporation process.

Zero-discharge ponds must conform to the general requirements for wet ponds or wetlands, whichever is required. Refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***, ***4.7.2 Non-Serviced Sites***, and ***4.8.4 Zero-Discharge Facilities*** for further design information.

4.9.7 Pond Authorizations

All stormwater ponds (i.e., dry ponds, wet ponds, and wetlands) require the appropriate authorization from Water Resources and Alberta Environment prior to construction. Pursuant to Alberta's *Environmental Protection and Enhancement Act (EPEA)*, a registration is required for the construction of all stormwater ponds.

The consultant is responsible for preparing and submitting the required information (Refer to ***APPENDIX A: Alberta Environment Registration Process***) to Water Resources. Water Resources will then submit the registration to Alberta Environment. For more information, refer to ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES***.

For non-serviced sites requiring evaporation ponds, contact Water Resources for the current authorization policy.

4.10 Hydraulics

In general, hydraulic design of the storm pipe system for a DSSP lot is not complicated for small sites. However, where large sites (greater than 2 ha) are involved, additional care should be taken in the design of the storm pipe system. ***CHAPTER 5: HYDRAULIC DESIGN*** should be consulted for more information. Further information regarding hydraulic requirements for pipes and weeping tile drains can be found in ***3.3.2.11 Hydraulics*** and ***3.3.6.6 Hydraulics***.

It is the designer's responsibility to ensure that the on-site storm pipe system functions properly. Hydraulic conditions from the adjacent public main or stormwater ponds must also be taken into consideration, where required. Where the public storm sewer system is surcharged, the hydraulic analysis of the flow controls, HGL, and trap low storage requirements within the private site must be based on the HGL of the public storm sewer system.

4.11 Lot Grading and Drainage

Carefully designed and controlled lot grading is an important component of the Major System and good stormwater management. Without proper grading, buildings and adjacent properties could be subject to flooding. All grading details (such as berm elevations and cross sections, overland emergency spillover elevations and cross sections, pond grading information, trap low grading, and top of slab elevations) should be carefully planned and shown on the applicable drawings or plans. **When establishing the overland emergency spillover elevations, the designer must verify and identify the highest potential spillover elevation, whether located within the private lot itself or beyond the private lot.**

For all lots where a trap low is located in the bordering road right-of-way (RoW), the minimum grade within the lot adjacent to the trap low must be 0.30 m higher than the 1:100 year elevation in the trap low or the (highest potential) spillover elevation. This minimum grade must be achieved within a 6.0 m distance from the common property line of the lot and the road RoW.

Lot Grading must adhere to *Lot Grading Bylaw 32M2004*. Refer to ***3.4.2 Lot Grading & Drainage*** for lot grading and drainage information. For all other drainage components, refer to ***3.4 Major System Component Design***.

4.12 Water Quality

In the past there has been a tendency to regard stormwater as a relatively minor source of pollution. However, numerous studies have found that there can be significant pollution in stormwater runoff. Contaminants from commercial and industrial lots can be a significant source of pollution if measures are not taken to mitigate the problem. The implementation of BMPs and other SCPs can help mitigate these pollution problems and enhance urban runoff quality (refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES***).

The City of Calgary must meet regulatory requirements for water quality of urban runoff. The current objective is to provide a minimum of 85% removal of Total Suspended Solids (TSS) for particle sizes greater than (or equal to) 50 µm. All wet ponds and wetlands are required to provide enhanced water quality. **Site specific provisions may also be required to provide water quality enhancement. This may include, but is not limited to, industrial and commercial sites.**

Refer to ***CHAPTER 7: WATER QUALITY*** for more information on requirements and water quality modelling. Any permitted runoff must adhere to *Drainage Bylaw 37M2005*.

4.13 Best Management Practices (BMPs)

BMPs are activities or practices, or a combination of practices, that are designed to reduce runoff volume and/or prevent or reduce the release of pollutants to receiving waters or streams. BMPs operate by trapping stormwater runoff and detaining it until unwanted pollutants such as sediment, phosphorous, and other harmful contaminants, are allowed to settle out or be filtered through underlying soils. The trapped pollutants are then removed through periodic maintenance.

The selection and design of stormwater BMPs must incorporate both water quantity and water quality concerns. Current stormwater quality criteria for the City of Calgary requires the removal of a minimum of 85% TSS for particle sizes greater than (or equal to) 50 µm. Care should be made in selecting the appropriate BMP or combination of BMPs.

Use of BMPs is recommended for **all** sites. However, BMPs are **required** for the following sites:

- Sites subject to runoff volume targets.
- Large sites (greater than 2 ha).
- Gas stations, lube and oil change facilities, vehicle maintenance and mechanical shops (including adjacent parking lots), and sites with on-site storage of fuel.
- Heavy industrial and manufacturing sites.

Pre-treatment of runoff for sediment removal using oil/grit separators (or approved equivalent) is required for industrial/commercial sites that drain into vegetated swales or ditches. The pre-treatment system must remove a minimum of 85% TSS for particle sizes greater than or equal to 50 µm.

Refer to ***4.4 Runoff Volume*** for more information on runoff volume targets.

Although there are several BMPs that can be implemented, the BMPs recommended by Water Resources for DSSPs are oil/grit separators, green roofs, absorbent landscaping, bioswales and bioretention areas, and stormwater ponds (where required). It is the designer/consultant's responsibility to ensure that all BMPs are properly designed according to site conditions or constraints, and that details are provided on the drawings. To this effect, an O&M manual and sample maintenance log must be provided to the owner of the BMPs.

All BMPs require the approval of Water Resources. As well, all BMPs must be inspected and maintained on a regular basis as per *Drainage Bylaw 37M2005*; records should be kept to demonstrate this. To this effect, an O&M manual and sample maintenance log must be provided to the owner of BMPs. Installation and maintenance costs of all on-site BMPs are to be borne by the owner. Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** for more information and details.

4.14 Erosion and Sediment Control

Urbanization can have a profound impact on the quality of Calgary's rivers, streams, and creeks. Construction activities can result in a rapid increase in erosion and sedimentation, and if left uncontrolled, can irreparably harm the environment, resulting in the loss of valuable topsoil, the erosion of fine-grained subsoils, and the subsequent sedimentation of rivers and other water bodies.

Sedimentation of our rivers, streams, and creeks can negatively affect water supplies, flood control, fish habitat and fishing, navigation, and recreational activities. Excessive sedimentation of BMPs such as bioswales, bioretention areas and permeable pavement will shorten their life-span and may necessitate complete reconstruction of those features. On average, erosion rates for construction sites with no erosion control measures are 200-400 times higher than natural erosion rates for rural land use. However, erosion and sediment control techniques can help protect these valuable resources by reducing the environmental impacts caused by sediment entering our receiving streams.

Refer to ***CHAPTER 9: EROSION AND SEDIMENT CONTROL*** for more information and The City of Calgary's *Guidelines for Erosion & Sediment Control*. ***8.2 Pollution Prevention Strategies*** provides additional information on SCPs for Good Housekeeping Practices.

There is federal, provincial, and municipal legislation governing urban development and erosion and sediment control in general. This is discussed in more detail in ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES*** and ***9.3 Planning and Design Approach***. Failure to comply with the legislation can result in fines and/or imprisonment.

Erosion and sediment control requirements for DSSPs include the following:

i) All construction projects that disturb soil require planning, implementation, and inspection and maintenance to control erosion and sedimentation.

ii) In general, sites less than, or equal to, 0.40 ha (1 acre) in overall size are considered to be **small** sites and can be controlled through the implementation and maintenance of Good Housekeeping Practices (refer to ***8.2 Pollution Prevention Strategies***, ***9.3 Planning and Design Approach*** and ***9.5 Temporary Practices vs. Permanent Practices***) and (where practicable) erosion and sediment controls to temporarily stabilize and control runoff on-site.

iii) Sites greater than (or equal to) 0.40 ha but less than (or equal to) 2 ha in overall size are considered to be **medium** sites, and generally require some measures in addition to Good Housekeeping Practices to divert clean runoff away from disturbed areas, capture and treat sediment-laden runoff, stabilize soils, and prevent sediment from leaving the site perimeter or entering area storm drains. For medium sites, Water Resources, Water Quality Services may require submission of a report and/or drawings, depending on site erosion potential and the risk of off-site damage.

iv) Sites with an overall size greater than 2 ha are considered to be **large** sites, and require careful planning, implementation, inspection, and maintenance of erosion and sediment controls in keeping with the size of the site, the construction activities, and the length of time for construction. The City requires submission of both a report and drawings (including construction and maintenance details for erosion and sediment controls), and detailed planning, implementation, and inspection and maintenance of controls for such projects, as well as a construction schedule.

4.15 Technical Requirements

Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** for more information on required reports and drawings.

CHAPTER 5: HYDRAULIC DESIGN

5.1 Hydraulic Considerations

The hydraulic design of a storm sewer system requires an understanding of hydrology and hydraulic concepts and principles. The hydraulic design of a storm sewer system should take into account the effects of backwater, surcharging, inlet capacity, and energy losses in the system. The complexity of the system will determine the extent that these factors must be considered. A hydraulic analysis might be required to ensure that the pipe system operates properly; otherwise, excessive surcharging and flooding can occur. Important hydraulic principles include flow classification, conservation of mass, conservation of momentum, and conservation of energy.

When a pipe system is flowing partially full, the system acts as an open channel; there is a free water surface. However, when a pipe is flowing full, the system starts acting as a pressure (or pipe) flow system. It is important that pipes and appurtenances be properly designed to minimize and/or alleviate surcharging of the pipe system.

There is a loss of energy when flow passes through a bend in the sewer, a manhole (MH), junctions, or transitions. The losses can be small or substantial depending on the system design. The energy losses from large diameter pipes flowing full and turning 90^o can be very large. It is the designer's responsibility to provide a system that is hydraulically smooth.

5.1.1 Flow Types

Several categories of flow can be identified: steady, unsteady, uniform, non-uniform (varied), gradually varied, and rapidly varied. Channel flow is distinguished from closed conduit (pipe) flow based on the fact that the cross section of flow is dependent not solely on the geometry of the conduit, but also on the free surface (or depth). The free surface will vary with respect to space and time and is a function of the discharge.

For the design of storm systems, an assumption is typically made that the flow is steady and uniform. This means that the flow and depth in each reach is assumed to be constant with respect to time. However, in reality the flow at each inlet may be variable and flow conditions are not steady or uniform.

Two design philosophies exist for sizing storm systems under steady uniform flow conditions: open channel (or gravity flow) and pressure flow. The flow in a closed conduit is not necessarily pressure flow; if the flow has a free surface, it is classified as open channel (i.e., pipes flowing less than full). When pipes start flowing under pressure, design for pressure flow must be considered.

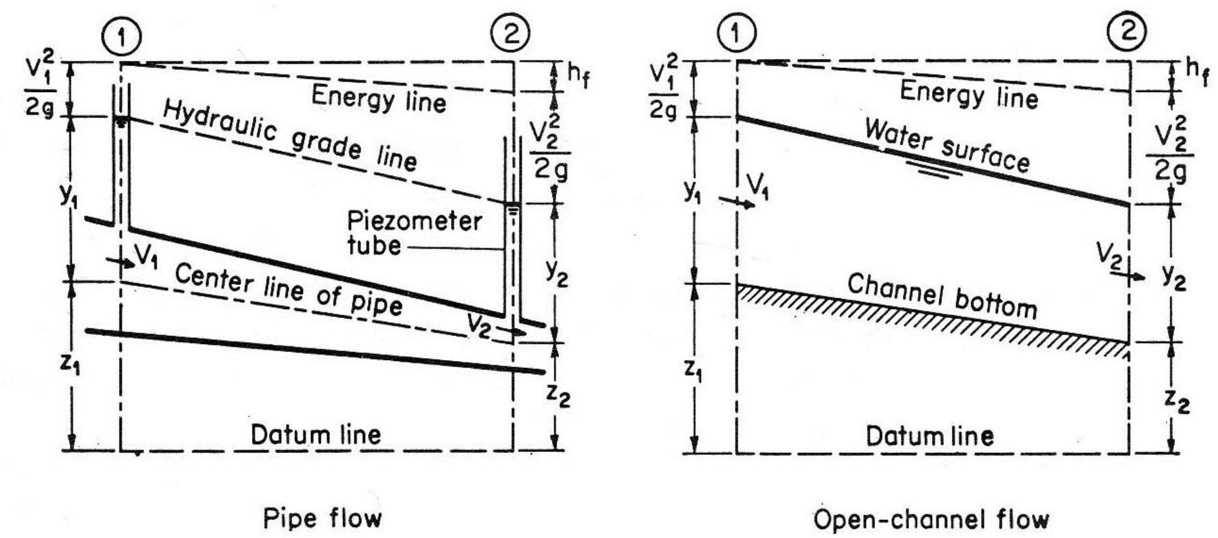
5.1.2 Bernoulli Equation

The law of conservation of energy expressed by the Bernoulli Equation is the basic principle most often used in hydraulics. The equation may be applied to any conduit with a constant discharge. The law states that the energy head at any cross-section must equal that in any other downstream section plus the intervening losses. The Bernoulli equation may be used in both open channel and closed conduit (pressure) flow.

5.1.3 Hydraulic and Energy Grade Lines

Hydraulic and energy grade lines are useful in hydraulic analysis. Refer to ***Figure 5-1***. The Hydraulic Grade Line (HGL) is a measure of flow energy and is represented by the level of water maintained by the pressure exerted by the fluid in the pipe. The Energy Grade Line (EGL) is the total energy in the flow, taking into account the velocity head ($v^2/2g$). Loss of energy due to fluid flowing from section to section is defined as h_f.

Figure 5-1: Energy in Closed Conduit (pipe) and Open Channel[21]



Two types of flow conditions can be distinguished for free flow: subcritical conditions and supercritical flow conditions. Subcritical conditions are typically characterized by a mild slope, with high flow depth and low velocity, resulting in a Froude number smaller than 1. Supercritical conditions are typically characterized by a steep slope, with low flow depth and high velocity, resulting in a Froude number greater than 1.

21. Source: Chow 1959 (page 166).

The Froude number is defined in the following equation:

Equation 5-1: Froude Number

$$\mathbf{Fr} = \frac{\bar{u}}{(gD)^{0.5}}$$

where: $\bar{u}$ = average velocity (m/s)

g = gravity acceleration (9.81 m^2/s)

D = hydraulic depth (m)

Caution must be exercised when a system is designed to operate under supercritical flow conditions, since tail water conditions, bends, or obstructions in the pipe or channel (which can be simple mis-aligned joints) might cause a hydraulic jump. This hydraulic jump, in turn, could cause the flow to “jump” out of the channel or seal off the pipe, resulting in undesirable hydraulic transients and improper ventilation. In these situations, the conduit or channel must be designed to fully contain the hydraulic jump under atmospheric conditions.

5.2 Energy Losses

The hydraulic capacity of a storm system is controlled by its size, shape, slope, and friction resistance. When using the Bernoulli Equation for hydraulic design, it is necessary to account for the energy losses. The losses are expressed in terms of head, and can be classified as:

i) **Friction Losses** - Losses due to the shear stress between the moving fluid and the boundary material.

ii) **Form Losses** - Losses caused by abrupt transitions resulting from the geometry of MHs, bends, expansions, and contractions.

It is a common mistake to include only friction losses in the hydraulic analysis when form losses can constitute a major portion of the total head loss. It is important to take form losses into account in the design of the system.

All drainage systems **must** be hydraulically designed. **The designer or consultant is responsible for consulting appropriate references and ensuring proper design.** The following references are recommended reading for information about energy losses, but should not be used solely when other sources are available. Full source information is available in the ***WORKS CITED*** list.

- ASCE's "Design and Construction of Urban Stormwater Management Systems".
- Corrugated Steel Pipe Institute's *Modern Sewer Design.*
- Ven Te Chow's *Open Channel Hydraulics.*
- American Public Works Association's *Urban Stormwater Management-Special Report No. 49*.
- J. Marsalek's *Head Losses at Selected Sewer Manholes.*
- U.S. Department of Transportation's "Urban Drainage Design Manual-Hydraulic Engineering Circular No. 22".
- W. Hager's *Wastewater Hydraulics: Theory and Practice.*
- Alberta Transportation & Alberta Environment's *Water Control Structures - Selected Design Guidelines*.

5.2.1 Friction Losses

The major loss in a channel or pipe system is the friction or boundary shear loss. The head loss is computed from the general definition:

Equation 5-2: Computation of Friction Loss

$$H_f = S_f L$$

where: H_f = head loss due to friction

S_f = average friction slope

L = length of channel or pipe

Depending on flow conditions, the friction slope (S_f) can be computed from one of three friction formulas:

i) **Hazen-Williams Formula** - smooth flow in a pipe.

ii) **Darcy-Weisbach Equation** - primarily for flow in pipes.

iii) **Manning Equation** - uniform and gradually varied flow in pipes and open channels. Refer to ***3.3.2.2 Capacity & Size*** for more information about Manning's Equation.

5.2.2 Form Losses

In addition to friction losses, form losses, also known as "minor" losses, can account for some head loss. These losses are caused by sudden changes due to transitions, bends, junctions, entrances, exits, obstructions, and control devices (i.e., orifices and gates). If the pipe is long (L/D>>1000), form losses are usually very small in comparison to the friction losses, and can be neglected. However, if the pipe is very short and/or there are a number of manholes, changes in direction, junctions, or changes in pipe size, then the form losses can actually exceed the friction losses.

Form losses are expressed either as a coefficient times the velocity head, or as a coefficient times the difference in velocity heads, depending on the type of loss. In general, minor losses are expressed as:

Equation 5-3: Computation of Minor Head Losses

$$H_L = K_c(v^2/2g)$$

where: H_L = minor head loss

K_2 = loss coefficient

$v^2/2g$ = velocity head

There are three types of form losses that should be taken into account: transition losses, manhole and junction losses, and bend losses.

5.2.2.1 <u>Transition Losses</u> (K_e and K_c)

A transition occurs where a pipe or channel changes size. The change in cross-sectional area results in a change in velocity, and therefore a loss of head. The energy losses are defined for expansion and contraction.

Equation 5-4: Computation of Expansion and Contraction Losses - Free Flow Conditions

Expansion: $$H_e = K_e(v_1-v_2)^2/2g \qquad \text{for } v_1>v_2$$

Contraction: $$H_c = K_c(v_2-v_1)^2/2g \qquad \text{for } v_2>v_1$$

where: H_e, H_c = head loss due to expansion or contraction

K_e, K_c = transition loss coefficients

v_1 = upstream velocity above the transition

v_2 = downstream velocity below the transition

These expansion and contraction losses are for non-pressure flow. Refer to ***Figure 5-2*** for typical transition loss coefficients.

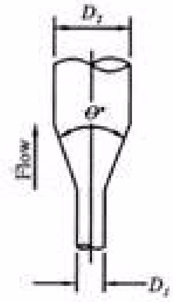
Figure 5-2: Typical K_e and K_c Values for Non-Pressure Flow

(Linsley and Franzini 1964)

(a) Expansion (K_e)

θ*	$\frac{D_2}{D_1} = 3$	$\frac{D_2}{D_1} = 1.5$
10	0.17	0.17
20	0.40	0.40
45	0.86	1.06
60	1.02	1.21
90	1.06	1.14
120	1.04	1.07
180	1.00	1.00

*The angle θ is the angle in degrees between the sides of the tapering section.

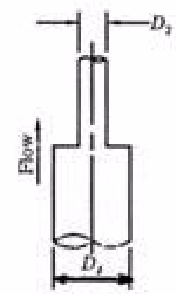


(b) Pipe Entrance from Reservoir

Bell-mouth	$H_L = 0.04 \frac{V2}{2g}$
Square-edge	$H_L = 0.5 \frac{V2}{2g}$
Groove end U/S For Concrete Pipe	$H_L = 0.2 \frac{V2}{2g}$

(c) Contractions (K_c)

$\frac{D_2}{D_1}$	K_c
0	0.5
0.4	0.4
0.6	0.3
0.8	0.1
1.0	0



For pipes under pressure flow, expansion and contraction head losses are defined as follows:

Equation 5-5: Computation of Expansion and Contraction Losses - Pressure Flow Conditions

Expansion: $$H_e = K_e(v_1)^2/2g$$

Contraction: $$H_c = K_c(v_2)^2/2g$$

Under pressure flow conditions, the following tables[22] should be used for determining transition loss coefficients.

22. Source: AISI 1996 (page 123).

Table 5-1: Values of K_e for Sudden Enlargement in Pipes

d_2/d_1 = ratio of larger pipe to smaller pipe V_1 = velocity in smaller pipe

$\frac{d_2}{d_1}$	Velocity, V_1, in metres per second												
	0.6	0.9	1.2	1.5	1.8	2.1	2.4	3.0	3.6	4.5	6.0	9.0	12.0
1.2	.11	.10	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09	.08
1.4	.26	.26	.25	.24	.24	.24	.24	.23	.23	.22	.22	.21	.20
1.6	.40	.39	.38	.37	.37	.36	.36	.35	.35	.34	.33	.32	.32
1.8	.51	.49	.48	.47	.47	.46	.46	.45	.44	.43	.42	.41	.40
2.0	.60	.58	.56	.55	.55	.54	.53	.52	.52	.51	.50	.48	.47
2.5	.74	.72	.70	.69	.68	.67	.66	.65	.64	.63	.62	.60	.58
3.0	.83	.80	.78	.77	.76	.75	.74	.73	.72	.70	.69	.67	.65
4.0	.92	.89	.87	.85	.84	.83	.82	.80	.79	.78	.76	.74	.72
5.0	.96	.93	.91	.89	.88	.87	.86	.84	.83	.82	.80	.77	.75
10.0	1.00	.99	.96	.95	.93	.92	.91	.89	.88	.86	.84	.82	.80
∞	1.00	1.00	.98	.96	.95	.94	.93	.91	.90	.88	.86	.83	.81

Table 5-2: Values of K_e for Gradual Enlargement in Pipes

d_2/d_1 = ratio of diameter of larger pipe to diameter of smaller pipe. Angle of cone is twice the angle between the axis of the cone and its side.

$\frac{d_2}{d_1}$	Angle of cone													
	2°	4°	6°	8°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°
1.1	.01	.01	.01	.02	.03	.05	.10	.13	.16	.18	.19	.20	.21	.23
1.2	.02	.02	.02	.03	.04	.09	.16	.21	.25	.29	.31	.33	.35	.37
1.4	.02	.03	.03	.04	.06	.12	.23	.30	.36	.41	.44	.47	.50	.53
1.6	.03	.03	.04	.05	.07	.14	.26	.35	.42	.47	.51	.54	.57	.61
1.8	.03	.04	.04	.05	.07	.15	.28	.37	.44	.50	.54	.58	.61	.65
2.0	.03	.04	.04	.05	.07	.16	.29	.38	.46	.52	.56	.60	.63	.68
2.5	.03	.04	.04	.05	.08	.16	.30	.39	.48	.54	.58	.62	.65	.70
3.0	.03	.04	.04	.05	.08	.16	.31	.40	.48	.55	.59	.63	.66	.71
∞	.03	.04	.05	.06	.08	.16	.31	.40	.49	.56	.60	.64	.67	.72

Table 5-3: Values of K_c for Sudden Contraction

Values of K_3 for determining loss of head due to sudden contraction from the formula $H_3 = K_3(V_2^2/2g)$

d_2/d_1 = ratio of larger to smaller diameter V_2 = velocity in smaller pipe

$\frac{d_2}{d_1}$	Velocity, V_2, in metres per second												
	0.6	0.9	1.2	1.5	1.8	2.1	2.4	3.0	3.6	4.5	6.0	9.0	12.0
1.1	.03	.04	.04	.04	.04	.04	.04	.04	.04	.04	.05	.05	.06
1.2	.07	.07	.07	.07	.07	.07	.07	.08	.08	.08	.09	.10	.11
1.4	.17	.17	.17	.17	.17	.17	.17	.18	.18	.18	.18	.19	.20
1.6	.26	.26	.26	.26	.26	.26	.26	.26	.26	.25	.25	.25	.24
1.8	.34	.34	.34	.34	.34	.34	.33	.33	.32	.32	.31	.29	.27
2.0	.38	.38	.37	.37	.37	.37	.36	.36	.35	.34	.33	.31	.29
2.2	.40	.40	.40	.39	.39	.39	.39	.38	.37	.37	.35	.33	.30
2.5	.42	.42	.42	.41	.41	.41	.40	.40	.39	.38	.37	.34	.31
3.0	.44	.44	.44	.43	.43	.43	.42	.42	.41	.40	.39	.36	.33
4.0	.47	.46	.46	.46	.45	.45	.45	.44	.43	.42	.41	.37	.34
5.0	.48	.48	.47	.47	.47	.46	.46	.45	.45	.44	.42	.38	.35
10.0	.49	.48	.48	.48	.48	.47	.47	.46	.46	.45	.43	.40	.36
∞	.49	.49	.48	.48	.48	.47	.47	.47	.46	.45	.44	.41	.38

Entrance losses can be estimated using the entrance loss coefficients in ***Figure 5-3*** and ***Equation 5-6***.

Equation 5-6: Computation Entrance Losses

$$H_e = k_e(v)^2/2g$$

Figure 5-3: Values of k_e for Culverts, Outlet Controls, and Full or Partly Full Entrance[23]

Type of Structure and Design of Entrance	Coefficient K_e
• **Pipe, Concrete**	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end	0.2
Square-edge	0.5
Rounded (radius = D/12	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2
• **Pipe. or Pipe-Arch. Corrugated Metal**	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2
• **Box, Reinforced Concrete**	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of D/12 or B/12 or beveled edges on 3 sides	0.2
Wingwalls at 30^0 to 75^0 to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of D/12 or beveled top edge	0.2
Wingwall at 10^0 to 25^0 to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

*Note: "End Sections conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

23. Source: U.S. Department of Transportation 2005 (page 223).

5.2.2.2 Manhole (MH) and Junction Losses

Junctions are locations where two or more pipes join together to form another pipe or channel. They represent critical points in terms of design; multiple pipes coming together at a junction should flow together smoothly to avoid high head losses. Losses at junction MHs can typically account for 20-30% of total head loss, though wide variances are possible. Careful design and construction can minimize losses.

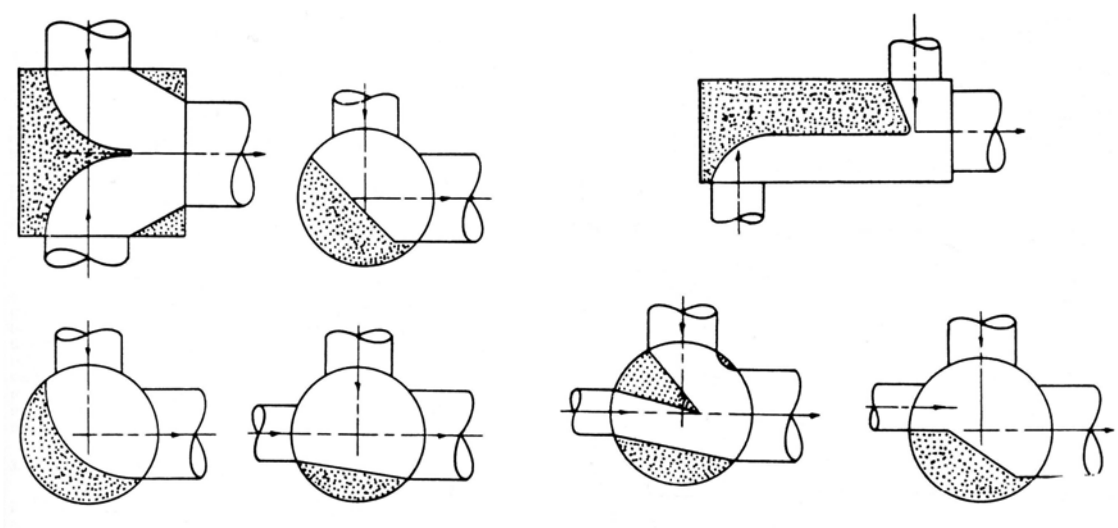
In a three junction study by Marsalek, the following was found:

- In pressurized flow, the most important flow variable was the relative lateral inflow for junctions with more than two pipes. The losses increased as the ratio of the lateral discharge to main line discharge increased.
- The important junction geometrical parameters are relative pipe sizes, junction benching, and pipe alignment. Base shape and relative MH sizes were less important.
- In junctions where two lateral inflows occurred, head losses increased as the difference in flows between the two laterals increased. Head loss was minimized when lateral flows were equal.
- Full benching to the obvert of the pipe significantly reduced losses compared to half pipe benching or no benching.

5.2.2.2.1 Deflectors

Efficient and inefficient MH configurations are illustrated in ***Figure 5-4***.

Figure 5-4: Manhole Configurations[24]

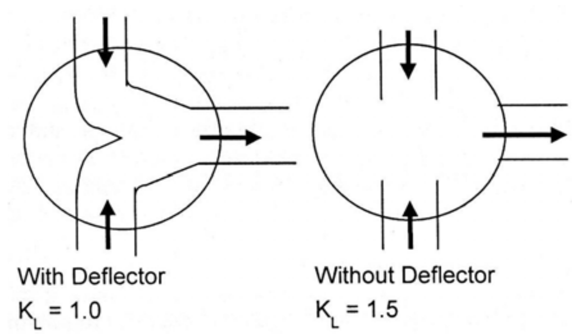


Efficient Manhole Configurations   Inefficient Manhole Configurations

For junctions with inlets at or near right angles, the head loss coefficient varies depending on whether the incoming flow is deflected or if the incoming flows impinge. When a deflector the full height and width of the incoming pipes is used, there is less head loss.

24. Source: Urban Drainage and Flood Control District 1999.

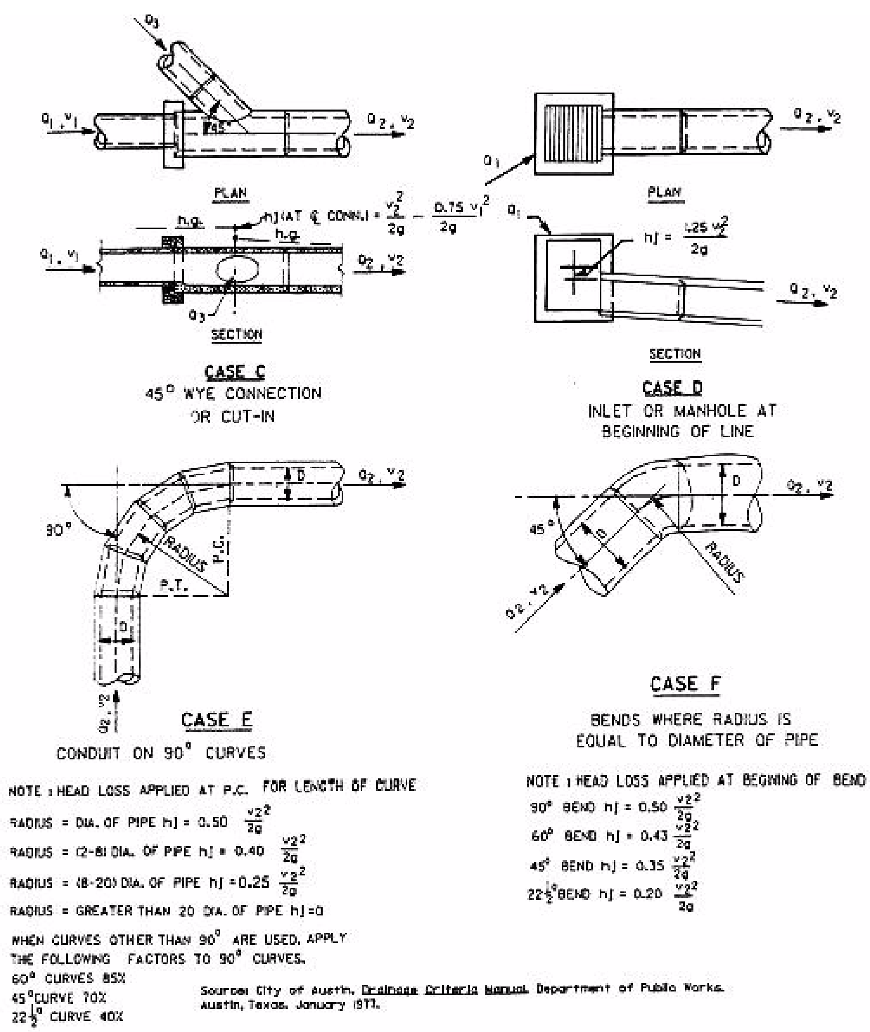
Figure 5-5: Deflectors[25]



5.2.2.2.2 Alignment

Pipe alignment is also an important parameter. ***Figure 5-6*** illustrates the head loss coefficients for different alignments.

Figure 5-6: Losses Due to Turbulence at Manholes[26]



25. Source: City of Edmonton 2008 (page 94).
26. Adapted from City of Austin 2010 (Appendix E: Figures 5-10 and 5-11 - values for “Case E” corrected).

In a straight-through MH, where there is no change in pipe size, the head losses are estimated using the following equation:

Equation 5-7: Computation of Manhole Losses - Straight-Through Flow Conditions

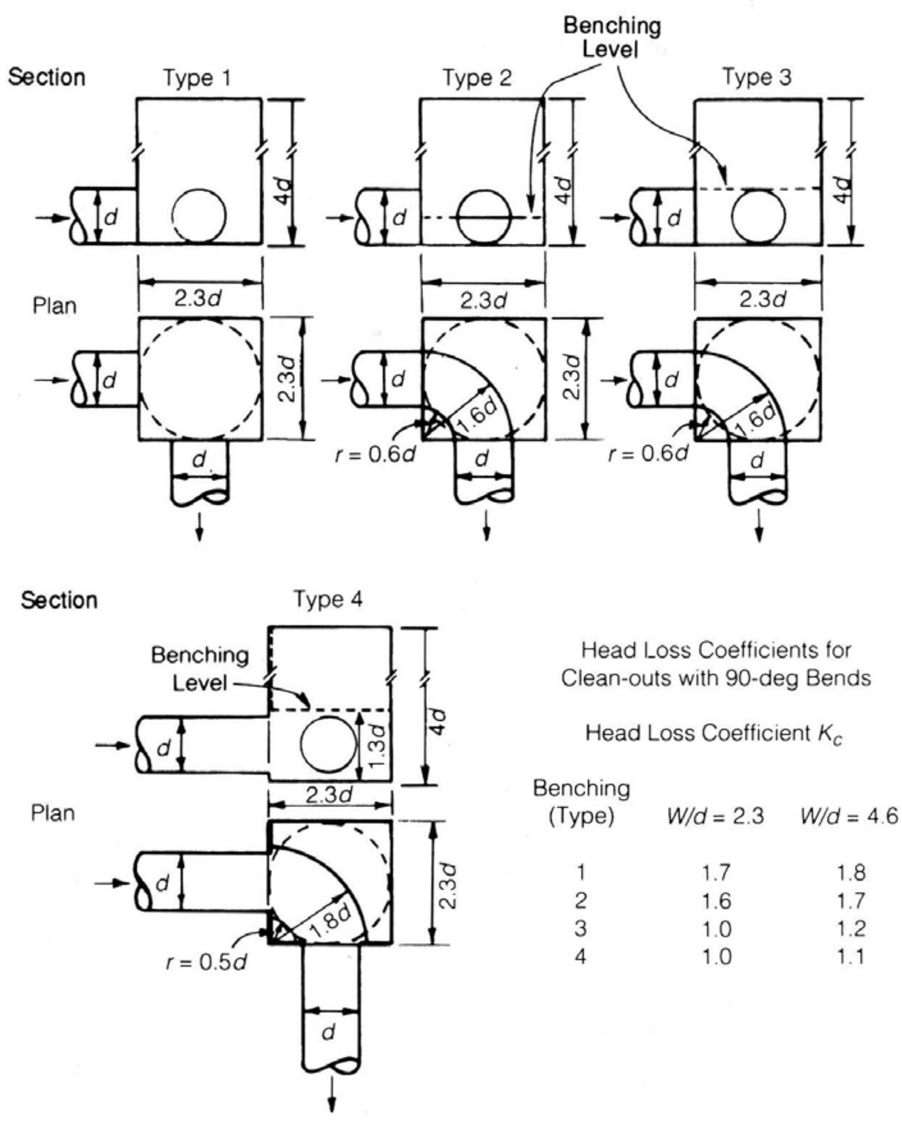
$$H_m=0.05\ (v^2)/2g$$

For radiused pipes and MHs with curved deflectors, refer to ***5.2.2.3 Bend Losses (Kb)***.

5.2.2.2.3 Benching

Benching is an important parameter. In a study by Marsalek, benching had the most pronounced effect on head loss (refer to ***Figure 5-7***). Full pipe benching is recommended for MHs with a 90^o bend.

Figure 5-7: Head Loss Coefficient Values for Benching



Head Loss Coefficients for Clean-outs with 90-deg Bends

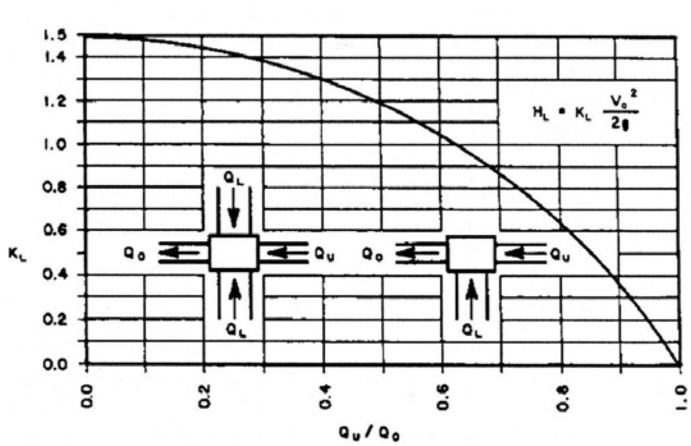
Head Loss Coefficient K_c

Benching (Type)	W/d = 2.3	W/d = 4.6
1	1.7	1.8
2	1.6	1.7
3	1.0	1.2
4	1.0	1.1

5.2.2.2.4 Lateral Inflow

In pressurized flow, the relative lateral inflow for junctions with more than two pipes is important. Lateral inflow losses are illustrated as follows:

Figure 5-8: Bend Losses[27]



5.2.2.3 Bend Losses (K_b)

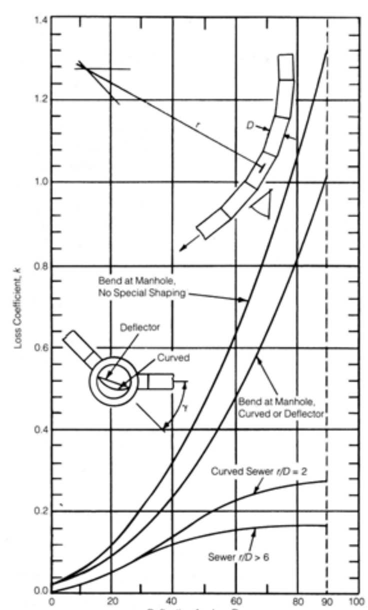
Bend losses can be estimated with ***Equation 5-8***:

Equation 5-8: Computation of Bend Losses

$$H_b = K_b(v)^2/2g$$

Bend losses in pipes can be estimated using the bend loss coefficients in ***Figure 5-9*** or other appropriate/up-to-date information sources.

Figure 5-9: Values of K_b for Bends and Radiuses[28]



27. Source: City of Edmonton 2008 (page 95).
28. Source: Wright 1969.

5.3 Special Structures

Special structures such as inlets, culverts, outfalls, energy dissipators, drop structures, and outlet structures require careful hydraulic design consideration to ensure that they function properly. It is the responsibility of the designer or consultant to ensure the structures are properly designed. Reference material should be consulted for more information. All special structures are subject to approval by Water Resources.

All culverts must be hydraulically designed. Please note that the guidelines in ***3.3.8.1 Major Culverts*** and ***3.3.8.1 Major Culverts*** are minimum guidelines that should be adhered to at all times. **The designer or consultant is responsible for consulting appropriate references and ensuring proper design.** The following references are recommended reading for information about culvert design, but should not be used solely when other sources are available. Full source information is available in the ***WORKS CITED*** list.

- Alberta Transportation's *Design Guidelines for Bridge Size Culverts*.
- Alberta Transportation's *Hydrotechnical Design Guidelines for Stream Crossings*.
- Alberta Transportation's *Culvert Sizing Considerations*.
- Alberta Transportation's *Fish Habitat Manual*.
- Alberta Transportation's *Engineering Consultant Guidelines for Highway and Bridge Projects, Volume 1, Design and Tender*.
- Transportation Association of Canada's *Drainage Manual, Volume 2, Culverts and Storm Sewers*.
- US Department of Transportation's *Hydraulic Design of Energy Dissipators for Culverts and Channels: Hydraulic Engineering Circular No. 14, Third Edition.*

5.4 Stage-Discharge Curves

A stage-discharge (performance) curve defines the relationship between the depth of water and the discharge (outflow) from a stormwater storage facility. Stormwater ponds will typically have a principal and an emergency outlet. The principal outlet is designed to convey the design flows without allowing flow to enter the emergency spillway. The structure for the principal outlet (commonly called an outlet or control structure) often consists of an orifice, weir, or other hydraulic control device. The following information provides general design relationships for typical outlet controls. Appropriate reference material must be consulted for more information or for items not listed (i.e., flap gates).

5.4.1 Orifices

For a single orifice, flow is determined by the following equation:

Equation 5-9: Orifice Equation

$$Q = C_0 A_0 (2gH_0)^{0.5}$$

where:
- Q = orifice flow rate (m^3/s)
- C_0 = discharge coefficient (0.40-0.60)
- A_0 = area of orifice (m^2)
- H_0 = effective head on the orifice measured from the centroid of the opening (m)
- g = acceleration due to gravity (9.81 m^2/s)

If the orifice discharges as a free outfall, the effective head is measured from the centreline of the orifice to the upstream water surface elevation. If the orifice is submerged, the effective head is the difference in elevation of the upstream and downstream water elevations.

A discharge coefficient of 0.60 is typically used for sharp-edged, uniform orifice entrance conditions.

5.4.2 Weirs

A weir is often used in the outlet control structure as an alternate emergency spill in the case of orifice blockage. Equations for rectangular sharp crested and broad crested weirs are as follows:

i) Sharp Crested:

Equation 5-10: Sharp Crested Weir

$$Q = C_{scw} L H^{1.5}$$

where:
- Q = discharge (m^3/s)
- L = horizontal weir length (m)
- H = head above weir crest excluding velocity head (m)
- H_c = height of weir (m)
- C_{scw} = 1.81 + 0.22 (H/H_c)

Sharp crested weirs will be affected by submergence when the tailwater rises above the weir crest elevation. Smith[29] suggests a value of 1.837 for C_{scw}.

ii) Broad Crested:

Equation 5-11: Broad Crested Weir

$$Q = C_{bcw} L H^{1.5}$$

where:
- Q = discharge (m^3/s)
- L = broad crested weir length (m)
- H = head above weir crest (m)
- C_{bcw} = broad crested weir coefficient (1.44 - 1.70)

Smith[30] suggests a value of 1.705 for C_{bcw}.

5.4.3 Emergency Spillways

The overland emergency spillway provides an alternate source of discharge from the stormwater pond. The discharge through a broad crested emergency spillway is:

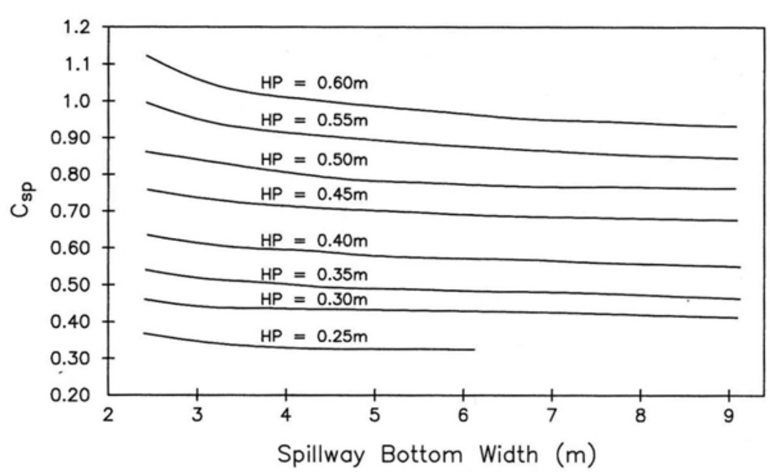
Equation 5-12: Broad-Crested Emergency Spillway Discharge

$$Q = C_{sp} b H_p^{0.5}$$

where:
- Q = discharge (m^3/s)
- C_{sp} = discharge coefficient
- b = bottom width of the emergency spillway (m)
- H_p = effective head on the emergency spillway (m)

The discharge coefficient, C_{sp}[31] is a function of the spillway bottom width and effective head. HP in ***Figure 5-10*** is the same as H_p in ***Equation 5-12***.

Figure 5-10: Discharge Coefficient for Emergency Spillway



29. Source: Smith 1985.
30. Source: Smith 1985.
31. Source: U.S. Department of Transportation 2001.

5.5 Technical Requirements

5.5.1 Submissions

i) Energy losses must be properly accounted for in the design of a storm sewer system. Head losses are controlled by both flow characteristics and junction geometry. These losses should be used to determine EGL and HGL elevations. It is the designer/consultant's responsibility to ensure that the system functions hydraulically to prevent unacceptable surcharging and flooding. The information in the preceding sections and other appropriate reference material must be used in the design.

ii) HGL calculations (and hydraulic designs) must be submitted for the following situations:

- Areas where backwater effects from stormwater ponds at the HWL cause storm sewer surcharge conditions. The lowest top of footing (LTF) elevation must be a minimum of 0.30 m above the HGL elevation. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface to avoid compromising catchbasin (CB) interception.** Also, proper aeration and venting must be considered as per ***5.5.2 Design***. Hand calculations or EPA SWMM or XP-SWMM computer modelling (when carefully used) are acceptable methods for determining HGLs.
- Large diameter pipe (pipe larger than 750 mm) with 90^{o} (or similar) bends or junctions.
- Pipe transitions to smaller diameters or smaller cross-sectional area. Typically, pipe sizes should **not** decrease in a downstream direction.
- Trunk slopes changing from steep to flat resulting in a hydraulic jump in the system.
- Special structures, as requested by Water Resources.

5.5.2 Design

i) Efficient MH or junction designs should be used. Junctions with two opposed incoming laterals must be carefully designed. Generally, high head losses result when there is uneven distribution of the lateral inflows: lower losses result when the lateral inflows are comparable.

ii) Sudden extreme changes in direction should be avoided for large flows and high velocities.

iii) The use of prefabricated bends and curved pipe is recommended to provide efficient hydraulics.

- The ratio of the radius of the bend (r), measured to the centreline of the pipe, to the pipe's inside diameter (D), should be greater than, or equal to 2. Refer to ***Figure 5-9*** for more information.
- For r/D ratios less than 2, the maximum bend deflection should be 45^{o}.

iv) For MHs with a 90^{o} bend, **full benching** to the obvert of the pipe is required to reduce energy head losses. Half pipe benching is not as effective. Details and/or requirements must be indicated on the construction drawings.

v) A minimum drop of 30 mm is required in a through MH where there is no change in pipe diameter. A minimum drop of 60 mm is required in a bend where there is no change in pipe diameter.

vi) Design considerations that can help overcome hydraulic concerns could include, but are not limited to:

- Increase pipe size.
- Provide MH benching at 90^{o} bends. Full pipe benching is recommended.
- Provide proper aeration and venting.
- Install MH drops (which act as energy dissipators) to reduce steep grades and high velocities.
- Use curved pipe and/or bends.
- Smooth transition entrances.

vii) All storm pipes must be rubber gasketed, except where approved by Water Resources.

CHAPTER 6: STORMWATER PONDS AND WETLANDS

6.1 General

Stormwater facilities (dry ponds, wet ponds, and wetlands, or a combination thereof) receive stormwater runoff from conveyance systems (ditches, drainage swales, roads and gutters, and storm sewers); they discharge to receiving waters such as wetlands, lakes, ponds, and streams, and/or to downstream conveyance systems, at the rates determined as part of the Water Management Plan (WMP), Master Drainage Plan (MDP), or Staged Master Drainage Plan (SMDP) reports. Consultants can obtain an electronic copy by contacting the Librarian/Records Administrator in The City of Calgary's Infrastructure & Information Services business unit, Knowledge & Document Management division.

The purpose of stormwater facilities is to provide temporary storage of stormwater for water quantity rate control, water quality enhancement, and in some cases, opportunities for runoff volume control and stormwater re-use prior to discharge. As well, these facilities are also types of end-of-pipe Best Management Practices (BMPs). Selection of a facility type is a function of quantity control, water quality and erosion control. For more information on wetlands, refer to The City of Calgary Parks/Water Services' *Principles for Stormwater Wetlands Management in the City of Calgary* and the *Calgary Wetland Conservation Plan*. Detailed pond design philosophies are described further in ***6.2 Dry Ponds***, ***6.3 Wet Ponds*** and ***6.4 Wetlands***, while general criteria and philosophies are described in this section. Design criteria is a compilation of Alberta Environment's *Stormwater Management Guidelines for the Province of Alberta (1999)*, *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*, and the City of Calgary's criteria. Where design criteria between the Province and the City vary, the more conservative design criteria will govern.

All stormwater ponds require the appropriate authorization from Water Resources and Alberta Environment prior to construction. Pursuant to Alberta's *Environmental Protection and Enhancement Act (EPEA)*, a registration is required for the construction of all stormwater ponds. The consultant is responsible for preparing and submitting the required information to Water Resources. Water Resources will then submit the registration to Alberta Environment. Refer to ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES*** and ***APPENDIX A: Alberta Environment Registration Process*** for information and requirements.

6.1.1 Terminology

It is important that stormwater pond and wetland terminology used is understood, given the vast amount of information available. A combination of facility types may also be considered as part of the design process.

i) Detention Storage

Detention storage refers to the temporary storage in and gradual release of stormwater from a storage facility. There is little or no infiltration of the stored stormwater. The main purpose of detention storage is to provide quantity control by attenuating runoff. Dry ponds, wet ponds, and wetlands are the most common types of detention storage.

ii) Retention Storage

True retention storage refers to the collection and storage of runoff for a considerable length of time, where release is by evaporation, transpiration, or infiltration. Retention facilities are typically designed to provide the dual functions of stormwater quantity and quality control. Infiltration ponds and evaporation ponds are examples of retention facilities. Although the terms detention, retention, and extended detention have true definitions, they are often used interchangeably.

iii) In-line Storage

In-line storage refers to storage that is constructed directly on (or on the same alignment as) the minor conveyance system. It also includes storage elements formed by construction of an embankment across a natural or existing drainage course. In general, these types of facilities are discouraged.

iv) Off-line Storage

Off-line storage occurs when the minor conveyance system conducts flows to an outlet with restricted discharge. The peak flows, over and above the carrying capacity of the conveyance system, are then routed to storage facilities such as ponds, tanks, or basins. These storage facilities do not form part of the minor system.

v) Permanent Pool

The permanent pool is the portion of a stormwater pond which retains a permanent volume and depth of water. All wet ponds and wetlands will have a permanent water elevation delineated as the permanent water level (PWL), more commonly referred to as the normal water level (NWL).

The permanent pool acts as a buffer by slowing down stormwater entering the pond and trapping pollutants. Thus, the permanent pool is the pond's primary source of water quality enhancement.

For wet ponds where water is re-used for irrigation or other purposes, the NWL is not constant; rather, it fluctuates between an upper (U) NWL and a lower (L) NWL. Discharge to receiving waters or a downstream drainage system commences when the water level in the wet pond exceeds the (U)NWL. Re-use ceases when the water level has dropped to the lower normal water level.

vi) Sediment Forebay

A sediment forebay is a permanent pool that is designed to facilitate maintenance and improve pollutant removal by trapping larger particles near the inlet of the pond. The forebay is often designed to be the deepest area of the pond to minimize the potential for particle re-suspension and to prevent conveyance of the suspended material to the outlet. It is important that the sediment forebay be properly sized, and be designed to accommodate cleaning of the forebay for maintenance purposes. Sedimentation vaults or oil/grit separators could also be used in lieu of sediment forebays, subject to the approval of Water Resources.

vii) Extended Detention Storage/Active Storage

Also commonly referred to as Active Storage, Extended Detention Storage refers to the active or live storage area. Typically, this is a component of dry ponds, wet ponds, and wetlands, and is primarily designed for water quantity control. The area is subject to the frequent wetting from storm events.

This area corresponds to the temporary storage volume provided in a stormwater pond. In a dry pond, this is the storage between the bottom of the pond and the high water level (HWL). In a wet pond or wetland, this is the storage between the NWL and the HWL.

viii) Wet Pond-Wetland/Hybrid Wet Pond-Wetland/Other Hybrid Ponds

Although wet ponds and wetlands have many common design elements, the distinction between a wet pond and a wetland can be difficult to determine. The main criteria used to differentiate between the two is the vegetation design and the proportion of deep (greater than 0.50 m) and shallow areas. A wet pond has a greater portion of deep water zones (generally 2.0 to 3.0 m), and aquatic vegetation is concentrated along the perimeter of the pond. Conversely, wetlands are dominated by shallow water zones, and vegetation is found throughout the pond. A hybrid wet pond-wetland uses both shallow and deep water zones. Other hybrid ponds can include combinations of dry and wet stormwater ponds.

6.1.2 Level of Service

Stormwater ponds must be designed to provide adequate flood protection by providing quantity control, water quality, and in some cases runoff volume control. Refer to ***3.1.4 Runoff Volume***. The **most conservative** (highest) volume of the criteria (quantity, quality or runoff volume) identified below will dominate. Refer to ***6.2 Dry Ponds***, ***6.3 Wet Ponds***, and ***6.4 Wetlands*** for more detailed information on sizing requirements.

i) The permissible discharge rate must conform to the approved unit area release rates as identified in the relevant WMP, MDP, and/or SMDP report(s).

ii) All stormwater facilities must be designed to provide active storage for a 1:100 year event based on a 24 hour storm event and continuous modelling (refer to ***CHAPTER 3: STORMWATER DESIGN***). The return frequency of the pond volume is assumed to be the same as the return frequency of the single-event design storm. For continuous modeling, a statistical analysis is performed on a series of maximum annual pond volumes. The design of the pond must be based on the more conservative of the two results. The corresponding water level is the HWL for the pond. Special considerations apply to the design of zero-discharge facilities (refer to ***4.9.6 Zero-Discharge Facilities*** for more information.

iii) For water quality, the pond must also be sized to provide a minimum 85% removal of Total Suspended Solids for particle sizes greater than, or equal to, 50 µm.

iv) As well, a minimum permanent storage volume based on either of the following is required for water quality enhancement in wet ponds:

- The modelled volume of runoff from a 25-mm storm event over the catchment.
- 25 mm over the entire catchment area times the overall catchment imperviousness ratio (25 mm x area x overall imperviousness ratio)

The first method must be used if the imperviousness ratio is smaller than 20%. A 1-hour, 1:25 year event substitutes for the 25 mm storm event when modelling is used.

v) A minimum detention time of 24 hours for a 25 mm event must be provided for wet ponds and wetlands. Detention time is approximated using the drawdown time. The drawdown time in the pond can be estimated using the classic falling head orifice equation (***Equation 6-1***), which assumes a constant pond surface area. If modelling is used to verify the detention or drawdown time, a 1-hour, 1:25 year event will substitute for the 25-mm event.

Equation 6-1: Classic Falling Head Orifice Equation

$$t = \frac{2 A_p}{C A_o (2g)^{0.5}} \left(h_1^{0.5} - h_2^{0.5}\right)$$

where:
- t = drawdown time in seconds
- A_p = surface area of the pond (m^2)
- C = discharge coefficient (typically 0.63)
- A_o = cross-sectional area of the orifice (m^2)
- g = gravitational acceleration constant (9.81 m/s^2)
- h_1 = starting water elevation above the orifice (m)
- h_2 = ending water elevation above the orifice (m)

vi) For areas requiring runoff volume control (Pine Creek watershed, Nose Creek watershed, and others), refer to ***3.1.4 Runoff Volume***.

Re-developed areas should also abide by these design considerations where possible; deviations from this standard require approval from Water Resources. A lower level of service may be allowed for **retrofit** facilities subject to approval from Water Resources.

6.1.3 Overland Drainage and Escape Routes

i) Overland drainage routes, besides the storm sewer system, that direct flows from the 1:100 year storm event to the pond area must be provided. Overland flow design velocities (v) and depths (d) must be in accordance with *Stormwater Management Guidelines for the Province of Alberta (1999)*. Refer to ***Table 3-18*** and ***Figure 3-10*** in ***CHAPTER 3: STORMWATER DESIGN*** for more information.

ii) Overland drainage routes entering the pond should be directed into the forebay. If this is not feasible, the runoff might need to be pre-treated before it is allowed to enter the pond. Trap lows adjacent to the pond may spill into the main cell(s) of the pond, provided that the trap lows fully contain the runoff from a 1:5 year event without spillover. Similarly, localized sheet flow from areas directly adjacent to the pond are permitted into the main cell(s) of the pond provided that flows are kept to a minimum.

iii) A designated continuous emergency overland escape route **from** all ponds is to be provided. In general, the design capacity of the overland emergency escape route (refer to ***Figure 6-1***) from the pond will be the greater of either:

- The resulting spillover rate for a 24 hour, 1:100 year event, assuming that the regular outflow is 0 m^3/s and the starting water level is equal to the pond bottom (dry ponds), NWL (wet ponds with no water re-use and wetlands), or UNWL (for wet ponds with water re-use). Refer to ***6.3 Wet Ponds*** and ***Figure 6-8*** for more information about (U)NWLs for wet ponds.
- 1.0 m^3/s.

The magnitude of the design capacity of the overland escape route must be determined at the time of pond design. The configuration and capacity should be adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route. Proper engineering design based on the local circumstances is required.

A minimum 0.30 m freeboard must be provided above the water level that corresponds to the design overland emergency discharge rate. The freeboard elevation is the minimum elevation along the perimeter of a pond or wetland that ensures safe operation without negative impact to adjacent or downstream property. The property line elevation for all properties along the perimeter of the pond should be above the freeboard elevation, unless a berm is provided along the perimeter of the pond to safeguard lower properties. In addition, the top of the outlet control structure (including access/maintenance roads), any associated electronic equipment, and any safety benches along the perimeter of the pond must be at or above the freeboard elevation.

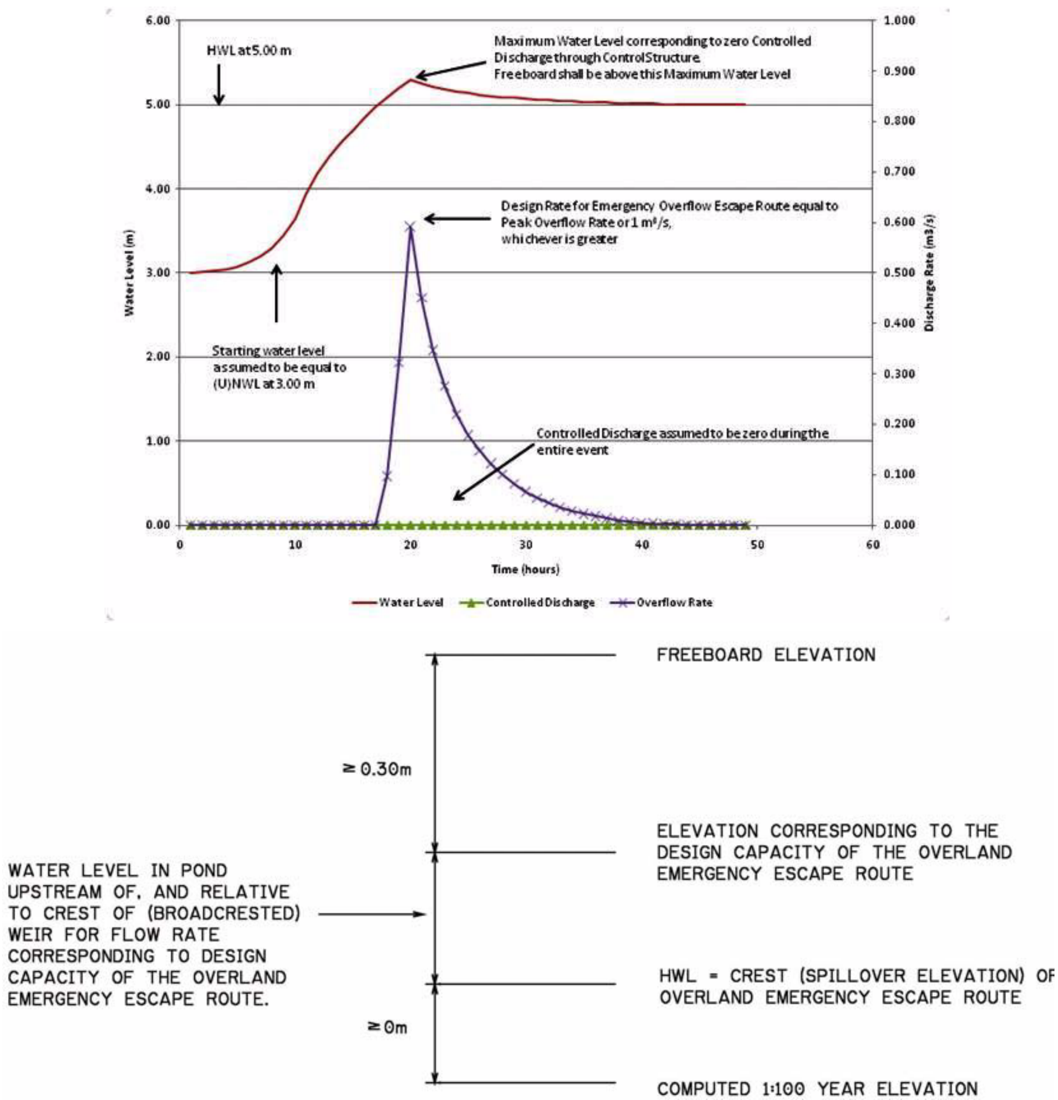
iv) Optionally, additional freeboard over and above what is required can be considered in cases where it is difficult to establish an escape route. The additional freeboard would provide a higher level of service overall; however implications to the HGL upstream of the pond must be considered.

v) Sanitary sewer manholes (MHs) must be located outside of impoundment (pond) areas.

vi) Whenever possible, sanitary sewer MHs should not be located within the overland drainage route. When the situation is unavoidable, sanitary sewer MHs must be sealed. Bolting is at the discretion of Water Resources.

vii) Erosion control needs must be evaluated for both the overland drainage routes into the pond and the overland emergency escape route from the pond.

Figure 6-1: Design Capacity of Overland Emergency Escape Route.



Note: The HWL is allowed to be equal to the 1:100 year elevation; however, consider the construction tolerances outlined in ***<u>11.6.3 Stormwater Ponds</u>***.

viii) In the demonstrated absence of a practical overland emergency escape route, and subject to approval by Water Resources, the following options may be considered (in declining order of desirability):

- Provision of a pipe emergency escape route (i.e., culvert that daylights downstream) with a diameter equal to or greater than 600 mm, and capacity greater than 1.0 m^3/s. The freeboard elevation must be 0.50 m above the water level that corresponds to the design overland emergency discharge rate, or 0.50 m above the obvert of the culvert, whichever is higher.
- Increase the design flow rate of the downstream storm sewer system by a minimum of 1.0 m^3/s. The freeboard elevation must be 0.50 m above the water level that corresponds to the design overland emergency discharge rate.
- The freeboard elevation must be 0.50 m above the 1:500 year elevation.

6.1.4 Vegetation Use

Vegetation is an important component in the design of stormwater ponds. Design and use of vegetation should only be undertaken by qualified consultants. Refer to ***APPENDIX E: Recommended Plant Species*** for suitable plant species. The selection of vegetation should consider the following:

i) Slope Stabilization:

The root systems of many tree, shrub and plant species help bind soils to provide resistance to erosion. Suitable planting schemes should be selected to provide long-term stability.

ii) Temperature Mitigation:

Through shading, the location of deciduous and coniferous trees along the edges of wet ponds and wetlands can contribute to the mitigation of water temperature increases. Water depth can also impact temperature.

iii) Public Access Mitigation:

Suitable shrubs and vegetation can create an effective barrier to deter the public from accessing pond areas, steep slopes, and structures that are potentially hazardous.

iv) Enhancement and Aesthetic Benefits:

Vegetation can create visual buffers, enhance views and contribute to the character and enhancement of a development. Consideration should be given to the requirements of the users, recreational requirements, and public safety.

v) Other:

Vegetation may be used to filter sediments, trap floatables, and conceal structures and fencing. In pond areas subject to frequent inundation, sod should be used. Areas not affected by varying inundation can be seeded.

6.1.5 Wildlife Deterrence

Waterfowl in certain proximity of the Calgary International Airport is not desirable, therefore mitigation is required to deter them from using the pond as a home or resting place. Waterfowl cause problems for airplanes and can also lead to fecal contamination of the water in the ponds, which eventually discharges into rivers and streams.

The establishment of a dense band of woody vegetation around the perimeter of wet ponds and wetlands can deter undesirable species of waterfowl. In some areas, wires are installed at the NWL of the pond; however vegetation and other low maintenance remedies are preferred. Consultation with Parks and the Calgary Airport Authority is required. There might also be other non-vegetative methods that can be used to deter waterfowl.

6.1.6 Water Quality

Dry ponds typically provide little water quality improvement unless sediment forebays or equivalents are installed. However, wet ponds and wetlands are considered more appropriate facilities for providing water quality enhancement. All wet ponds and wetlands must be designed to meet the water quality standards described in ***6.3.2.7 Water Quality*** and ***6.4.2.8 Water Quality*** and ***CHAPTER 7: WATER QUALITY***. While oil/grit separators are not typically an appropriate replacement for a stormwater pond, sedimentation vaults or oil/grit separators may be considered in lieu of sediment forebays, subject to the approval of Water Resources.

6.1.7 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of all stormwater ponds (wet ponds and wetlands, and dry ponds if requested). The purpose of the report is to determine criteria such as subdrainage design, liner requirements (infiltration), and special design conditions such as slope stability, particularly for sites classified as a dam (refer to ***2.3.3.2 Dam and Canal Safety***). For ponds requiring a liner, preference should be given to using clay, where possible, or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Concerns due to potential infiltration, exfiltration, construction dewatering, and liner uplifting should also be addressed. Where liner uplifting is a concern, a subdrain might be required to provide relief.

When infiltration/percolation into the subsoils is proposed to meet runoff volume targets, the proponent must:

- Assess the impact on the groundwater table.
- Demonstrate that the assumed percolation rates are sustainable in the long run on a local and a regional level.
- Demonstrate that the percolating runoff will have no detrimental impact on adjacent roadways or any down stream structures.

- Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

Infiltration and/or percolation into the subsoils are not permitted if the runoff is contaminated with highly mobile constituents, as assessed by an environmental specialist with The City of Calgary's Environmental & Safety Management business unit.

The report must be submitted and approved by Water Resources prior to submission of the construction drawings. The geotechnical report should be submitted with the Pond Report, the MDP report, or the SMDP report, whichever is the most feasible. Required details must be indicated on the construction drawings.

A dam safety assessment, including supporting geotechnical reports, must be submitted to Water Resources at the pre-design stage for stormwater ponds that could be classified as having a dam (refer to ***2.3.3.2 Dam and Canal Safety***); approval under the *Water Act* is required. Drawings of the pond must also be submitted. After internal review, Water Resources will forward the information to Alberta Environment's Dam Safety Branch as part of the review process.

Mitigation strategies for potential impacts from failure of a pond, which has an embankment that is not classified as a dam under the *Water Act* but has a total (i.e., dead + live) 1:100 year storage volume of more than 10,000 m^3 and an embankment of more than 1.0 m above original ground, will be assessed on a case-by-case basis. The embankment might require an impermeable core, penetrations of the embankment by utilities should be avoided, and the design capacity of the overland escape route might be greater than would result from following the procedures in ***6.1.3 Overland Drainage and Escape Routes***. Contact Water Resources as early as possible in the design process for more information. Refer to the Canadian Dam Association's *Dam Safety Guidelines* and associated Technical Bulletins for more information on how to conduct a dam safety assessment.

Based on local conditions, the consultant might be required to submit an assessment of the pond embankment and potential downstream impacts. The assessment might include:

- Analysis of embankment stability in case of rapid drawdown of the pond.
- Estimation of breach width and peak outflow rate.
- Identification of probable downstream flow routes, peak flow rates and travel/ peak-arrival times.
- Inundation studies, with and without embankment failure.
- Assessment of the erodibility of downstream flow routes.
- Identification of potential transportation and egress route disruptions.
- Listing of infrastructure, populations and addresses at risk, including institutional and utility features.

- Listing of downstream safety issues including potentially damaged utilities, road wash-outs, etc.
- Identification of temporary diversion, containment or flood protection measures.
- Plans for notification, evacuation and recovery.
- Inspection and maintenance protocols.

6.1.8 Signage

All ponds are required to have appropriate signage. Signage is required at all entrances to the pond and at any other critical points; this does not include private gates from single-family residential lots. Maximum spacing between the signs is 200 m; signs should be easily visible (and readable) from the pathway system (where applicable). Locations should be identified on the Site/Overall pond drawing. Refer to ***APPENDIX D: Signage for Ponds*** and Water Resources' *Standard Specifications Sewer Construction* for sign requirements. The developer is responsible for the cost of purchasing and installing all signage. Arrangements can be made with Water Services to order and/or install the signs.

Signs promoting public education are encouraged. Signs may include information regarding the operation and purpose of the pond, protection of the environment, water conservation, native landscaping, the impact of chemicals and interpretative trails. Contact Water Services and/or Parks for more information

6.1.9 Operating and Maintenance (O&M) Manuals

To ensure that the designed stormwater pond is operated and maintained properly, an Operating and Maintenance (O&M) manual is typically required for dry ponds, wet ponds, and wetland facilities. The need for an O&M manual will be determined by Water Resources upon review of the construction drawings. The O&M manual must be prepared by the owner/developer, or his designated consultant, and be submitted at the time of Final Acceptance Certificate (FAC) application. The manual must contain the following:

- A list of additional mechanical and electrical equipment used in the design of the facility. This will include equipment/part lists, manufacturer's operation requirements, maintenance, service and repair instructions, and warranties.
- An outline of normal expected operational requirements.
- An outline of emergency operating requirements.
- Long term and short term maintenance requirements for vegetation.
- Any special maintenance requirements or conditions such as waterfowl controls or special maintenance agreements and contacts for appurtenances not maintained by The City.

For ponds with a simple control system, the O&M manual may be as small as one or two pages. Water Resources will forward a copy of the manual to Water Services' Field Services Operations Engineering team, who is responsible for maintenance.

6.1.10 Monitoring Systems

Remote water level monitoring equipment is required at all ponds to allow monitoring by Water Services staff when the pond is being used for storage. The equipment will be installed at the developer's expense. Refer to ***APPENDIX C: Monitoring Equipment for Ponds*** for information on monitoring equipment requirements.

6.1.10.1 Equipment

A copy of the latest specification is available upon request. Contact Water Resources' Industrial Control Systems Engineer for more information. **The equipment identified in the specifications must be used**; other equipment may not be compatible.

The monitoring equipment consists of a panel containing an ultrasonic sensor, a mechanical float, and a Remote Terminal Unit (RTU), which are integrated with a centralized storm pond monitoring (or Supervisory Control and Data Acquisition (SCADA)) system.

6.1.10.1.1 Ultrasonic Sensors

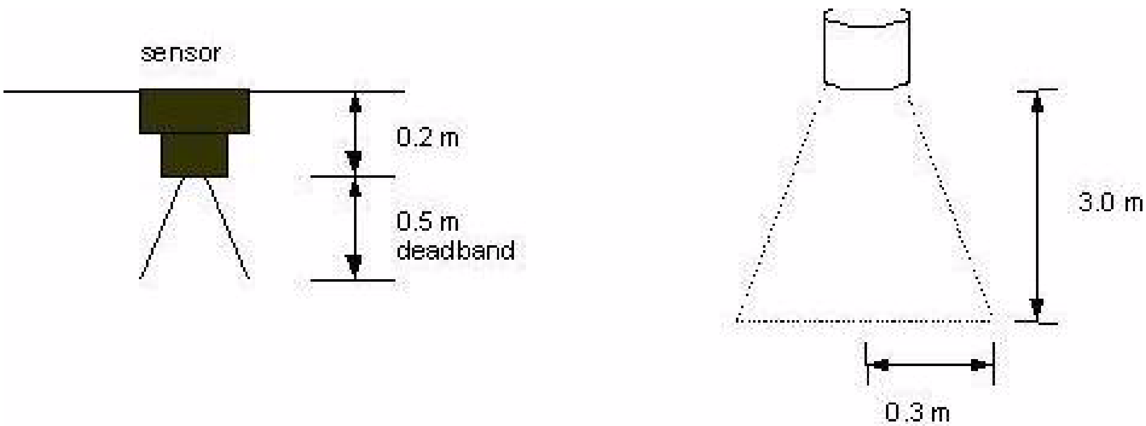
The ultrasonic sensor is typically mounted in the outlet control structure on the upstream side. As an alternative for wet ponds and wetlands, a stilling well MH may be installed adjacent to the pond to house the monitoring equipment. The sensor measures the level of the water in the structure, which relates back to the level of water in the pond.

The sensor must also be set to send an alarm to Water Services' Duty Supervisor when the following elevations are reached:

- LWL (bottom elevation) and HWL in a dry pond.
- NWL and HWL in a wet pond/wetland.
- (L)NWL, (U)NWL, and HWL in wet ponds where water is re-used for irrigation or other purposes. A written authorization from Water Services, Field Services is required for irrigation re-use.

In order to operate properly, a deadband of 0.50 m is required for the sensor (refer to ***Figure 6-2***). This is the distance between the bottom of the sensor and the highest recordable elevation (or depth) required, which is usually the HWL. Where possible, the HWL elevation should be set below the required deadband to provide additional clearance.

Figure 6-2: Dead Band and Sensor Band for Ultrasonic Sensors



Due to the conical shape of the sensor band, it is important that there be sufficient radial clearance (refer to ***Figure 6-2***) between the signal from the sensor and any structure wall or protrusions. A radial distance of 0.30 m per 3.0 m of vertical distance is required. Ensure that MH rungs, trash racks, etc., do not interfere with the signal.

As a backup to the ultrasonic sensor, a mechanical float (Flygt bulb) is installed at or just below the HWL elevation.

6.1.10.1.2 Remote Terminal Units (RTUs)

The Remote Terminal Unit (RTU) is a critical component of the monitoring system. There are 5 conditions that must be programmed into the RTU:

- LWL (pond bottom) elevation for dry ponds, NWL (plus 0.10 m) for wet ponds/ wetlands, or (L)NWL (plus 0.10 m) for wet ponds with re-use provisions.
- HWL elevation.
- Flygt bulb set at HWL.
- Loss of power.
- Intrusion alarm.

When any one of these conditions is encountered, the storm pond monitoring system sends an alarm to Water Services' Duty Supervisor, who then responds to the alarm(s).

6.1.10.1.3 Storm Pond Monitoring Systems

All ponds that are ultimately owned by The City of Calgary are connected to a centralized storm pond monitoring system (SCADA). When monitoring equipment is installed, The City of Calgary is notified of the new pond by its service provider.

6.1.10.2 Setup and Calibration

Due to the complexity of the equipment, setup must be completed by a qualified contractor. A calibration certificate from the service provider (or the equipment vendor) is also required to ensure that the elevations (HWL, NWL, and pond bottom) have been set correctly. Calibration certificates and phone numbers must be submitted to Water Resources. Monitoring equipment must be operational prior to CCC; delays in servicing phone and electrical lines must be approved by Water Resources.

6.1.10.3 Alarms

Once the monitoring equipment has been set up and calibrated, Water Services will respond to any alarms received. However, during the maintenance period, if any of the alarms are caused by maintenance problems, vandalism, telecommunication problems, etc., the developer/consultant will be contacted. It is the developer's responsibility to fix any problems during the maintenance period.

6.1.11 Maintenance Periods

For more information, refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS*** and ***APPENDIX I: Stormwater Pond Inspection Requirements***.

6.1.11.1 Staged Construction

Staged construction will be considered for wet ponds and wetlands on a case-by-case basis, depending on the size of the drainage area and the risk of or impact from erosion from unstabilized recently excavated areas in the pond, as well as where future expansion consists of independent cells that can be fully isolated from the earlier constructed cells. Small facilities should be constructed in their entirety."

Water Resources must approve any proposed staged construction. Staging information must be submitted as part of the SMDP and/or Pond Report (to confirm pond volumes and water levels) and/or construction drawing submissions. Stubs allowing for future connections from future cells should preferably be pre-installed.

Note: Any expansions to stormwater ponds require an amending approval from Alberta Environment.

Where staged construction is permitted, the FAC will not be issued until the required maintenance period has elapsed after the last phase of staged construction, unless otherwise approved by Water Resources. The conditions pertaining to staged construction of ponds, including CCC and FAC, will be site-specific and must be outlined in the Development Agreement for the development in question. The developer responsible for subsequent stages will be required to remediate any damage and/or to remove excess sediment from the earlier constructed cells of the pond.

Separate approval for staged construction of landscaping must be received from Parks.

6.1.11.2 Stormwater Facility CCC and FAC Issuance

6.1.11.2.1 Construction Completion Certificates (CCCs)

A CCC will only be issued after the required as-builts for the pond have been submitted and approved by Water Resources. Any requests for omissions must be accompanied by a letter of intent that indicates the proposed installation date.

A separate CCC must also be issued by Parks, primarily for grading, loaming, seeding, and landscaping. Some of these items are also included in the CCC issued by Water Resources.

For more information with respect to inspections at the time of CCC application, refer to ***APPENDIX I: Stormwater Pond Inspection Requirements***.

6.1.11.2.2 Final Acceptance Certificates (FACs)

A maintenance period of 3 years is required on all dry ponds, wet ponds, and wetlands. During this time, the developer is responsible for any maintenance associated with the pond, as well as all electrical and telephone bills. Prior to The City taking over the pond, sediment removal must be completed. To ensure that the pond is clean and in acceptable condition, a sediment survey of the pond bottom should be completed for wet ponds and wetlands.

Upon FAC, the developer (consultant) must send a request to the Senior Operations Engineer, Field Services to transfer the telephone and utility accounts to The City of Calgary. This request must include copies of the utility bills. Water Resources will subsequently request the transfer of the utilities. Once the FAC has been issued, Water Services will assume all responsibility for the pond and utility bills.

A separate FAC must also be issued by Parks, primarily for grading, loaming, seeding and landscaping. Some of these items are also included in the FAC issued by Water Resources.

For more information with respect to inspections at the time of FAC application, refer to ***APPENDIX I: Stormwater Pond Inspection Requirements***.

6.1.11.3 Automatic Control Gates

6.1.11.3.1 Construction Completion Certificates (CCCs)

The CCC will only be issued after the required as-builts for the gates have been submitted and approved by Water Resources. Requests for omissions will not be permitted. An O&M manual must also be submitted.

6.1.11.3.2 Final Acceptance Certificates (FACs)

A maintenance period of 3 years is required on all automatic control gate systems. During this time, the developer is responsible for any maintenance associated with the gates, and all electrical and telephone bills. Once the FAC has been issued, Water Services will assume all responsibility for the gates and utility bills.

6.1.12 Temporary Ponds

Typically, Water Resources does not favour the construction of temporary ponds. If temporary ponds are implemented, the final pond must be constructed within a time frame to be agreed upon beforehand with Water Resources. Water Resources will not take over temporary ponds. The conditions pertaining to temporary ponds, including CCC and FAC, will be site-specific and must be outlined in the Development Agreement for the development in question.

6.2 Dry Ponds

6.2.1 Introduction

Dry ponds are impoundment areas used to temporarily store stormwater runoff in order to restrict downstream discharge to predetermined rates, and to reduce downstream flooding and erosion potential. Usually they are incorporated as multi-purpose facilities.

Dry ponds may be constructed by an embankment or through excavation of a depression. Most dry ponds have no permanent pool of water. As a result, they can be effectively used for quantity control. Generally, dry ponds are not intended as water improvement facilities. Water quality enhancement is required through the use of sediment forebays that include a permanent pool, or through an alternate design approved by Water Resources, Development Approvals.

Dry ponds may be constructed where topographic or planning constraints exist that limit the implementation of wet ponds or wetlands. Although water quality requirements will prompt more construction of wet ponds and wetlands than dry ponds, dry ponds still have a place in the stormwater drainage system. Use of dry ponds is appropriate for retrofit projects where water depth is an issue, for areas where dry recreational or passive use is required, or where water quality can be implemented in a downstream wet pond or wetland.

6.2.2 Design

Figure 6-3 illustrates the components of a dry pond, while ***Table 6-1*** summarizes the pertinent design criteria for dry ponds. These criteria are discussed in more detail in subsequent sections.

Figure 6-3: Dry Pond with Forebay

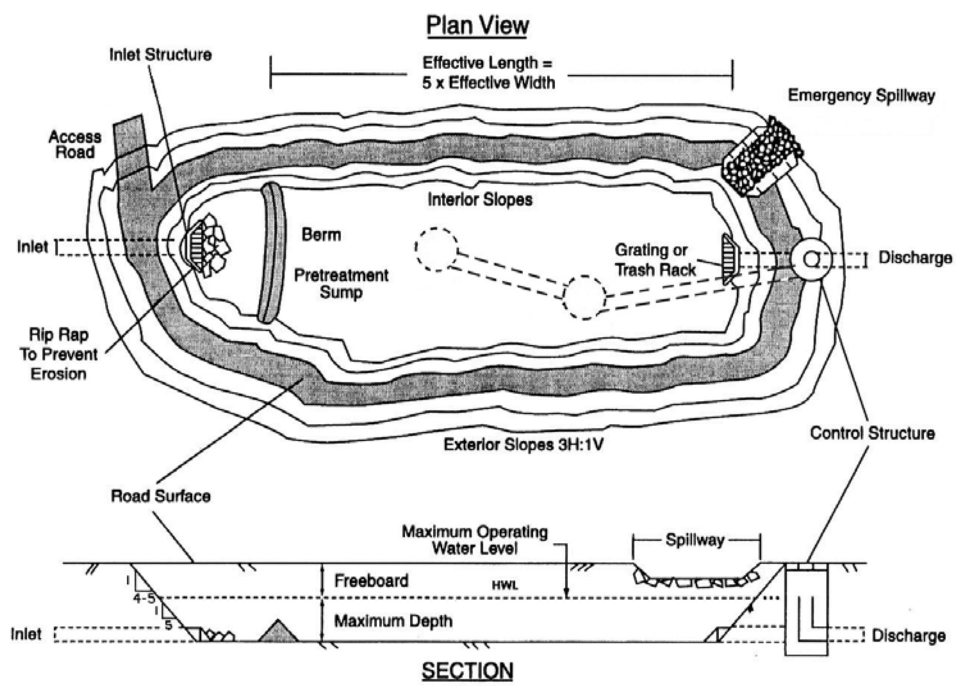


Table 6-1: Design Summary Guide for Dry Ponds

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service / Volumetric Sizing	Provision of approximate level of protection and adequate volume.	1:100 year design.	
Land Dedication	Appropriate location.	MR, PUL, non-significant ER, and MSR.	MR, PUL, and non-significant ER.
Drainage Area	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume.	Not applicable.	Not applicable.
Pond Area/ Number of Ponds	Maximize pond area to limit number of ponds.	Minimum 0.80 ha at HWL	
Sediment Forebay	Pre-treatment (sedimentation).	• Minimum depth: 1.50 m (typically measured from bottom of forebay to forebay NWL) • Approximate Length and Width according to ***6.3.2.8 Sediment Forebay***	2.0 m.
Active Storage Detention Time	Suspended Solids Setting.	Minimum 24 hours.	
Length:Width Ratio	Maximize flow path and minimize short-circuiting.	Minimum 3:1.	4:1 to 5:1.
Pond Depth	Safety.	• Max 1.50 m • **Freeboard: 0.30m** minimum. Refer to ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	Maximum 1.50 m
Overland Routes	Safety.	Meets Alberta Environment Depth-Velocity guidelines.	
Escape Route	Safety.	Minimum 1.0 m^3/s. Refer to ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	Maximum possible.
HGL	To prevent backup.	Surcharging 1.20 m below surface, except for last pipe segment into the pond.	HGL impact confined to pipe adjacent to pond.
Landscaping	Public amenity and safety.	Approval of Water Resources and Parks	
Bottom Grading	Drainage.	1.5%.	2.0%.
Side Slopes	Safety.	• No steeper than 5H:1V for inundated area. • No steeper than 4H:1V above HWL for inward facing slopes • No steeper than 3H:1V for outward facing slopes	
Inlet	Avoid clogging/freezing.	Minimum 450mm diameter. Refer to ***Table 6-2 : Design Summary Guide for Wet Ponds*** for more information if a forebay is utilized.	

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Catchbasins/ Drain Inlets	Avoid clogging.	0.90 m diameter CB barrel for shallow installations.	1.20 m diameter Type 5A MH.
Gratings	Avoid clogging and safety.	• Armtec Type V. • Galvanized coating, depending on the use of the site • Size: Maximum 3.0 m x 1.0 m per section for inlet. • Maximum 1.50 m/s inlet velocity • Bolting required.	• Vinyl Coating (or approved equivalent).
Outlet	Safety and maintenance.	1.20 m x 1.20 m per chamber.	1.80 m x 1.80 m per chamber.
Orifice	Avoid plugging.	50 mm diameter minimum.	100 mm diameter minimum.
Trash Rack	Protect orifice from plugging	Required when orifice $\leq$ 200mm diameter.	
Gate Valve	Bypass and maintenance	Required (300 mm diameter).	
Maintenance Vehicle Access	Access for equipment (typically 13 tonne vactor truck) and safety	• Width: 3.0 m with additional consideration for width at turns or bends. • Turning Radius: 8.0 m. • Access gate(s) from the main road is required. • Road structure must accommodate maintenance vehicle weight and loading.	Width 4.0 m.
Fencing	Safety	Not generally required.	
Monitoring Equipment	Safety and design.	Required (refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds***).	
Signage	Safety.	Required (Refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary Water Resources' *Standard Specifications Sewer Construction*).	
Note: Refer to detailed information provided in following sections.			

6.2.2.1 Level of Service/Volumetric Sizing

Dry ponds must provide a storage capacity for a 1:100 year condition; the corresponding water level is the HWL (refer to ***6.1.2 Level of Service*** (Item ii)). This capacity is based on quantity control. A lower level of service may be allowed for retrofit facilities, subject to approval from Water Resources. Where possible, a wet pool should be provided to facilitate settling of suspended solids for dry ponds that include a sediment forebay. Refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS***.

Release rates from the ponds must conform to the rates set out in the approved MDP report and/or approved SMDP report.

6.2.2.2 Land Dedication

Refer to The City of Calgary Parks' *Open Space Plan* for more information.

i) Dry ponds that will ultimately be operated by the City of Calgary must be located within the following:
   - Municipal Reserves (MRs)
   - Public Utility Lots (PULs)
   - Non-significant Environmental Reserves (ERs), as approved by Parks.

ii) The use of Municipal School Reserves (MSRs) will only be supported provided the location, size, and recreational function of the reserve is not prejudiced. Use of School Reserves (SRs) is not supported.

iii) Dry ponds should not be located in Major Natural Area Parks.

iv) Dry ponds should not be located in river valleys unless there are no other viable locations.

v) Where a dry pond is located on privately owned land, an easement is required to permit encroachment of water onto the property and to restrict development in the areas subject to inundation. For ponds proposed on provincial lands, approval is required from the Province of Alberta. Contact the appropriate provincial department.

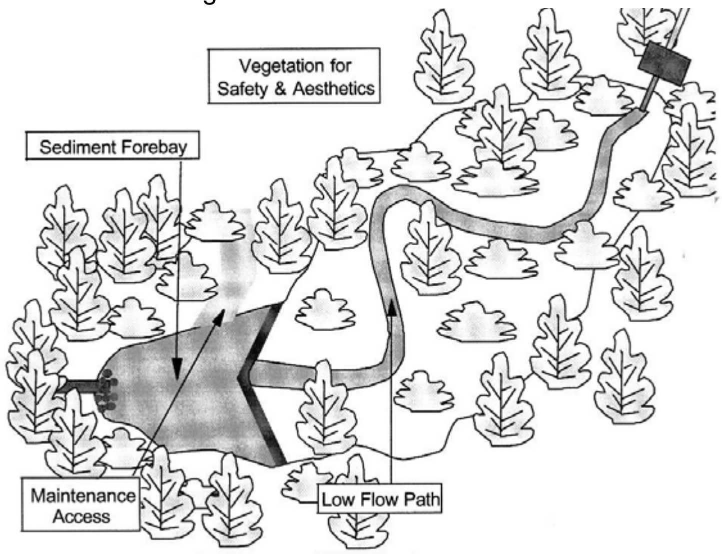
vi) A maintenance agreement is required for any public (City-owned) pond that will be operated and maintained by a private owner. Contact Water Resources for more information.

vii) The maximum level of inundation, or the HWL, must not encroach onto private property. Lots bordering the dry pond are required to have abutting property elevations a minimum of 0.30 m above the design emergency overland flow elevation of the pond when the pond has an overland emergency escape route. This must be increased to a suitable higher elevation in the absence of an overland emergency escape route (refer to ***6.1.3 Overland Drainage and Escape Routes***).Contact Water Resources for more information.

6.2.2.3 Frequency of Inundation

Where possible, a subsurface low flow bypass system should be used to minimize the frequency of inundation. Alternatively, where the high frequency of inundation cannot be altered, it is recommended that a low flow channel be constructed through the pond. Suitable vegetation along the channel must be used.

Figure 6-4: Low Flow Channel



6.2.2.4 Drainage Area

There currently is no minimum drainage area requirement. The contributing drainage area requirement for a dry pond is a function of the permitted release rate.

6.2.2.5 Pond Area and Number of Ponds

The minimum area of a dry pond must be 0.80 ha at HWL. Smaller areas will only be considered on a site-specific basis, at the discretion of Water Resources. In such cases, the private owner might be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer, larger ponds. The developer must make every effort throughout the planning process to limit the number of ponds required.

6.2.2.6 Winter Operation

Dry ponds are normally the least affected by winter/spring conditions, since there is typically no permanent pool. However, precautions should be taken to minimize the effects of freezing of pipes and orifices.

6.2.2.7 Sediment Forebay

In the past, most dry ponds in Calgary have not utilized sediment forebays, since water quality was not typically an objective. However, a sediment forebay can be used to facilitate maintenance and provide some degree of pollutant removal for the larger sediment particles. When a forebay is included, the forebay should be a minimum of 1.50 m deep to minimize the potential for scour and re-suspension of sediments. The recommended minimum depth is 2.0 m. Sizing of the forebay is dependent on the inlet configuration. Refer to ***6.3.2.8 Sediment Forebay*** for sizing criteria. Sedimentation vaults or oil/grit separators may also be considered, subject to approval by Water Resources.

6.2.2.8 Forebay Berms

When a forebay is included in the design of the dry pond, an earthen berm can be used to separate the forebay from the rest of the pond. Since the downstream side of the berm will be dry, the berm should be designed as a small dam. A weir should be designed at the top of the berm to convey flows to the downstream section of the pond during storm events. The forebay can also be incorporated as a permanent pool set below the bottom elevation of the dry pond.

To facilitate cleaning of the forebay, a maintenance pipe should be installed in the berm. A valve, to open and close the pipe, should be installed on the upstream side of the pipe. Under normal operating conditions, the valve should be closed. During maintenance periods, the valve should be open to allow draining of the forebay.

Vegetation should be planted on the top of the berm to promote filtration of water as is passes over the berm. Suitable vegetation includes American bulrush and softstem bulrush. The vegetation should be planted on the forebay side of the berm at a depth no greater than 30 cm. As a secondary benefit, the vegetation will also act as a barrier to public access.

6.2.2.9 Detention Time

Where possible, a minimum detention time of 24 hours is preferred to promote water quality enhancement for dry ponds. Where water quality enhancement is provided by other means (i.e., a downstream wet pond or oil/grit separator), shorter detention times might be considered. Refer to ***6.1.2 Level of Service*** for definition of detention time.

6.2.2.10 Length:Width Ratio

For dry ponds with a continuous flow path, all stormwater should be conveyed to one inlet location, if possible. To provide the longest flow path through the pond, the inlet should be located as far away from the outlet as possible. A pond with a length to width ratio greater than, or equal to, 3:1 will have an acceptable flow path. The preferred length to width ratio ranges from 4:1 to 5:1. Effective length excludes forebay length.

For dry ponds governed by other planned uses, such as playfields, relaxation of the length to width ratio will be considered by Water Resources. Contact Water Resources for more information.

6.2.2.11 Pond Depth

The **maximum** active depth for a dry pond is 1.50 m, measured from the elevation of the pond bottom to the 1:100 year elevation or HWL. In addition, a minimum freeboard of 0.30 m is required above the water level in the pond that corresponds to the design overland emergency discharge rate. Refer to ***6.1.3 Overland Drainage and Escape Routes*** for the definition of design overflow emergency discharge rate. The primary factor in establishing this depth restriction is concern for the safety of children.

If the pond includes a sediment forebay, the maximum active depth from the NWL in the forebay to the 1:100 year elevation (or HWL) must be 1.50 m. For the depth of the forebay, refer to ***6.2.2.7 Sediment Forebay***.

6.2.2.12 Overland Drainage and Escape Routes

Overland drainage and escape route requirements include the following:

i) Overland drainage routes that direct flows from the 1:100 year storm event **to** the pond area must be provided. Overland flow design velocities (v) and depths (d) must be in accordance with *Stormwater Management Guidelines for the Province of Alberta (1999)*. Refer to ***Table 3-18*** and ***Figure 3-10*** in ***CHAPTER 3: STORMWATER DESIGN*** for more information.

ii) Overland drainage routes entering the pond should be directed into the forebay (if applicable). If this is not feasible, the runoff might need to be pre-treated before it is allowed to enter the pond. Trap lows adjacent to the pond may spill into the main cell(s) of the pond provided that the trap lows fully contain the runoff from a 1:5 year event without spillover. Similarly, localized sheet flow from areas directly adjacent to the pond are permitted into the main cell(s) of the pond, provided that flows are kept to a minimum.

iii) A designated continuous emergency overland escape route from all ponds is to be provided. In general, the design capacity of the overland emergency escape route (refer to ***Figure 6-1***) from the pond should be the greater of either:

   - The resulting spillover rate for a 24 hour, 1:100 year event, assuming that the regular outflow is 0 m^3/s and a starting water level of HWL.
   - 1.0 m^3/s.

   The magnitude of the design capacity of the overland escape route must be determined at the time of pond design. The configuration and capacity must be adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route. Proper engineering design based on the local circumstances is required.

   A minimum 0.30 m freeboard must be provided above the water level that corresponds to the design overland emergency discharge rate.

iv) Optionally, additional freeboard over and above what is required may be considered in cases where it is difficult to establish an overland escape route. The additional freeboard would provide a higher level of service overall; however implications to the HGL upstream of the pond must be considered.

v) Sanitary sewer MHs must be located outside of impoundment (pond) areas.

vi) Whenever possible, sanitary sewer MHs should not be located within the overland drainage route. When the situation is unavoidable, sanitary sewer MHs must be sealed. Bolting is at the discretion of Water Resources.

vii) Erosion control needs must be evaluated for both the overland drainage routes into the pond and the overland emergency escape route from the pond.

6.2.2.13 Hydraulics

The 1:100 year elevation will be established taking into consideration adjacent footing elevations. When the dry pond is at the 1:100 year elevation, water should not back up through the storm sewer system and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting HGL should be kept to a minimum. Free flow conditions are preferable; this is achieved when the obvert of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Water Resources. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

When free flow conditions are not achieved based on the HWL, HGL elevations in the storm sewer system must be determined based on the pond at HWL, and the appropriate losses must be taken into account (i.e., junction losses, pipe losses, etc.). Alternatively, a dynamic hydraulic analysis can be carried out to establish the HGL elevations. **Surrounding lowest top of footing (LTF), or slab, elevations must be a minimum of 0.30 m above the HGL.**

Other options for protecting weeping tile connections include a separate weeping tile drainage system connected downstream of the pond or a sump pump to the surface. Weeping tile drains connected to the sanitary system are not permitted under any circumstances.

Except for the last pipe segment into the pond, sewer pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface (refer to *3.1.2.1 General Requirements*).** Also, proper aeration and venting must be considered as per ***5.5.2 Design***. Contact Water Resources for more information.

Backflow prevention devices are required on all weeping tile connections as per the *National Plumbing Code of Canada*.

All upstream storm piping below the HWL and resulting HGL, must be rubber gasketed as per The City of Calgary Water Resources' *Standard Specifications Sewer Construction*.

6.2.2.14 Landscaping and Vegetation

Landscaping and vegetation plans must be submitted with the construction drawings, to be reviewed and approved by Water Resources and Parks. All landscaping must be prepared by a qualified consultant and must conform to The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*. Also refer to ***APPENDIX E: Recommended Plant Species*** for information about recommended plant species.

6.2.2.14.1 General

General landscaping and vegetation requirements include the following:

- Collaboration with Parks is required when designing a multi-use dry pond to ensure that the best possible design is achieved.
- Where the pond access is shared with a park pathway, the pathway must be constructed in accordance with pond access requirements.
- Playfields should be located outside of the inundation area where possible. Where playfields must be located within the pond, it is preferable to have soccer fields if possible, since the shale associated with baseball diamonds tends to cause maintenance problems. Certain surfacing materials are more suitable than others.
- Playgrounds are **not** permitted in the inundation area of the pond.
- In general, trees are to be planted above the area of inundation (HWL elevation).
- The area below the area of inundation (HWL) must be sodded to establish grass cover. Areas above the level of inundation may be seeded.

6.2.2.14.2 Extended Detention Areas/Active Storage Areas

Extended detention areas are the areas subject to frequent wetting from storm events. The area is generally defined as the land between the pond bottom and the HWL for a dry pond.

Growing conditions in this area are generally harsher than in other areas of the dry pond, and plant establishment is more difficult. Hardy hydric grass should be used. When planting shrubs, only the lower branches are permitted to be inundated during a storm event.

For dry ponds that include a sediment forebay, vegetation is permitted adjacent to the forebay. As well, hydric plants may be planted in areas subject to frequent flows across the surface of the dry pond.

6.2.2.14.3 Fringe Areas

The fringe area is a zone of infrequent inundation. In a dry pond, this is the area just below and slightly above the HWL. The influence of inundation is less pronounced in this area, so plants must be able to tolerate infrequent inundation. Consideration should be given to using the appropriate species of grasses and shrubs. In general, trees are to be planted above the HWL.

6.2.2.14.4 Upland Areas

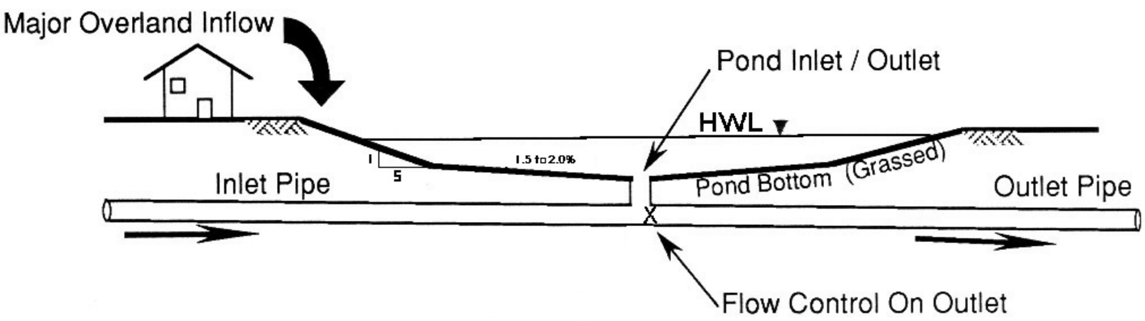
Upland areas are the landscaped areas above the HWL that surround the pond. Plantings in this area should provide a minimum of a 3.0 m wide buffer strip above the HWL. The selection of plants in this area should consider:

- The type of amenity.
- Access restrictions to steep areas or inlet/outlet locations.
- Careful planning of deciduous trees to minimize plugging of catchbasins (CBs) and inlets/outlets in the pond due to leaves.

• Minimization of maintenance (naturalized landscaping where possible).
• Topography and surface drainage.
• Soil conditions.

6.2.2.15 Grading/Slopes

Figure 6-5: Dry Pond Slopes



6.2.2.15.1 Bottom Grading

The bottom of dry ponds must be graded to properly drain all areas after operation. The bottom slope must be steeper than 1.5%. The recommended bottom slope is 2.0%.

6.2.2.15.2 Side Slopes

The maximum side slope must be no steeper than 5H:1V from pond bottom to high water level (HWL), including the freeboard.

Above the HWL, side slopes no steeper than 4H:1V are permitted for inward facing slopes. If the depth of the interior slope is significant, then stairs, or other means of exit, must be provided to ensure the safety of individuals, particularly children, exiting the pond. Subject to the approval of Water Resources, steeper side slopes in localized areas may be allowed above the inundated area for a limited distance, provided that a 2.0 m wide safety bench is provided above the freeboard elevation.

Side slopes of no steeper than 3H:1V are permitted for outward facing slopes. This is the maximum slope permitted for mowing grass.

6.2.2.16 Subdrainage Systems

A subdrainage system (or weeping tile drainage system) is required for all dry ponds, regardless of the elevation of the water table. The type of system installed should reflect the soil conditions at the location. Although there is no set standard for the subdrainage system, french drains or similar should be installed. The purpose of the subdrainage system is to improve drainage at the bottom of the pond so recreational fields (where permitted) are useable as soon as possible after inundation, and maintenance (such as mowing or cleaning) can be performed. The depth and type of loam used in the dry pond must not adversely impact the function of the subdrainage system. All systems must be approved by Water Resources.

6.2.2.17 Inlets, Inlet/Outlets, and Catchbasins (CBs)

Depending on the design of the dry pond, there are generally three types of structures that permit the inflow of stormwater into the pond: inlet(s), inlet/outlet(s) and CBs. Inlet/outlet structures facilitate both inlet and outlet flow control and are often referred to as “outlet control structures” (refer to ***6.2.2.18 Outlet Control Structures***).

Requirements include the following:

i) The use of CBs (or drain inlets) in the bottom of the pond is encouraged. Standard 0.90 m diameter CBs are permitted for shallow (single-barrel deep) installations. For all other installations, the drain inlets must be 1.20 m diameter Type 5A barrels. The gratings must be bolted to the top of the barrel.

ii) The number of inlets into the pond should be kept to a minimum.

iii) Due to concerns for winter operation, the diameter of the inlet pipe should be 450 mm or larger. Inlet, inlet/outlet structures and CBs should be located to minimize exposure to blowing snow, and to maximize exposure to sunlight to reduce potential for ice buildup during freeze-thaw conditions.

iv) Where a forebay has been included as part of the dry pond, the inlet should be designed in accordance to the design used for wet ponds (refer to ***6.3.2.20 Inlets***).

v) Erosion control measures should be provided at the bottom of the inlet/outlet structure(s). Erosion control should include interlocking stone or an approved concrete revetment system, either on the surface or subsurface. Typically, the erosion protection should extend along the side slope to the bottom of the pond.

vi) Clay plugs are required for all inlet and outlet pipes.

vii) Inlet velocities (through the gratings) should be limited to 1.50 m/s where possible to minimize erosion and scour, as well as re-suspension of sediments.

viii) Appropriate fencing and safety railings must be provided where the vertical depth is greater than, or equal to, 1.0 m. In general, it is preferable that the structure be landscaped into the slope.

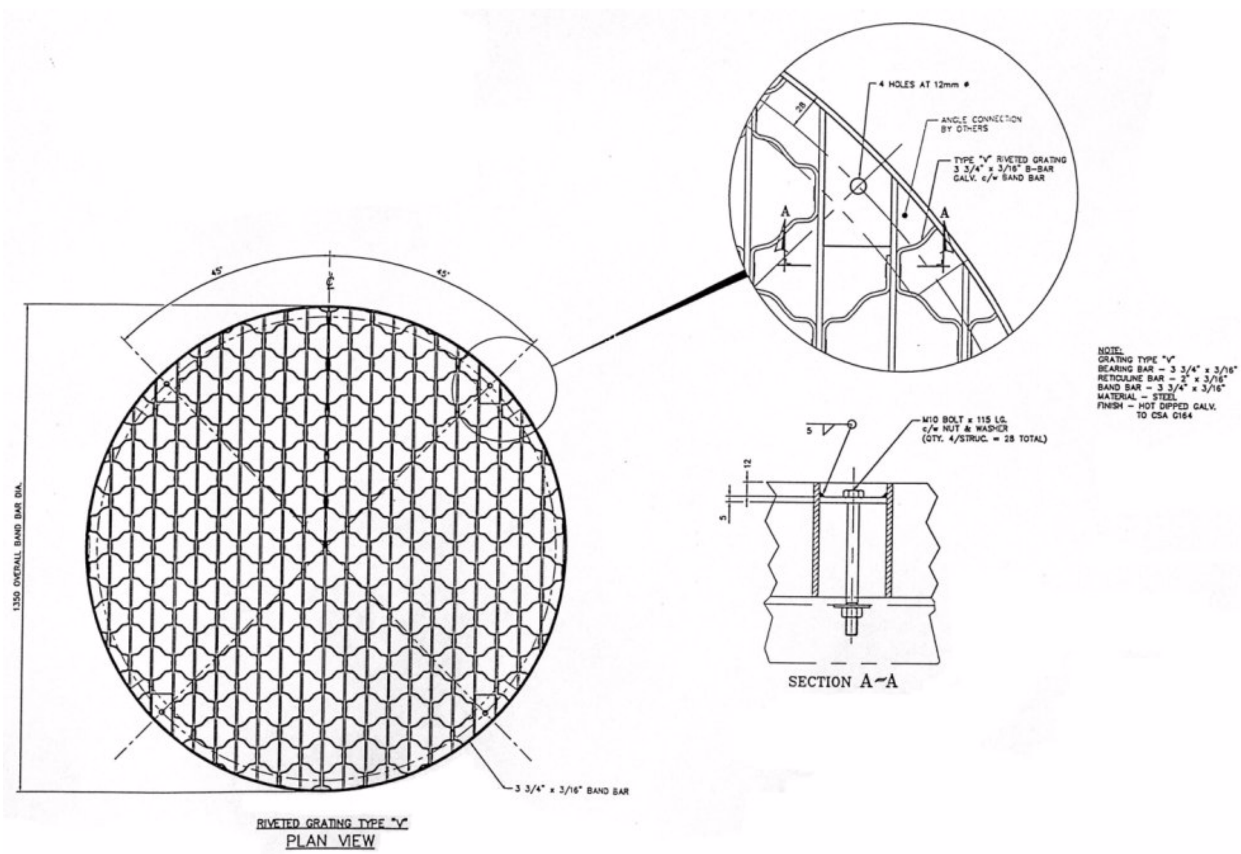
ix) Gratings:

- All inlet pipes and CBs must have gratings over their openings to prevent access by children or unauthorized persons. The only exception is submerged inlets when there is a permanent pool. In this case, the submerged inlets do not require gratings.
- All gratings must be bolted. Bolting should be recessed wherever possible. Inlet grates must have a minimum of 2 bolts per section; CBs must have a minimum of 2 bolts.
- In general, Armtec Type V riveted grating (3-3/4” x 3/16” b-bar, galvanized) should used (refer to ***Figure 6-6***). When flared-end sections are used for

inlets, the manufacturer's grating may be used. Any other grating type requires approval from Water Resources.

- The velocity of the flow passing through the grating of the inlet/outlet structure should not exceed 1.50 m/s. Excessive velocities create a concern for potential erosion and for children's safety during flooding.
- All gratings must be galvanized steel or an approved equivalent. At a minimum, the gratings must have galvanized coating. Depending on the use of the site, and subject to approval by Parks, the final coating might need to be vinyl (with an approved product) to provide a measure of safety for children.
- The size of a grating section on the inlet/outlet should not exceed 3.0 m x 1.0 m. Where larger gratings are required, more than one section should be used. The size of the gratings must be kept manageable to facilitate removal for maintenance purposes.

Figure 6-6: Typical CB Grating



6.2.2.18 Outlet Control Structures

Typically, the outlet control structure (also referred to as the “control structure” or the “outlet structure”) serves as the source of control for the release of stormwater from the pond. It is important that the structure be properly designed and constructed to provide minimal maintenance and to enhance safety. Design of the outlet control structure must be approved by Water Resources. Refer to ***5.3 Special Structures*** and ***5.4 Stage-Discharge Curves*** for additional design information.

Outlet control structures typically consist of two chambers, with a weir wall dividing them. For maintenance access, the size of each chamber should be a minimum of 1.20 m; the preferred size, however, is 1.80 m.

6.2.2.18.1 Orifices

The orifice provides the control for the permitted release rate for the pond. Typically, the orifice is located in the weir wall.

Subject to approval by Water Resources, orifices configurations other than circular openings can be considered. However, circular configurations with a slot are preferred for orifices along the floor bottom, because they better promote swirling flow and scour of deposited sediment at the bottom of the orifice. Supporting information, including hydraulic calculations for the proposed configurations, are to be provided to Water Resources as part of the Pond Report submission.

Orifice requirements include the following:

- The recommended minimum orifice diameter is 50 mm, to minimize the possibility of clogging at the outlet. The preferred minimum diameter, however, is 100 mm.
- Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event of blockage of the primary orifice.
- The orifice plate should preferably be constructed of stainless steel (306); however, galvanized steel or an approved equivalent are acceptable. The minimum gauge shall be 3 (1/4”).

6.2.2.18.2 Weir Wall

Dry ponds will typically have a weir wall in the outlet control structure to allow for pond overflow in the event of an orifice blockage. The weir wall spill elevation should be set at the HWL elevation, or the calculated HGL elevation.

6.2.2.18.3 Trash Rack

A trash rack must be installed to protect the orifice when the orifice diameter is less than (or equal to) 200 mm. The trash rack must be galvanized, and an access to the orifice for maintenance purposes must be provided. The openings in the trash rack must be large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable.

6.2.2.18.4 Gate Valve

All dry ponds require a gate valve. The gate valve is used as a bypass for the orifice, in the event the orifice plugs, and for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. Consideration should be given to not exceeding the design capacity in the downstream storm pipe, except in emergency situations.

All gates should have non-rising stems that are operated either mechanically or manually (with a T wrench). The T wrench should be located on the downstream end of the outlet control structure in an easily accessible location.

The use of automatic control gate systems is not advocated, but Water Resources will consider these designs on a site-specific basis. An O&M manual is required for all automatic control gate systems.

6.2.2.18.5 Hydraulics

The hydraulic performance of the outlet control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to ***CHAPTER 5: HYDRAULIC DESIGN***.

6.2.2.19 Maintenance Vehicle Access

Maintenance vehicle access requirements include the following:

i) Maintenance vehicle access from an adjacent street or lane must be provided to:
   - The outlet control structure
   - The inlet structure(s)
   - The skimming weir(s) or skimming manhole(s) in the upstream storm trunks.
   - The forebay (if any).

   Operations staff using 1 tonne trucks must be able to access all areas of the pond. In addition, a boat ramp shall be provided to the forebay (if any). The boat ramp must extend to at least 1.0 m below the NWL.

ii) To ensure proper access to the outlet control structure and associated electronic equipment, the entire maintenance vehicle access road including the top of the control structure and any associated electronic equipment must be at or above the freeboard elevation.

iii) At the inlet, maintenance vehicle access must be provided to the first manhole upstream of the forebay or pond inlet.

iv) Access to the forebay (for sediment removal and weed control) must be provided to the NWL. If a pond has multiple forebays, access must be provided to each forebay.

v) The first manhole upstream of the pond inlet, as well as the skimming weir/ skimming manhole, should preferably be located in a public roadway. If this roadway is subject to high traffic volumes (i.e., a primary collector and major/ arterial roadways), a turnout should be provided.

vi) Transportation Infrastructure or Roads should be consulted prior to pond design to ensure that the pond access road location is not an issue when the pond is located adjacent to or accessed from a major roadway and/or freeways/expressways. Access from major roadways or freeways should be avoided where possible due to safety concerns. Access should be designed to minimize interference with pedestrian activity and public safety. Pathways should not be used as a means of accessing pond maintenance areas (except by 1 tonne trucks) where possible, and maintenance areas should not impede or interfere with pedestrian activity and public safety.

vii) The vehicle access route must be a minimum of 3.50 m wide, but preferably 4.0 m wide. Additional consideration for width at turns and bends is required. The surface must be driveable, and the entrance must be gated with a bollard or equivalent at the property line (or any location where a public vehicle could otherwise access the pond site), to prevent unauthorized access.

viii) Sharp turns are to be avoided; the minimum turning radius is 12.0 m. Turn-arounds must be provided at the control or outlet structure, the inlet(s), and skimming weir/skimming manhole(s) if they are situated more than 30.0 m from the adjacent roadway. No turnaround is required for access to the forebay(s).

ix) Suitable surfacing material is to be used (i.e., pavement, gravel, etc.). The subgrade for the access route to the outlet control structure, inlet structure(s), and skimming weir/skimming manhole(s) must be able to withstand a 23 tonne tandem truck; the boat ramp must be able to withstand a 1 tonne truck. The subgrade must conform to a “Lane” road standard as per The City of Calgary Roads’ *Standard Specifications Roads Construction*. Alternatives will be considered, and are subject to approval, by Water Resources.

x) The slope of the access route to the outlet control structure, inlet structure(s), and skimming weir/skimming manhole(s) (using a 23 tonne tandem truck) should be flatter than 5%, with a maximum slope of 8%. The slope for the boat ramp (if any) and access around the pond (using a 1 tonne truck) must be flatter than or equal to 5H:1V.

6.2.2.20 Fencing

In general, full perimeter fencing is not advocated, unless required by Parks or other business units. Most dry ponds provide recreational amenities that must be accessible to the public. Alternatives, such as the strategic planting of vegetation to provide effective barriers, are advocated. However, some facilities might be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern, including areas where the vertical drop is greater than, or equal to, 1.0 m. Chain link fence is less desirable than safety railings, and is only acceptable when the attached fencing does not protrude above the top rail.

Any required fencing must be in accordance with The City of Calgary Parks’ *Development Guidelines and Standard Specifications-Landscape Construction.*

6.2.2.21 Monitoring System

Remote water level monitoring equipment is required at all dry ponds to allow monitoring by Water Services Field Services' staff when the pond is being used for storage. The use of solar panels for a power supply is discouraged; pre-approval for use is required by Water Resources. The equipment will be installed at the developer's expense. Refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds*** for details.

6.2.2.22 Signage

All ponds must have appropriate signage. Signage is required at all public entrances to the pond, at other critical points, and/or where there are long distances between signs. Locations should be identified on the Site/Overall pond drawing. Refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary Water Resources' *Standard Specifications Sewer Construction* for sign requirements. The developer is responsible for the cost of sign purchase and installation. Arrangements can be made with Water Services to order and/or install the signs.

Signs promoting public education are encouraged. Signs may include information regarding the operation and purpose of the pond, protection of the environment, water conservation, native landscaping, the impact of chemicals, and interpretative trails. Contact Water Services and/or Parks for more information.

6.2.2.23 Enhancements

In general, Water Resources will not fund any enhancements outside of the design specified above. However, Water Resources might support enhancements if they are funded and permanently maintained by the Developer or others, and if they do not negatively impact the design of the system. Contact Water Resources for more information.

6.3 Wet Ponds

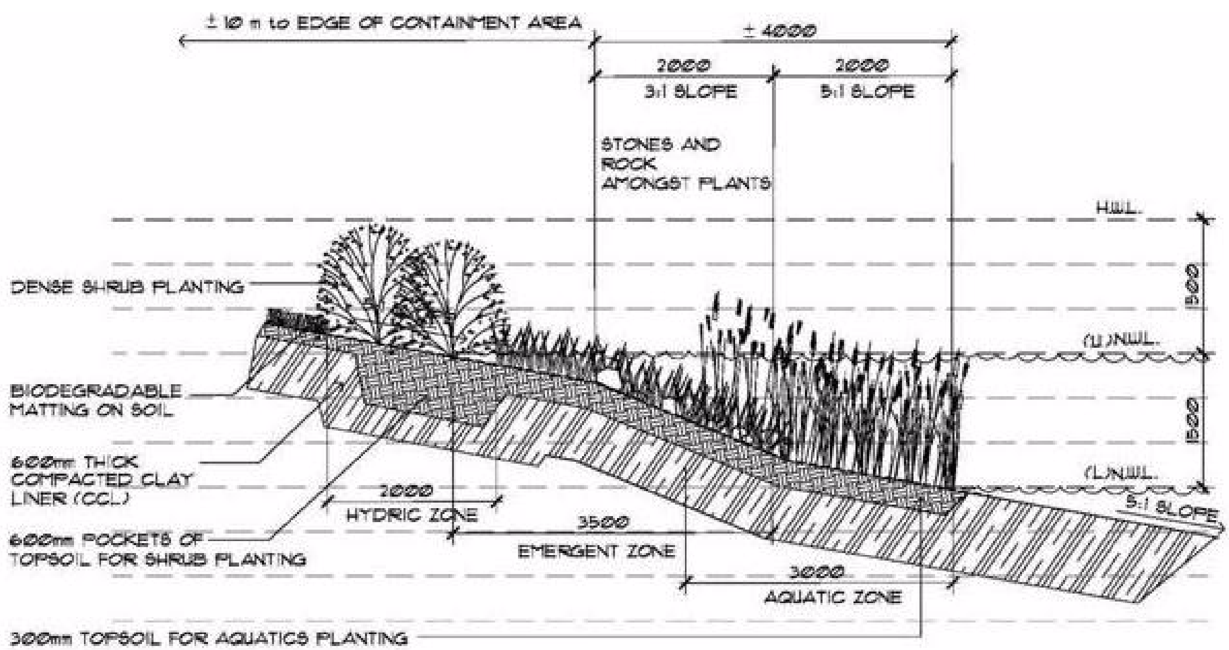
6.3.1 Introduction

Wet ponds are impoundment areas used to temporarily store stormwater runoff in order to promote settlement of runoff pollutants, as well as to restrict downstream discharge to predetermined rates to reduce downstream flooding and erosion potential. Wet ponds are similar to lakes in that there is always a permanent body of water. During rainfall events, additional temporary storage is provided above the permanent level. After the rainstorm, the water level gradually recedes back to its original level.

Wet ponds can be constructed by an embankment or through excavation of a depression. Design of the facility usually includes the upper stage (above NWL), where the volume from storm events is stored, and the lower stage (below NWL), where sedimentation is promoted. It is the lower stage that provides the pond's primary source of water quality enhancement. Sediment forebays are required on all wet ponds to help confine settlement for larger pollutant particles.

In the case of wet ponds where the water is re-used for irrigation or other purposes, the normal water level is not constant, but rather fluctuates between a (U)NWL and a (L)NWL level. Discharge to receiving waters or a downstream drainage system commences when the water level in the wet pond exceeds the (U)NWL. Re-use ceases when the water level has dropped to the (L)NWL.

Figure 6-7: Standard Pond Profile[32]



32. Source: Westhoff Engineering Resources Inc.and IBI Group 2009 (page 64).

Wet ponds are a reliable end-of-pipe BMP. As well, they normally require less land than wetlands and are reliable in operation. Wet ponds have a moderate to high capacity to remove urban pollutants, and establishing vegetative zones around the pond can enhance pollutant removal efficiency. Therefore, wet ponds can be used to provide both water quantity and water quality. However, good design of a wet pond involves attention to a variety of criteria.

Unless water accumulated in the wet pond is re-used for irrigation or other purposes, wet ponds typically have limited capability for runoff volume reduction, except by evaporation and, if applicable and appropriate, infiltration.

6.3.2 Design

Figure 6-8 illustrates the components of a wet pond, while ***Table 6-2*** summarizes the pertinent design criteria for wet ponds. These criteria are discussed in more detail in subsequent sections.

Figure 6-8: Wet Pond

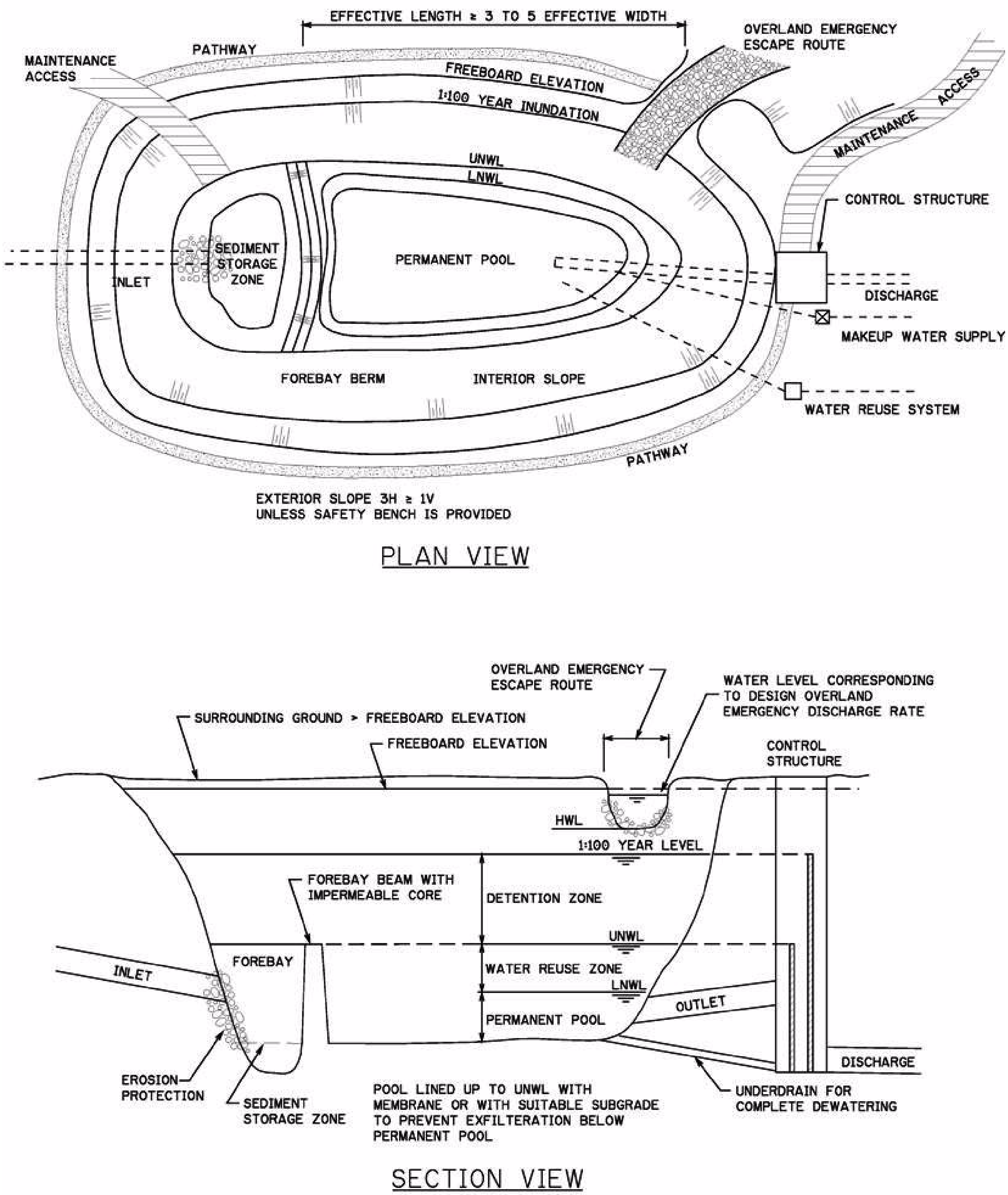


Table 6-2: Design Summary Guide for Wet Ponds

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service/ Volumetric Sizing.	Provision of appropriate level of protection and adequate volume for quantity and quality.	• Largest (most conservative) volume for 1:100 year storage capacity and 85% removal of TSS based on: - 24 hr, 1:100 year event. - Continuous simulation with statistical analysis of annual maxima - 85% removal of TSS for particles sizes ≥ 50 μm. • Minimum quality volumes: BTM to (L)NWL - 25 mm x catchment area x overall catchment imperviousness ratio.	
Land Dedication.	Appropriate location.	PUL or ER.	PUL.
Drainage Area.	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume.	Not applicable.	Not applicable.
Pond Area/ Number of Ponds	Maximize pond area to limit number of ponds.	Minimum 2 ha at (U)NWL.	
Circulation.	Prevent stagnation	Turnover rate of 2 times/year.	
Water Quality.	Pre-treatment	• 85% removal of TSS for particle sizes ≥ 50 μm. • Minimum 25 mm x catchment area x overall catchment imperviousness ratio for permanent (wet pool) storage	
Sediment Forebay.	Pre-treatment (sedimentation).	• Maximum area ≤1/3 permanent pool surface area. • Depth: 1.50 m minimum (typically measured from bottom of forebay to (L)NWL).	2.0m
Forebay Length:Width Ratio.	Maximize flow path and minimize short-circuiting.	Minimum. 3:1 measured along flow path.	Minimum 4:1 to 5:1
Active Storage Detention Time.	Suspended Solids Setting.	Minimum 24 hours.	
Length:Width Ratio.	Maximize flow path and minimize short-circuiting.	Minimum 3:1.	4:1 to 5:1
Pond Depth.	Safety and control of weed growth.	• Bottom to (L)NWL: 2.0 m Minimum and 3.0 m Maximum. • (L)NWL to (U)NWL: 1.50 m maximum (for ponds subject to re-use or withdrawal for irrigation) • (U)NWL to HWL: 2.0 m maximum • Freeboard: 0.30 m Minimum. Refer to ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	• 2.50 m • 1.0 m Max

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Overland Routes.	Safety.	Meets Alberta Environment Depth-Velocity guidelines.	
Escape Route.	Safety.	Minimum 1.0 m^3/s. Refer to also ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	Maximum possible.
HGL.	Prevent backup.	Surcharging 1.20 m below surface, except for last pipe segment into the forebay.	HGL impact confined to pipe adjacent to pond.
Landscaping.	Public amenity and safety.	• Approval of Water Resources and Parks • Edge treatment required	
Recreational Activities.	Public safety.	Refer to List in ***6.3.2.17 Recreational Activities***	
Side Slopes (pertains to pond and forebay areas).	Drainage and safety.	• Above HWL: No steeper than 4H:1V to 5H:1V. • Outward/Exterior facing: No steeper than 3H:1V. • (L)NWL to HWL: No steeper than 5H:1V. • Below (L)NWL: - 2m wide band 3H:1V. - Remainder no steeper than 5H:1V to 7H:1V. • Benches: 150 mm to 300 mm drop.	(L)NWL to HWL: No steeper than 7H:1V.
Geotechnical.	Infiltration.	Max: 1×10^{-6} cm/s	
Inlet.	Safety and maintenance.	• Obvert: 0.80 m below (L)NWL. • Invert: 100 mm above bottom. • Skimmer MH required (to remove floatables, oil/grit. etc.).	
Outlet.	Safety and maintenance.	1.20 m x 1.20 m per chamber.	1.80 m x 1.80 m per chamber.
Orifice.	Avoid plugging.	50 mm diameter Minimum.	100 mm diameter minimum.
Trash Rack (Exposed Outlet).	Protect orifice from plugging.	• Required when orifice $\leq$200 mm diameter (no trash rack required when outlet is fully submerged).	
Gate Valve.	Bypass and maintenance.	Required (300 mm diameter).	
Maintenance Vehicle Access.	Access for equipment (typically 13 tonne vactor truck) and safety.	• Width: 3.0 m with additional consideration for width at turns or bends. • Turning Radius: 8.0 m. • Access gate(s) from the main road required. • Road structure must accommodate maintenance vehicle weight and loading. • Boat/Equipment ramp required.	Width: 4.0 m
Fencing.	Safety.	Not generally required.	

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Monitoring Equipment.	Safety and design.	Required (refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds***).	
Signage.	Safety.	Required (refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary Water Resources' *Standard Specifications Sewer Construction*).	
Note: Refer to detailed information provided in following sections.			

6.3.2.1 Level of Service/Volumetric Sizing

Wet ponds must provide a storage capacity for a 1:100 year condition; the corresponding water level is the HWL (refer to ***6.1.2 Level of Service*** (Item ii)). The 1:100 year volume must be contained before spillover is permitted. A lower level of service may be allowed for retrofit facilities, subject to approval from Water Resources. However, the pond must also be sized to provide a minimum of 85% removal of Total Suspended Solids (TSS) for particle sizes greater than, or equal to, 50 μm for water quality. The more conservative volume of the two criteria will dominate. Refer to ***CHAPTER 3: STORMWATER DESIGN*** for more information.

There are two **minimum** water quality sizing criteria that must be met:

- As a minimum, the permanent pool (pond bottom to (L)NWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area times the overall catchment imperviousness ratio (25 mm x catchment area x overall catchment imperviousness ratio).
- A minimum detention time of 24 hours must be provided.

Release rates from the ponds must conform to the rates set out in the approved Master Drainage Plan report and/or approved Staged Master Drainage Plan report.

6.3.2.2 Land Dedication

Land dedication requirements are as follows. Refer to The City of Calgary Parks' *Open Space Plan* for more information.

i) Wet ponds that are to be ultimately operated by The City of Calgary are to be located on PULs.

ii) The use of MR and MSR lands for wet ponds will not be supported. Land located adjacent to public utility lands may be designated MR if the design of the pond provides a pathway or visual amenity (subject to Parks' approval).

iii) Use of ERs may be supported if the wet pond can function as part of the natural drainage system and can be appropriately designed and managed. Approval from Parks is required.

iv) Retrofit wet ponds may be supported in Major Natural Area Parks when there is minimal disturbance to the natural system. Approval from Parks is required.

v) Wet ponds should not be located in the flood plain of the Bow River, Elbow River, Nose Creek, West Nose Creek, Fish Creek, Pine Creek or in ravines **unless there are no other viable locations**. **At no time are wet ponds acceptable in the floodway!** Contact Water Resources for more information.

vi) Where a wet pond is located on privately owned land, an easement is required to permit encroachment of water onto the property and restrict development in the areas subject to inundation. For ponds proposed on provincial lands, approval is required from the Province of Alberta. Contact the appropriate provincial department.

vii) A maintenance agreement is required for any **public (City owned)** wet pond that will be operated and maintained by a private owner. Contact Water Resources for more information.

viii) The maximum level of inundation, or the HWL, must not encroach onto private property. Lots bordering the wet pond are required to have abutting property elevations a minimum of 0.30 m above the design emergency overland flow elevation of the pond when the pond has an overland emergency escape route. This must be increased to a suitable higher elevation in the absence of an overland emergency escape route. Refer to ***6.1.3 Overland Drainage and Escape Routes*** or contact Water Resources for more information.

6.3.2.3 Drainage Area

There currently is no minimum drainage area requirement. The contributing drainage area requirement for a wet pond is a function of the permitted release rate and water quality requirements.

6.3.2.4 Pond Area and Number of Ponds

The minimum area of a wet pond must be 2 ha at the (L)NWL. Smaller areas will only be considered on a site-specific basis at the discretion of Water Resources. In such cases, the private owner may be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer, larger wet ponds. The developer must make every effort throughout the planning process to limit the number of ponds required.

6.3.2.5 Winter Operation

During the winter, ice cover will reduce the design volume of the permanent pool. While there are currently no requirements to compensate for the loss of volume due to ice cover, precautions should be taken to minimize the effects of freezing of pipes and orifices. It should also be noted that methane (H_2S) gas is more likely to build up under the surface of the ice in winter, which can then seep back into the adjacent pipe system and lead to odour complaints.

6.3.2.6 Circulation

Narrow and/or dead bay areas are not permitted. Inlets and outlets should be located to maximize detention time and circulation, and to reduce short-circuiting through the pond. Refer to ***6.3.2.8 Sediment Forebay*** for more information.

A minimum turnover rate of the permanent pool volume is required: this should be twice per year based on Calgary's average annual precipitation.

6.3.2.7 Water Quality

All wet ponds are required to provide enhanced water quality. Wet ponds are to be sized to provide a minimum 85% removal of TSS for particle sizes greater than, or equal to, 50 μm. For more information on particle size and settling velocities for modelling purposes, refer to ***7.5.3.2 Particle Sizes and Settling Velocities***.

At a **minimum**, the permanent pool (pond bottom to (L)NWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area times the overall catchment imperviousness ratio (25 mm x catchment area x overall catchment imperviousness ratio). A minimum detention time of 24 hours must also be provided.

Water quality monitoring might be required during the maintenance period (refer to ***7.8 Water Quality Monitoring Programs***). Contact Water Resources, Development Approvals for more information. Costs of the program are to be covered by the developer during the maintenance period.

6.3.2.8 Sediment Forebay

A sediment forebay facilitates maintenance and improves pollutant removal of larger particles near the inlet of the pond. The forebay should be one of the deeper areas of the pond to minimize the potential for particle re-suspension.

Sediment forebays are required on all wet ponds. The forebay can be included within the wet pond area or as a separate facility. As well, each inlet location must have a forebay. The forebay area should not exceed one third of the total permanent pond surface area. Sedimentation vaults or oil/grit separators may also be considered as alternatives to forebays, subject to the approval of Water Resources.

6.3.2.8.1 Short-Circuiting

To avoid short-circuiting and to ensure that sediment will have sufficient time to settle out in the forebay, minimize the number of inlets into a pond and/or ensure that flow path length(s) are maximized. The resulting effective length to width ratio in the forebay should be 4:1 to 5:1, with a minimum ratio of 3:1. The length and width should reflect the anticipated actual flow path and are measured at the NWL; typically, the length is measured from the exit of the inlet to the toe of the forebay berm (refer to ***Figure 6-9***).Three dimensional modelling with programs such as Computational Fluid Dynamics (CFD) can be used to determine flow and velocity patterns, as well as sedimentation patterns.

6.3.2.8.2 Sizing

Sizing of the forebay depends on the inlet configuration. There are several calculations that need to be made to ensure that it is adequately sized. **A target particle size of 150 μm should be used for wet ponds.** Where possible, the sediment forebay should be sized to accommodate the amassed sediment for a minimum period of 25 years without affecting treatment capacity; this is to minimize the frequency of major cleaning.

The treatment capacity is considered maintained as long as the theoretical sediment accumulation, computed using ***Equation 6-2***, is at least 0.30 m below the invert of the incoming storm pipe.

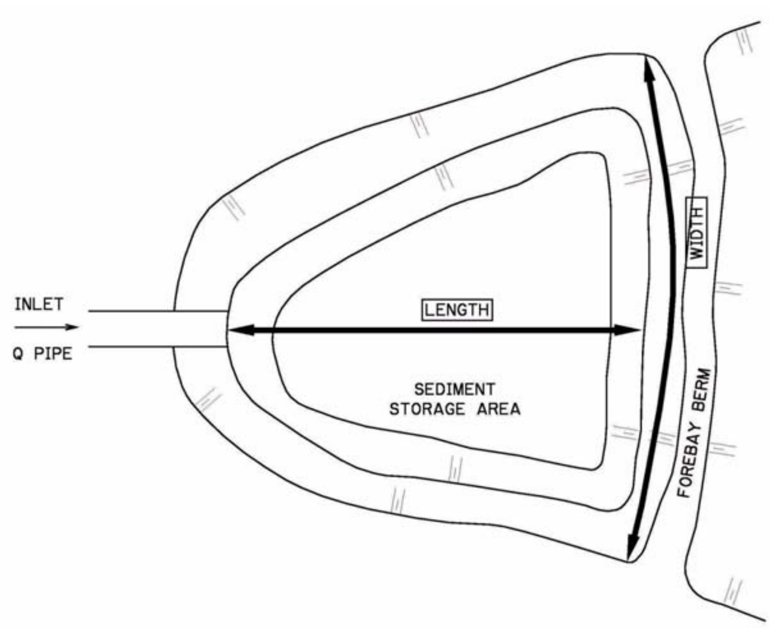
Equation 6-2:Theoretical Sediment Accumulation

$$\textbf{SSCR} = 25 \times \textbf{RV} \times \{\textbf{TSS-conc} / 1000\} \times \textbf{BF} \times \textbf{PSDF}$$

where:
- SSCR = sediment storage capacity required (kg).
- 25 = multiplication factor for 25 years of sediment storage.
- RV = computed average annual runoff volume (m^3).
- TSS-conc = TSS concentration from ***Table 7-2*** (mg/L).
- BF = bedload multiplication factor = 2
- PSDF = particle size distribution factor from ***Table 7-3***.

For instance, in the case of a wet pond in a 100 ha residential area, the theoretical sediment storage capacity in the forebay will be equal to 25 x150,000 m^3 (assumed average annual runoff volume) x {444 mg/L / 1000} x 2 x 0.32 (see ***Table 7-3***, for % Fraction greater than or equal to 150 μm) = 1,065,600 kg. The corresponding volume is then 1,065,600 kg / 2,650 kg/m^3 density = 402 m^3.

Figure 6-9: Forebay for Wet Pond



6.3.2.8.3 Settling Calculations

"The primary method to calculate forebay volume and length should be based on settling calculations. The calculations determine the distance required to settle out a certain size of sediment (refer to ***Table 7-3***). It is assumed that the flow out of the pond dictates the velocity through the forebay and the rest of the pond. Although this is not entirely correct, it is reasonable for the determination of an appropriate forebay length."[33]

Equation 6-3 defines the appropriate forebay length for a given settling velocity and hence particle size to be trapped in the forebay.

Equation 6-3: Forebay Settling Length)

$$\textbf{Length} = [rQ_p/V_s]^{0.5}$$

where: Length = forebay length (m)

r = length to width ratio of forebay

Q_p = peak flow rate from the forebay corresponding to a 1:5 year event (m^3/s)

V_s = settling velocity (dependent on the desired particle size to settle). Refer to ***Table 7-3*** for particle sizes and settling velocities. For wet ponds a particle size of 150 μm should be used; for wetlands a particle size of 75 μm should be used.

6.3.2.8.4 Dispersion Length

"The dispersion length refers to the length of fluid required to slow a jet discharge, such as pipe flow. A check can be made on the forebay length given by the settling calculation (***Equation 6-3***) to ensure that there is adequate dispersion. ***Equation 6-4*** provides a simple guideline for the length of dispersion required to dissipate flows from the inlet pipe. It is recommended that the forebay length is such that a fluid jet will disperse to a velocity of greater than, or equal to, 0.50 m/s (discharge jet) at the forebay berm."[34]

A check of the entire forebay cross-sectional area should ensure that the average velocity in the forebay is less than, or equal to, 0.15 m/s. This velocity (0.15 m/s) is the maximum permissible velocity before which erosion will occur in a channel.

Typically, the dispersion length is smaller than the settling length unless there is a large upstream drainage area or the pond is subject to large inflows. When this occurs, the pipe design capacity should be used. **In all cases, the forebay length (designated Length) should be greater than, or equal to, the larger of the two forebay lengths given by *Equation 6-3* and *Equation 6-4*.**

33. Source: Ontario Ministry of the Environment 2003 (page 4-55).
34. Source: Ontario Ministry of the Environment 2003.

Equation 6-4: Dispersion Length)

$$\textbf{Length} = (8Q/(dV_f)$$

where: Length = length of dispersion (m)

Q = inlet inflow rate corresponding to a 1:5 year event (m^3/s)

d = depth of the permanent pool in the forebay (m)

V_f = desired velocity in the forebay (m/s). A value $\leq$ 0.50 m/s should be used.

The depth of the permanent pool in the forebay (d) reflects the deep section of the forebay required to minimize re-suspension and scour.

6.3.2.8.5 Width

The minimum bottom width of the deep zone in the forebay is given by:

Equation 6-5: Minimum Forebay Bottom Width)

$$\textbf{Width}_{\textbf{bottom}} = \textbf{Length/8}$$

The bottom forebay width is calculated using the largest length derived from ***Equation 6-3*** and ***Equation 6-4***.

6.3.2.8.6 Depth

The minimum depth of the sediment forebay should be 1.50 m. The recommended minimum depth is 2.0 m.

6.3.2.8.7 Length:Width Ratio

The total length of the forebay should provide a length to width ratio greater than, or equal to, 3:1 for each inlet. A length to width ratio less than 3:1 is undesirable, since the wet pool will not be utilized effectively. In this case, the addition of flow baffles (or other means of lengthening the flow path in the forebay) may be used, subject to approval by Water Resources. When lengthening methods are used, effective length is measured along the flow path.

6.3.2.9 Forebay Berms

An earthen berm should be used to separate the forebay from the rest of the pond. The top of the berm should be submerged slightly, 0.15 m to 0.30 m below the NWL or (L)NWL, when the pond is used for irrigation withdrawal or re-use. A submerged berm provides a safety benefit to the public (provides a barrier to the public walking along the berm) and allows vegetation to be planted around and along the berm. Sections of the forebay berm can be above the (L)NWL, provided that they are protected against erosion when the berm overtops and is well vegetated in a way that inhibits public access.

The berm should be constructed with a solid substrate to facilitate removal of accumulated sediment and debris. In addition, the core of the berm must be impermeable and the berm itself geotechnically stable under submerged conditions. Sloughing of the berm must be greater than, or equal to, 150 mm at the time of FAC.

Emergent vegetation should be planted along the berm to promote filtration of water as it passes over (refer to ***APPENDIX E: Recommended Plant Species*** for appropriate species). The plants should be established on the top and sides of the berm at a maximum planting depth of 30 cm.

Although not required, pipes may be installed in the berm to serve as the primary conveyance system from the forebay to the pond, or as a secondary conveyance system to supplement flows over the submerged berm. Flow calculations should be made to ensure that the conveyance system from the forebay to the pond operates as intended; that is, without unintended overflow from the forebay into the pond if the pipes in the berm serve as the primary conveyance system.

The invert of any conveyance pipes installed in the berm should be set at least 0.60 m above the bottom of the forebay to prevent siphoning of settled material into the rest of the pond. If only the forebay is to be pumped out or drawn down during maintenance, the forebay berm must be designed as an impermeable small dam since the rest of the pond will not be drained. Care must be taken not to compromise the structural integrity of the berm or liner during drawdown conditions.

6.3.2.10 Detention Time

A minimum detention time of 24 hours is required to promote water quality enhancement for active storage. Detention time is approximated by the drawdown time. Refer to ***6.1.2 Level of Service*** for a definition of detention time.

6.3.2.11 Length:Width Ratio

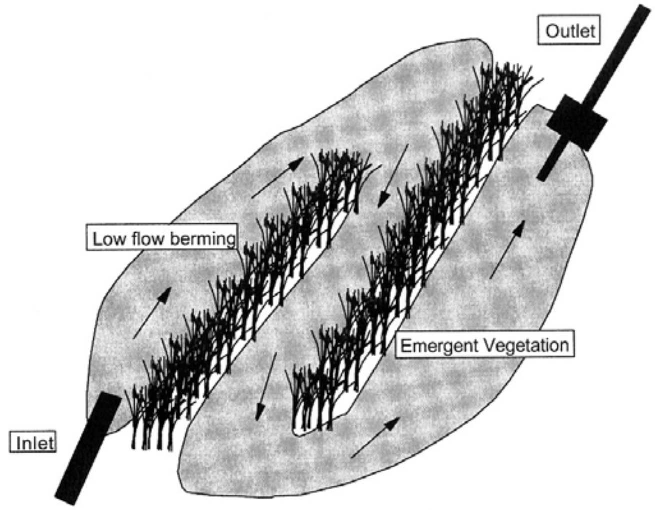
The overall performance of the pond is influenced by the flow path through the pond. Problems encountered with earlier pond designs include construction of the outlet too close to the inlet and having multiple inlets at opposing ends of the pond based on servicing convenience. In both cases, short-circuiting reduces the effective volume of the facility.

Where possible, all stormwater servicing should be conveyed to one inlet location. To provide the longest flow path though the pond, the inlet should be located as far away from the outlet as possible. A pond with a minimum length to width ratio greater than, or equal to, 3:1 will generally have an acceptable flow path. The length and width should reflect the anticipated actual flow path and are measured at the (L)NWL. The preferred length to width ratio ranges from 4:1 to 5:1. A ratio outside of this range requires the approval of Water Resources. Effective length excludes forebay length.

The provision of additional berms or flow baffles in the pond to redirect flows and lengthen the flow path is also acceptable to ensure that short-circuiting will not occur.

The use of hydrodynamic models is recommended to assess flow, velocity, and sedimentation patterns. Refer to ***3.2.2.10 Other Models*** for more information.

Figure 6-10: Extending the Flow Path



6.3.2.12 Pond Depth

The depths of the permanent and active storage areas are based on a variety of criteria, including potential stratification, the tolerance of plants to fluctuating water levels, and safety.

6.3.2.12.1 Permanent Storage Areas

The **minimum** depth from the pond bottom to (L)NWL must be 2.0 m, with the recommended depth being 2.50 m. A depth of 2.50 m minimizes aquatic growth in the pond and maximizes recreational potential.

A **maximum** depth of 3.0 m should not be exceeded. Depths in excess of 3.0 m require approval from Water Resources. Although ponds deeper than 3.0 m may have benefits in terms of temperature, stratification is more likely, resulting in anoxic conditions which release metals and organics from the pond sediments.

6.3.2.12.2 Active Storage Areas

The **maximum** active storage depth must be 2.0 m. Depths in excess of 2.0 m require approval from Water Resources. The active storage depth is defined as the depth between (U)NWL and HWL. In addition, a minimum freeboard of 0.30 m is required above the water level in the pond that corresponds to the design overland emergency discharge rate. Refer to ***6.1.3 Overland Drainage and Escape Routes*** for the definition of design overflow emergency discharge rate.

6.3.2.12.3 Stormwater Re-Use Storage Areas

The stormwater re-use storage area corresponds to the zone where water can be withdrawn for irrigation or other re-use purposes. The stormwater re-use depth is defined as the depth between (L)NWL and (U)NWL, and must not exceed a **maximum** depth of 1.50 m; the recommended depth is 1.0 m. A re-use depth of up to 2.0 m between the (U)NWL and (L)NWL will be considered by Water Resources on a case-by-case basis.

6.3.2.13 Overland Drainage and Escape Routes

Overland drainage and escape route requirements include the following:

i) Overland drainage routes that direct flows from the 1:100 year storm event **to** the pond area must be provided. Overland flow design velocities (v) and depths (d) must be in accordance with *Stormwater Management Guidelines for the Province of Alberta (1999)*. Refer to ***Table 3-18*** and ***Figure 3-10*** in ***CHAPTER 3: STORMWATER DESIGN*** for more information.

ii) Overland drainage entering the pond should be directed into the forebay. If this is not feasible, the runoff might need to be pre-treated before it is allowed to enter the pond. Trap lows adjacent to the pond may spill into the main cell(s) of the pond provided that the trap lows fully contain the runoff from a 1:5 year event without spillover. Similarly, localized sheet flow from areas directly adjacent to the pond are permitted into the main cell(s) of the pond, provided that flows are kept to a minimum.

iii) A designated continuous emergency overland escape route from all ponds is to be provided. In general, the design capacity of the overland emergency escape route (refer to ***Figure 6-1***) from the pond will be the greater of either:

- The resulting spillover rate for a 24 hour 1:100 year event assuming that the regular outflow is 0 m^3/s and there is a starting water level of (U)NWL.
- 1.0 m^3/s.

The magnitude of the design capacity of the overland escape route must be determined at the time of pond design. The configuration and capacity must be adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route. Proper engineering design based on local circumstances is required.

A minimum 0.30 m freeboard must be provided above the water level that corresponds to the design overland emergency discharge rate.

iv) Additional freeboard over and above what is required may be considered in cases where it is difficult to establish an overland escape route. The additional freeboard would provide a higher level of service overall; however, implications to the HGL upstream of the pond must be considered.

v) Sanitary sewer MHs must be located outside of impoundment (pond) areas.

vi) Whenever possible, sanitary sewer MHs should not be located within the overland drainage route. When the situation is unavoidable, sanitary sewer MHs located within overland drainage routes must be sealed. Bolting is at the discretion of Water Resources.

vii) Erosion control needs must be evaluated for both the overland drainage routes into the pond and the overland emergency escape route from the pond.

6.3.2.14 Hydraulics

The 1:100 year elevation will be established taking into consideration the adjacent footing elevations. When the wet pond is at the 1:100 year elevation, water should not back up through the storm sewer system and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting HGL should be kept to a minimum. Free flow conditions are preferable; this is achieved when the obvert of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Water Resources. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

When free flow conditions are not achieved based on the HWL, HGL elevations in the storm sewer system must be determined based on the pond at HWL and the appropriate losses taken into account (i.e., junction losses, pipe losses, etc.). Alternatively, a dynamic hydraulic analysis should be carried out to establish the HGL elevations. **Surrounding footing (or slab) elevations must be a minimum of 0.30 m above the HGL.** Other options to protecting weeping tile connections include a separate weeping tile drainage system connected downstream of the pond or a sump pump to the surface. Weeping tile drains connected to the sanitary system are not permitted in any circumstances.

Except for the last pipe segment into the forebay, sewer pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface (refer to *3.1.2.1 General Requirements*)**. Also, proper aeration and venting must be considered as per ***5.5.2 Design***. Contact Water Resources for more information.

Backflow prevention devices are required on all weeping tile connections as per the *National Plumbing Code of Canada*.

All upstream storm piping below the HWL and HGL must be rubber gasketed as per The City of Calgary Water Resources' *Standard Specifications Sewer Construction*.

6.3.2.15 Landscaping and Vegetation

Landscaping and vegetation plans must be submitted with the construction drawings. The drawings must be reviewed and approved by Water Resources and Parks. All landscaping must be prepared by a qualified consultant and must conform to The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*. Also refer to ***APPENDIX E: Recommended Plant Species*** for information about recommended plant species.

A planting strategy is required to provide shading, aesthetics, safety, enhanced pollutant removal, and waterfowl control. The purpose of the planting is to provide a sustainable community with **naturalized treatment**. Plants native to Calgary should be used where possible. Planting density may not have to be high, since natural succession will ultimately make up the vegetation. As well, the overall planting should be designed to minimize maintenance. Manicured and mown areas should be kept to a minimum, as these areas can attract waterfowl and become a problem. For a list of plant species, refer to ***APPENDIX E: Recommended Plant Species***.

6.3.2.15.1 Deep Water Areas

The majority of a wet pond is comprised of deep water areas. Planting in deep water areas is restricted to submergent vegetation. Pondweeds and other species can be planted in appropriate water depths. Refer to ***APPENDIX E: Recommended Plant Species*** for more information. The transition between shallow and deep water plantings will eventually establish itself according to water level fluctuations and light availability.

6.3.2.15.2 Shallow Water Areas

Shallow water areas are considered to be the areas of the permanent pool where the depth is greater than, or equal to, 0.50 m. This is usually defined as the perimeter of the pond.

The selection of vegetation should consider nutrient uptake, stormwater filtration, safety, and aesthetics. Benefits include the prevention of re-suspension of bottom sediments and the reduction of flow velocities to aid in sedimentation.

Plant species in this zone includes both submergent and emergent vegetation (refer to ***APPENDIX E: Recommended Plant Species***). Submerged plant species should be planted in water depths between 0.30 m and 0.50 m. Emergent plant species should be planted in water depths between 0 and 0.30 m. The side slopes will determine the amount of vegetation that can be established.

6.3.2.15.3 Fringe Areas

Where accumulated runoff in the wet pond is used for irrigation or other re-use purposes, special attention to the resulting soil moisture regime is needed to ensure the survival of the vegetation.

i) Shoreline Fringe Areas:

Shoreline fringe areas are the areas subject to frequent wetting from storm events. In general, this is the land delineated between the (L)NWL and HWL for erosion/water quality control. This area will typically have higher soil moisture conditions during the frequent storm events. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond, and must be adequately protected from erosion.

The planting strategy for this area should be similar to the shallow marsh area. Plant species should include hardy hydric grasses and shrubs (refer to ***APPENDIX E: Recommended Plant Species***). Due to the frequency of inundation, plant stocks should be used instead of seeds.

ii) Floodfringe Areas:

When the wet pond is used to control peak flow rates, a zone of infrequent inundation is created. This zone is referred to as the floodfringe area and is generally the area just below and slightly above the HWL. Plant species in this zone should include a range of grass, herb, and shrub species (refer to ***APPENDIX E: Recommended Plant Species***). In general, trees are to be planted above the HWL.

In addition, thorny or dense vegetation may be planted to provide safety measures, as an alternative to fencing. Together with other plantings, an effective barrier to public entry can be created.

6.3.2.15.4 Upland Areas

Upland areas are the landscaped areas above the HWL that provide aesthetic amenities around the pond. Plant species should be designed to restrict access to steep areas or inlet/outlet locations. Refer to ***APPENDIX E: Recommended Plant Species*** for a list of recommended plant species. A naturalized landscape should be designed to consider:

- Topography and drainage.
- Soil conditions.
- Adjacent plant communities.
- Availability of nursery stocks.
- Potential for on-site transplantation.
- Minimal maintenance.

A minimum horizontal buffer strip of 3.0 m should be provided between the HWL and the property line, or a 10.0 m horizontal buffer strip between the (U)NWL and the property line, whichever is greater.

Any pathways to be incorporated must be constructed above the 1:100 year elevation (HWL). Pathway locations and design should also have regard for protection of any native habitats created or protected. Any deviations require the approval of Water Resources and Parks.

6.3.2.16 Pond Edge Treatment

Edge treatment or shore protection is required. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond. This area must be adequately protected from erosion. Treatment must be compatible with the adjacent land use and must provide for low maintenance and safety.

The edge treatment must cover the ground surfaces a horizontal distance of 1.50 m below (L)NWL and 3 m above (U)NWL. The treatment must be adequate to prevent erosion of the edge due to wave action.

Although typical treatment in the past has been for granular material on top of filter fabric, the designer is encouraged to propose alternate edge treatments that exceed this standard and provide an overall “softening” effect.

For wet ponds subject to water withdrawal or re-use, aesthetically unappealing “mud flats” in the zone between the (L)NWL and (U)NWL should be prevented. Contact Water Resources and Parks to discuss landscaping options.

6.3.2.17 Recreational Activities

Stormwater wet ponds can add recreational and environmental features to an urban area. Although wet ponds can provide potential recreational benefits, there are also risks associated with these activities.

Contact with stormwater in a wet pond can cause skin irritation (swimmer's itch) and ingestion can make people and pets ill. Since the water quality in a wet pond does not generally meet Alberta's *Environmental Protection and Enhancement Act (EPEA)* water quality guidelines, activities that involve direct water contact are prohibited.

Swimming and wading are **prohibited** activities; this includes pets (animals). Also prohibited are non-motorized (canoeing, kayaking, paddle boating, rafting, etc.) and motorized boating activities. Motorized boating is a potential source of noise, nuisance, and petroleum product spills. The exception is the use of motorized boats for emergency or maintenance purposes.

Ice related activities, such as skating and cross-country skiing, are not permitted, since the ponds are not monitored for ice thickness. Tobogganing activities should be confined to safe areas.

Activities that are **permitted** include:

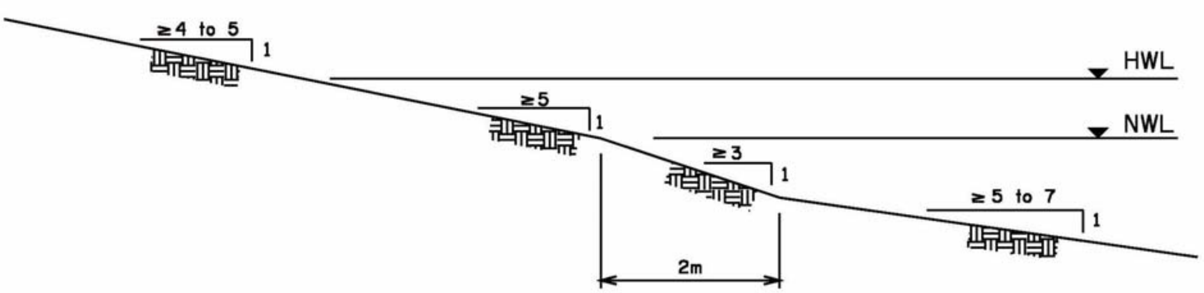
- Photography.
- Bird watching.
- Bicycle riding.
- Jogging.
- Walking.
- Tobogganing.
- Outdoor picnicking.
- Arts and crafts.

For more information, contact Water Resources.

6.3.2.18 Grading/Slopes

i) Grading and landscaping of the pond and adjacent areas are important for public safety and the functionality of the pond: Typical side slope requirements are shown in ***Figure 6-11***.

Figure 6-11: Typical Side Slopes for Wet Ponds



ii) Grading above the HWL must be no steeper than 4H:1V to 5H:1V. Subject to the approval of Water Resources, steeper side slopes in localized areas may be allowed above the HWL for a limited distance, provided that a 2.0 m wide safety bench is provided above the freeboard elevation. For outward facing slopes, grading must be no steeper than 3H:1V.

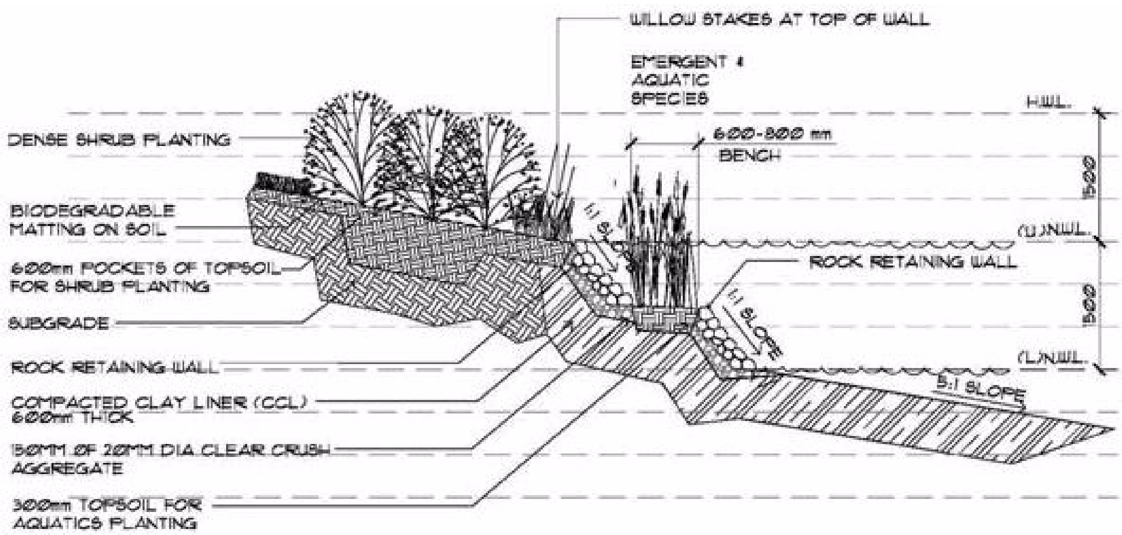
iii) Grading between NWL and HWL must be no steeper than 5H:1V. In ponds subject to water withdrawal or re-use, extending the 5H:1V grading to the zone between the (L)NWL and (U)NWL will be considered by Water Resources on a case-by-case basis.

iv) Below NWL, a 3H:1V slope is required for a horizontal distance of 2.0 m. This is to discourage weed growth and public access.

v) The remainder of slope below NWL must be between 5H:1V and 7H:1V.

vi) Alternative side slope designs will be considered specifically for the zone between (L)NWL and (U)NWL in wet ponds subject to water withdrawal or re-use (refer to ***Figure 6-12***). This includes aquatic benches to enhance vegetation and naturalization. Small drops of 150 mm to 300 mm can be incorporated to deter the public from accessing deeper water. Contact Water Resources for approval.

Figure 6-12: Split Retaining Wall Option[35]



6.3.2.19 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of the wet pond. The purpose of the report is to determine criteria such as dam safety (as required), underdrainage design (i.e., toe drains), liner requirements (infiltration), and any other special design conditions such as slope stability or groundwater. Refer to ***6.1.6 Water Quality*** for more information. Other considerations could include exfiltration (from pond to aquifer), construction dewatering, and possible liner uplift.

35. Source: Westhoff Engineering Resources Inc. and IBI Group 2009 (page 65).

Pond bottom material is to be composed of impervious material with a suitable low permeability (permeability coefficient in the order of 1 x 10^{-6} cm/s). Preference should be given to using clay, where possible, or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Organic soils are not permitted for use as a liner; however, they are permitted along the edge of benches for establishing vegetation.

The report must be submitted and approved by Water Resources prior to submission of the construction drawings. The geotechnical report should be submitted with the Stormwater Management Report (SWMR), the MDP report, or the SMDP report, whichever is the most practicable. Required details must be indicated on the construction drawings.

A dam safety assessment, including supporting geotechnical reports, must be submitted to Water Resources at the pre-design stage for stormwater ponds that could be classified as having a dam (refer to ***2.3.3.2 Dam and Canal Safety***); approval under the *Water Act* is required. Drawings of the pond must also be submitted. After internal review, Water Resources will forward the information to Alberta Environment's Dam Safety Branch as part of the review process.

6.3.2.20 Inlets

Depending on the design of the wet pond, an inlet is generally the only type of structure that permits the inflow of stormwater into the pond. In order to provide water quality treatment, the flow must go through the wet pond to the opposite end.

Inlet requirements include the following:

i) Inlets should **not** be located close to the outlet control structure to minimize short-circuiting.

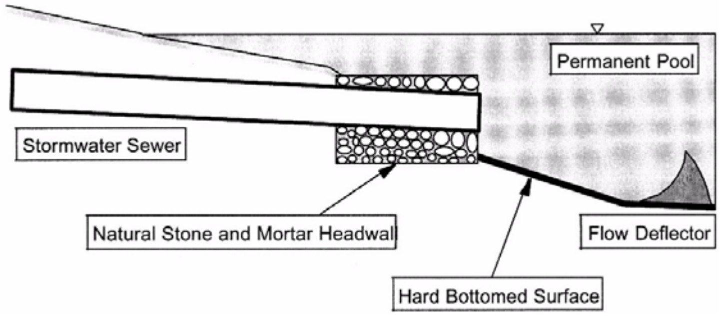
ii) Ideally there should only be one discharge location, or inlet, into the wet pond. Multiple inlets should be avoided where possible.

iii) All inlets and outlets are to be fully submerged with the obvert of the pipe a minimum of 0.80 m below NWL. Partially submerged inlets are not permitted due to ice formation concerns.

iv) Inlet and outlet pipe inverts are to be a minimum of 100 mm above the pond bottom; depths in excess of 100 mm are recommended to prevent sedimentation from blocking the inlet pipe. Erosion control measures must be provided at the bottom of the inlet structure(s) to control erosion and scour.

   Erosion control measures should include the installation of a hard-bottomed surface, interlocking stone, or an approved concrete revetment/armouring system near the inlet pipe. Other enhancements, such as dissipators or deflection structures, will help to minimize scour and re-suspension. The erosion protection must extend along the side slope to the bottom of the forebay to a distance where the velocity is no longer erosive.

Figure 6-13: Submerged Inlet



v) Clay plugs are required for all inlet and outlet pipes.

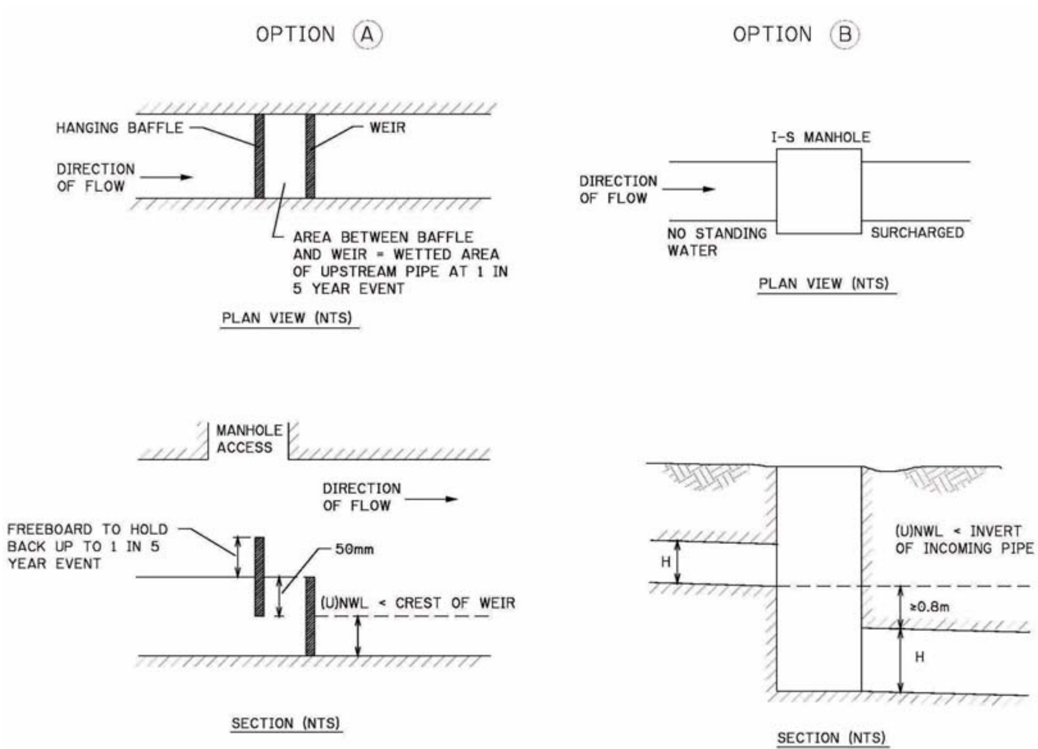
vi) Inlet velocities (at the end of the incoming pipe) should be limited to 1.50 m/s where possible to minimize erosion and scour, as well as re-suspension of sediments.

vii) The invert elevation of the inlet pipe(s) to the first MH upstream from the wet pond must be at or above the (U)NWL of the pond to avoid deposition of sediments in the inlet and freezing problems.

viii) A skimming type MH or approved equivalent (refer to ***Figure 6-14***) must be constructed on the first MH upstream of the inlet(s). The purpose of the skimming MH is to collect floatables (hydrocarbons, paint, etc.) and debris prior to entering the pond. The hydraulic losses associated with the incorporation of a skimming MH must be included in the modelling of the storm sewer system upstream of the pond.

ix) Gratings are not required on submerged inlets.

Figure 6-14: Skimming Manhole



6.3.2.21 Outlet Control Structures

Typically, an outlet control structure (also referred to as the “control structure” or the “outlet structure”) serves as the source of control for the release of stormwater from the pond and the preservation of the NWL elevation. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. Design of the outlet control structure must be approved by Water Resources. Refer to ***5.3 Special Structures*** and ***5.4 Stage-Discharge Curves*** for additional design information. Clay plugs are required for all inlet and outlet pipes.

The outlet control structure for a wet pond preferably consists of three chambers, although some outlet control structure designs include only two chambers. In a three-chambered structure, there are usually two weir walls: one to control the (U)NWL and one to control the HWL. For maintenance purposes, the size of each chamber should be a minimum of 1.20 m, but the preferred size is 1.80 m.

6.3.2.21.1 Orifices

Usually an orifice provides control for the permitted release rate for the pond. The recommended minimum orifice diameter is 50 mm, to minimize the occurrences of clogging at the outlet. The preferred minimum diameter is 100 mm.

Subject to approval by Water Resources, orifices configurations other than circular openings can be considered. However, circular configurations with a slot are preferred for orifices along the floor bottom, because they better promote swirling flow and scour of deposited sediment at the bottom of the orifice. Supporting information, including hydraulic calculations for the proposed configurations, are to be provided to Water Resources as part of the Pond Report submission.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event that the primary orifice becomes blocked.

The orifice plate should preferably be constructed of stainless steel (306); however, galvanized steel or an approved equivalent are acceptable. The minimum gauge shall be 3 (1/4”).

6.3.2.21.2 Weir Walls

Wet ponds will typically have two weir walls in the outlet control structure: one to control the (U)NWL and one to control the HWL to provide a source of overflow for the pond in the event that the orifice becomes blocked. The weir wall controlling the overflow should be set at the HWL elevation, or the calculated hydraulic grade line elevation.

6.3.2.21.3 Trash Racks

A trash rack could be required, depending on the design of the outlet pipe and/or outlet control structure. A submerged outlet pipe and/or outlet control structure will not require a trash rack.

For an exposed outlet control structure, a trash rack must be installed to protect the orifice when its diameter is less than (or equal to) 200 mm. The trash rack must be galvanized, and an access to the orifice for maintenance purposes must be provided. The openings in the trash rack must be large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable. Since the drainage area to a wet pond is usually large, the diameter of the orifice is normally large enough that a trash rack is not required.

6.3.2.21.4 Gate Valves

All wet ponds require a gate valve. The gate valve is used as a bypass for the orifice in the event the orifice plugs, as well as for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. The design flow in the downstream storm pipe should not be exceeded, except in emergency situations.

With the three-chamber design, two bypass gate valves are required, one in the NWL weir wall and one in the HWL weir wall.

All gates should have non-rising stems that are operated either mechanically or manually (with a T wrench). The T wrench should be located on the downstream end of the outlet control structure in an easily accessible location.

The use of automatic control gate systems is not advocated, but Water Resources will consider these designs on a site-specific basis. An O&M manual is required for all automatic control gate systems.

6.3.2.21.5 Hydraulics

The hydraulic performance of the outlet control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to ***CHAPTER 5: HYDRAULIC DESIGN***.

6.3.2.22 Maintenance Vehicle Access

Maintenance vehicle access requirements include the following:

i) Maintenance vehicle access from an adjacent street or lane must be provided to:

- The outlet control structure.
- The inlet structure(s).
- The skimming weir(s) or skimming manhole(s) in the upstream storm trunks.
- The forebay.

Operations staff using 1 tonne trucks must be able to access all areas of the pond. In addition, a boat ramp must be provided to the main cell of the pond or to the forebay; in case of the latter, at all times, (a) the berm must be submerged by 300 mm and (b) a 3.50 m wide passage must be available from the forebay to the main cell of the pond. The boat ramp must extend to at least 1.0 m below the NWL.

ii) To ensure proper access to the outlet control structure and associated electronic equipment, the entire maintenance vehicle access road (including the top of the control structure and any associated electronic equipment) must be at or above the freeboard elevation.

iii) At the inlet, maintenance vehicle access must be provided to the first manhole upstream of the forebay or pond inlet.

iv) Access to the forebay (for sediment removal and weed control) must be provided to the NWL. If a pond has multiple forebays, access must be provided to each forebay.

v) The first manhole upstream of the pond inlet, as well as the skimming weir/ skimming manhole, should preferably be located in a public roadway. If this roadway is subject to high traffic volumes (i.e., a primary collector and major/ arterial roadways), a turnout should be provided.

vi) Transportation Infrastructure or Roads should be consulted prior to pond design to ensure that the pond access road location is not an issue when the pond is located adjacent to, or accessed from, a major roadway and/or freeways/expressways. Access from major roadways or freeways should be avoided where possible due to safety concerns. Access should be designed to minimize interference with pedestrian activity and public safety. Pathways should not be used as a means of accessing pond maintenance areas (except by 1 tonne trucks) where possible, and maintenance areas should not impede or interfere with pedestrian activity and public safety.

vii) The vehicle access route must be a minimum of 3.50 m wide, but preferably 4.0 m wide. Additional consideration for width at turns and bends is required. The surface must be driveable, and the entrance must be gated with a bollard or equivalent at the property line (or at any location where a public vehicle could otherwise access the pond site) to prevent unauthorized access.

viii) Sharp turns must be avoided; the minimum turning radius is 12.0 m. Turnarounds must be provided at the outlet control structure, the inlet(s), and skimming weir/skimming manhole(s) if they are situated more than 30.0 m from the adjacent roadway. No turnaround is required for access to the forebay(s).

ix) Suitable surfacing material must be used (i.e., pavement, gravel, etc.). The subgrade for the access route to the outlet control structure, inlet structure(s), and skimming weir/skimming manhole(s) must be able to withstand a 23 tonne tandem truck; the boat ramp must be able to withstand a 1 tonne truck. The subgrade must conform to a "Lane" road standard as per The City of Calgary Roads' *Standard Specifications Roads Construction*. Alternatives will be considered, and are subject to approval, by Water Resources.

x) The slope of the access route to the outlet control structure, inlet structure(s), and skimming weir/skimming manhole(s) (using a 23 tonne tandem truck) should be flatter than 5%, with a maximum slope of 8%. The slope for the boat ramp and access around the pond (using a 1 tonne truck) must be flatter than or equal to 5H:1V.

6.3.2.23 Fencing

In general, full perimeter fencing is not advocated, unless required by Parks or other business units. If there is a concern for safety due to the pond being in a remote location, fencing might be requested. Most ponds provide recreational amenities that must be accessible to the public. Alternatives to fencing, such as the strategic planting of vegetation to provide effective barriers, are advocated. However, some facilities might be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern. This includes areas where the vertical drop is greater than, or equal to, 1.0 m. Chain link fence is less desirable than safety railings, and is only acceptable when the attached fencing does not protrude above the top rail.

Required fencing must be in accordance with The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*.

6.3.2.24 Monitoring Systems

Remote water level monitoring equipment is required at all wet ponds to allow level monitoring by Water Services, Field Services when the pond is being used for storage. The use of solar panels for power supply is discouraged; pre-approval for use is required from Water Resources. The equipment will be installed at the developer's expense. Refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds*** for details.

6.3.2.25 Signage

All ponds are must have appropriate signage. Signage is required at all public entrances to the pond, at other critical points, and/or where there are long distances between signs. Locations should be identified on the Site/Overall pond drawing. Refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary's *Standard Specifications Sewer Construction* for sign requirements. The developer is responsible for the cost of sign purchase and installation. Arrangements can be made with Water Services to order and/or install the signs.

As well, an informational sign (refer to ***APPENDIX C: Monitoring Equipment for Ponds***) is required at the most prominent entrance to the wet pond. The purpose of the sign is to inform people about the function of the wet pond, and to provide a contact number for more information or to report problems. It is the responsibility of the developer to supply and install the sign.

Signs promoting public education are encouraged. Signs may include information regarding the operation and purpose of the pond, protection of the environment, water conservation, native landscaping, the impact of chemicals, and interpretative trails. Contact Water Resources and/or Parks for more information.

6.3.2.26 Public Education

It is the responsibility of the developer to provide an educational brochure on wet ponds during the marketing of an area that includes a wet pond. The purpose of the brochure is to educate residents about:

- The specific function of wet ponds.
- The water quality inherent with the function of the pond and the impact of water quality resulting from fertilizers (which indirectly feeds into the sewer system by surrounding residents).
- Permitted recreational uses.
- Maintenance concerns and the potential for increased maintenance charges to residents to increase the level of maintenance deemed necessary.

6.3.2.27 Enhancements

In general, Water Resources will not fund any enhancements outside of the design specified above. This includes water fountains, aerators, waterfalls, etc. However, Water Resources might support enhancements if they are funded and permanently maintained by the Developer or others, and if they do not negatively impact the design of the system. Contact Water Resources for more information.

6.4 Wetlands

6.4.1 Wetland Categories

There are generally two categories of wetlands that are defined in relation to stormwater management: natural wetlands (including protected wetlands), and stormwater wetlands (including engineered natural stormwater wetlands and constructed stormwater wetlands).

6.4.1.1 Natural Wetlands

Natural wetlands are wetlands that have not been altered by humans. In urbanizing watersheds, natural wetlands will inevitably be impacted due to changes in the hydrological regime and water quality associated with urban development, even if there is no intention to use them for stormwater management. Protected wetlands are deemed significant. These include all naturally occurring wetlands that have been identified under the Stewart and Kantrud Wetland Classification System as seasonal, semi-permanent, or alkali ponds. They are not recommended for use as stormwater management facilities and are protected under local and provincial legislation. They are either owned by the Government of Alberta and protected under the *Water Act* or *Public Lands Act*, or have been identified as Environmental Reserve Areas by The City and are protected under the *Municipal Government Act*.

Wetlands deemed to be "Environmentally Significant" by The City can also be protected under the *Calgary Wetland Conservation Plan*, regardless of their classification under the Stewart and Kantrud Wetland Classification System, and are not recommended for stormwater management. Methods for determining wetland environmental significance are provided in Appendix F of The City of Calgary Parks' *Open Space Plan* and Appendix 2 of the *Calgary Wetland Conservation Plan*.

6.4.1.2 Engineered Natural Stormwater Wetlands

Engineered natural stormwater wetlands are natural wetlands that have been deemed appropriate for stormwater management purposes and have been modified with forebays, outlet control structures, or other engineered components to increase stormwater storage and treatment capability. These wetlands inevitably forego some natural ecological and amenity value in lieu of providing stormwater management benefits. Where a natural wetland is incorporated, protection of the wetland must be considered. Design and management objectives for these wetlands need to address a balance between ecological function and habitat, amenity value, and stormwater management requirements.

Where significant impacts from development cannot be avoided, wetlands deemed as Protected Wetlands under the Stewart and Kantrud Wetland Classification System could still (potentially) be used as engineered natural stormwater wetlands. Compensation might be required under these circumstances. The City is currently developing a compensation tool to offset wetland disturbance and loss of habitat.

The extent to which (treated) stormwater is allowed to enter a natural wetland or an engineered natural stormwater wetland must be agreed to by Water Resources and Parks prior to Outline Plan (OP) Approval. The degree of pre-treatment in the storm pond could affect the amount of compensation required.

6.4.1.3 Constructed Stormwater Wetlands

Constructed stormwater wetlands are wetlands that have been designed and constructed specifically for stormwater management purposes, and, if properly designed, provide some ecological value and amenity. Constructed stormwater wetlands should typically not be located within natural wetland areas, which provide a critical habitat and an ecosystem. As well, stormwater wetlands should not be used to mitigate the loss of natural wetlands. When stormwater becomes a major component of the water balance of a natural wetland, the functional and structural qualities of the wetland can be negatively altered. However, understanding how wetlands are structured and how they function will increase the likelihood of constructing a successful treatment wetland. It must be recognized that stormwater wetlands are first and foremost stormwater management facilities; they should never be considered to be significant natural areas requiring environmental protection.

Constructed stormwater wetlands can be created by an embankment or through excavation of a depression. The hydrology of a wetland is primarily one of slow flows and shallow water depth to allow the settling of sediments as the water passes through the wetland. Sedimentation, filtration, biological, and chemical processes account for the water quality benefits provided by the wetlands.

Stormwater wetlands are an end-of-pipe BMP. Although wetlands do provide water quality enhancement, the reliability for pollutant removal is similar to wet ponds[36]. There are also some drawbacks, including a relatively high land area requirement, the need for intensive management after establishment, and the potential for adverse impacts within sensitive watersheds.

Limited operational and water quality monitoring data from wetlands in Calgary makes it difficult to determine the effectiveness of wetlands compared to wet ponds. Wetlands do have the potential advantage of removing finer sediment particles than wet ponds, and in effectively treating nutrients, BOD and other pollutants.

Traditionally, stormwater wetlands have fallen into five basic designs: shallow marsh, pond-wetland, extended detention (ED) wetland, pocket wetland, and fringe wetland. These classic stormwater wetland designs, in particular the ED wetland and the pocket wetland, have struggled to replicate other functions of their natural counterparts, such as habitat, aesthetics, and species diversity. As a result, two additional wetland designs were introduced: emergent wetlands and wooded wetlands. Goals associated with these new designs are enhanced pollutant removal, increased habitat value, and reduced problems with invasive species and mosquitoes.

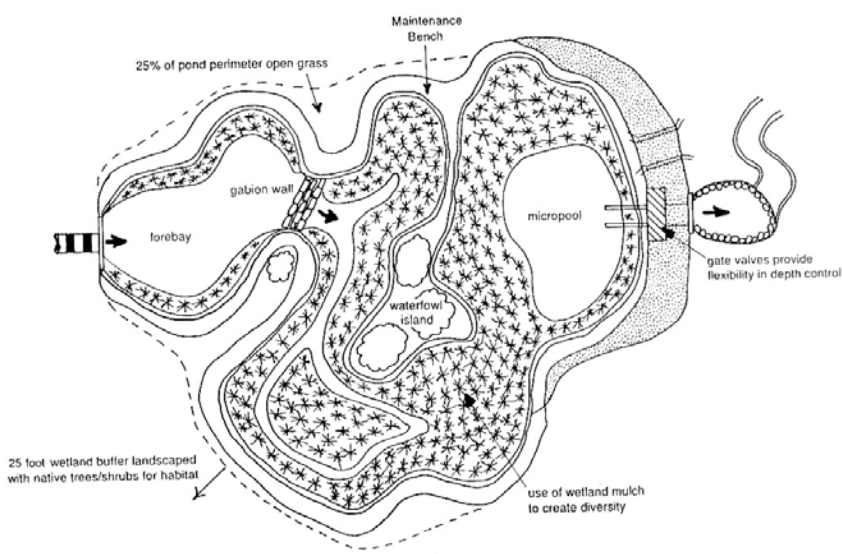
36. Source: Schueler 1992.

Two major design modifications are proposed to past design practice: the addition of trees and shrubs and the reduction of water level fluctuations (WLFs). The addition of trees and shrubs is recommended based on the literature information about the pollutant removal benefits of trees and shrubs. Reduced WLFs are recommended based on research that pinpoints changes in WLFs as the cause of habitat decline, including a decline in species richness and an increase in invasive plant species. Incorporating a multi-cell pond-wetland system significantly reduces the frequency and magnitude for WLFs in the wetland, without increasing the wetland's footprint. Studies show that WLFs greater than 8 to 10 inches (0.20 to 0.25 m) above the NWL elevation cause a decline in species diversity and richness. Other studies show that increased sediment and nutrient loads in natural wetlands cause a decline in species richness and an increase in invasive species. For more information, refer to ***APPENDIX F: Wetland Design Comparison***.

6.4.1.3.1 Shallow Marsh Systems

A shallow marsh system has a large surface area and requires a reliable source of baseflow or groundwater to support emergent vegetation (refer to ***Figure 6-15***). As a result, considerable area is required and a sizeable contributing drainage area to support the shallow permanent pool. A drainage area larger than 10 ha is generally required to support permanent water levels.

Figure 6-15: Shallow Marsh System[37]



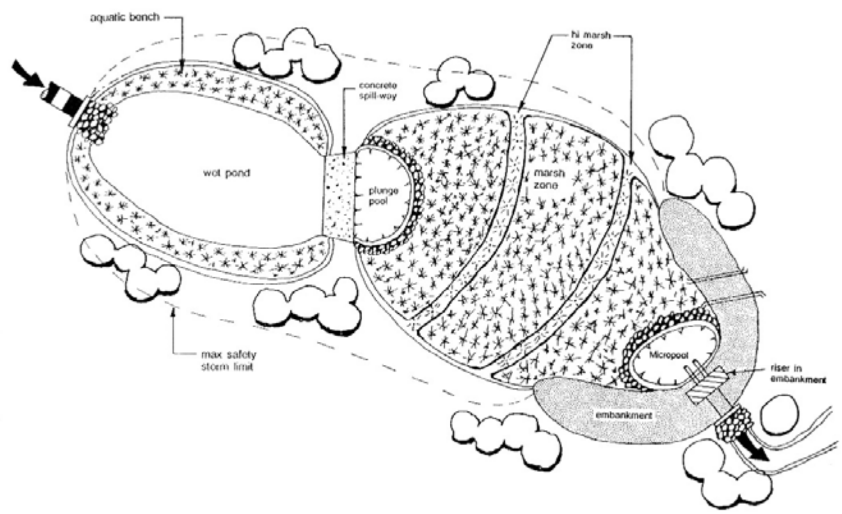
6.4.1.3.2 Pond-Wetland Systems

The pond-wetland system design uses two separate cells for stormwater treatment (refer to ***Figure 6-16***). The first cell is a wet pond and the second cell is a shallow marsh. The primary function of the wet pond is to trap sediments, to reduce the velocity of the incoming runoff, and to remove pollutants. The pond-wetland system requires less area than the shallow marsh system, since the majority of the

37. Source: Schueler 1992.

treatment is provided by the wet pond rather than the shallow marsh. In this case, the wet pond acts as the sediment forebay.

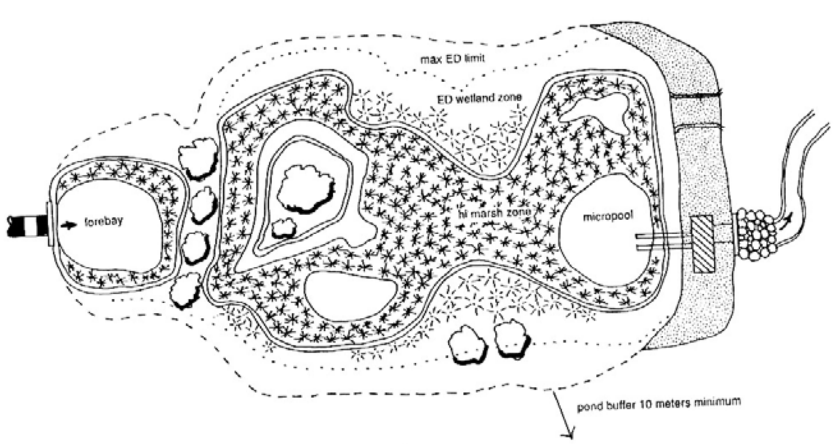
Figure 6-16: Pond-Wetland System[38]



6.4.1.3.3 Extended Detention (ED) Wetlands

In an extended detention wetland, additional temporary storage is created above the shallow marsh area (refer to ***Figure 6-17***). With this system, less space is required than in a shallow marsh system, since temporary vertical storage is partially substituted for shallow marsh storage. As a result, a new vegetation zone is created between the NWL and the HWL. The frequent water fluctuations create difficult growing conditions for plants, often resulting in low plant diversity and habitat value.

Figure 6-17: Extended Detention Wetland[39]



This type of wetland design is highly suited to the Calgary region, since it can be designed to accommodate seasonal and year-to-year hydrologic cycle variations.

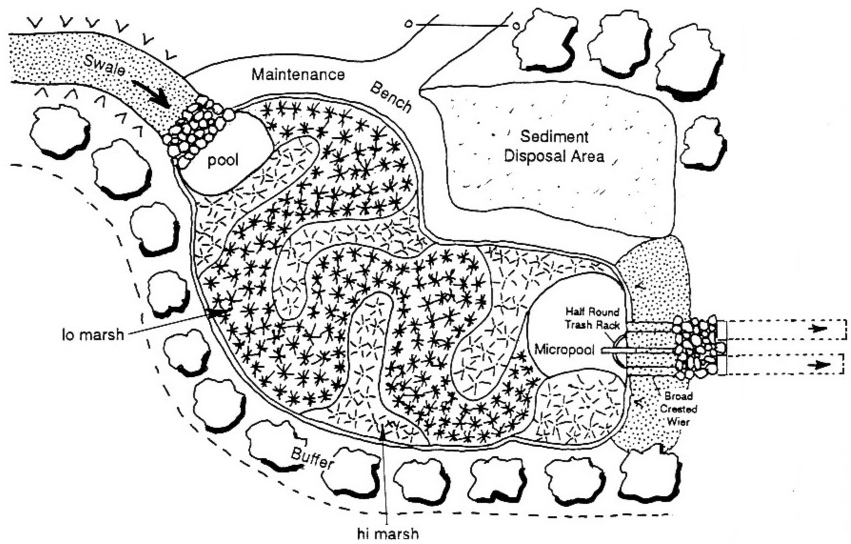
38. Source: Schueler 1992.
39. Source: Schueler 1992.

6.4.1.3.4 Pocket Wetlands

Pocket wetlands are adapted to serve smaller sites ranging from 0.40 ha to 4 ha. The systems are designed for widely fluctuating water levels, since there may not be a reliable source of baseflow (refer to ***Figure 6-18***). Some of the baseflow may be supported by excavating down to or below the water table.

In drier areas, the pocket wetland might only be supported by stormwater runoff, and during extended dry periods, there might not be a shallow pool. Due to their small size and fluctuating water levels, pocket wetlands often have low plant diversity, poor habitat value, and limited pollutant removal capability. To some extent, the pocket wetland mimics the prairie potholes that are common in Western Canada in terms of size and topography.

Figure 6-18: Pocket Wetland[40]



6.4.1.3.5 Fringe Wetlands

A fringe wetland is formed by constructing shallow aquatic benches along the perimeter of the permanent pool of a wet pond. The benches are usually 3.0 m to 5.0 m wide on both sides of the NWL. In Calgary, bench widths up to 10.0 m have been used.

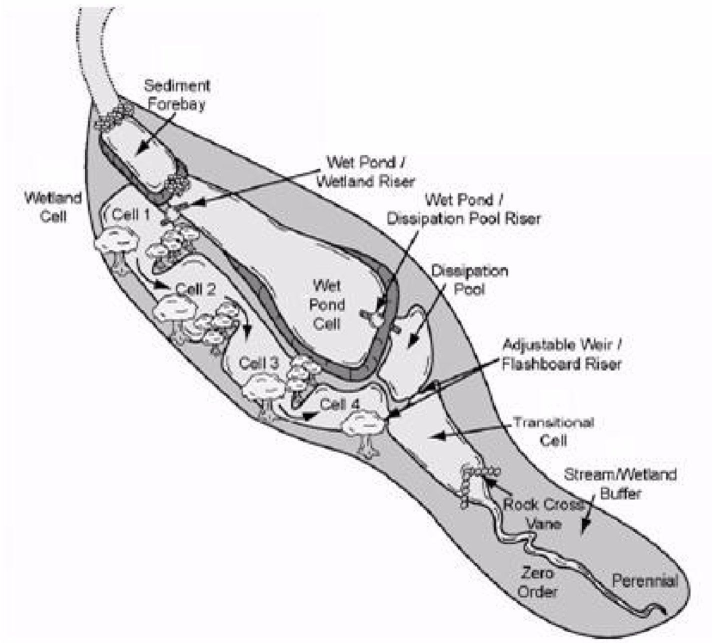
Fringe wetlands are a useful design feature in ponds, since they can be designed to promote a natural appearance, conceal trash and changes in water levels, reduce safety hazards, improve flow patterns and sediment removal, and provide some aquatic habitat. The wide benches are specifically of interest for ponds subject to water withdrawal for irrigation or other purposes.

40. Schueler 1992.

6.4.1.3.6 Emergent Wetlands

An emergent wetland (refer to ***Figure 6-19***) is a modification of the original pond/ wetland system, and is recommended for use in place of the shallow marsh and classic pond/wetland designs. It includes an on-line wet pond cell that supplies a steady supply of water to an off-line shallow wetland cell. The creation of the wet pond cell provides additional pre-treatment. This configuration significantly reduces the frequency and magnitude of WLFs within the wetland cell, which have been shown to reduce plant diversity and decrease habitat value. The key design elements for the emergent wetland option can be found in ***APPENDIX F: Wetland Design Comparison***.

Figure 6-19: Emergent Wetland[41]

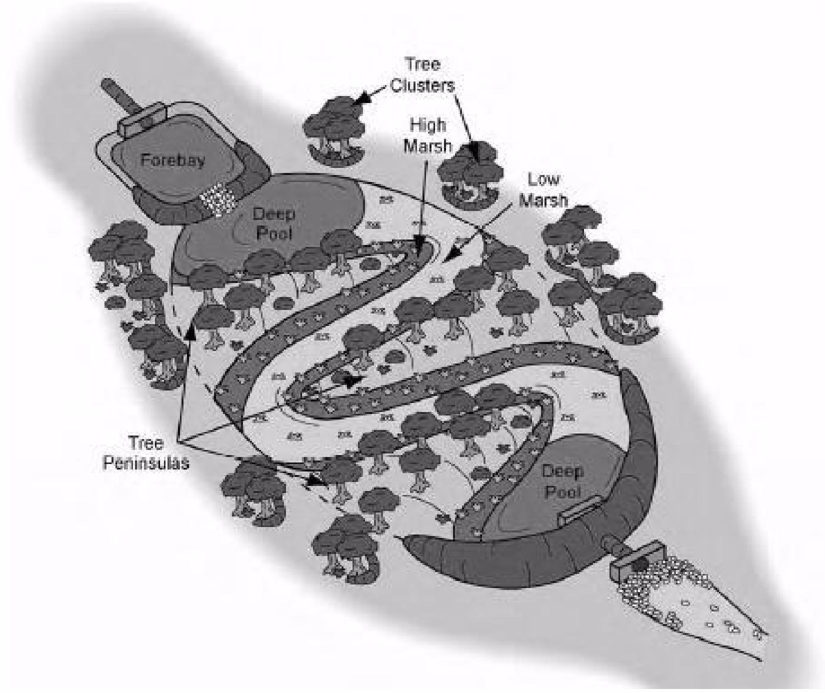


6.4.1.3.7 Wooded Wetlands

A wooded wetland (refer to ***Figure 6-20***) is a variant of the classic shallow marsh design that incorporates woody vegetation. The combination of trees and shrubs with emergent vegetation takes advantage of natural processes to maximize nutrient (nitrogen and phosphorus) removal and provides a greater range of habitat over the standard emergent wetland design. Trees also help to deter geese, as well as regulate the temperature of water leaving the wetland. As well, trees also provide a host of other benefits, including improved air quality and soil stabilization. Generally, clusters of trees are not recommended in the wetter portions of the wetland, since they can create ideal conditions for mosquito habitat. The key design elements for the wooded wetland option can be found in ***APPENDIX F: Wetland Design Comparison***.

41. Source: Cappiella 2008 (page 24).

Figure 6-20: Wooded Wetland [42]



6.4.1.3.8 Other Wetland Features

There are types of wetland systems that can be incorporated as features into other types of wetland systems to further enhance water quality treatment:

- A **Shallow Soil Infiltration Bed** is a type of wetland based on a common natural landscape feature of the foothills and boreal forest region. Shallow soil filtration can provide higher sediment removal rates than ponds, as well as better buffering of other pollutant concentrations (such as seasonal salt loading). Shallow soil filtration pertains to saturated conditions that are within the typical rooting depth of land plants (2.0 m).
- **Groundwater Infiltration** refers to wetlands or portions of wetland systems that are designed as infiltration facilities. In this type of system, all or a portion of the inundated stormwater volume will percolate through the soil profile to become deep groundwater. Deep groundwater refers to the saturated conditions below the typical rooting depth of land plants (2.0 m).

42. Source: Cappiella. 2008 (page 29).

6.4.2 Design

Table 6-3 summarizes the pertinent design criteria for wetlands. These criteria are discussed in more detail in subsequent sections.

Table 6-3: Design Summary Guide for Wetlands

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service/ Volumetric Sizing.	Provision of appropriate level of protection and adequate volume for quantity and quality.	Largest (most conservative) volume for 1:100 year storage capacity and 85% removal of TSS based on: • 24 hr, 1:100 year event. • Continuous simulation with statistical analysis of annual maxima • 85% removal of TSS for particles sizes ≥ 50 μm.	
Land Dedication.	Appropriate location.	PUL and ER.	PUL.
Drainage Area.	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume.	>4 ha.	≥10 ha.
Pond Area / Number of ponds.	Maximize pond area to limit number of ponds.	Minimum 2 ha at NWL.	
Circulation.	Prevent stagnation	Turnover rate of 2 times/year.	
Water Quality	Pre-treatment (sedimentation).	85% removal of TSS for particle sizes ≥ 50 μm.	
Sediment Forebay.	Pre-treatment (sedimentation).	• Area: 20% maximum. • Depth: 1.50 m minimum (typically measured from bottom of forebay to NWL).	• 10% maximum. • 2.0 m.
Forebay Length:Width Ratio.	Maximize flow path and minimize short-circuiting.	Minimum 3:1 measured along flow path.	Minimum 4:1 to 5:1.
Active Storage Detention Time.	Suspended Solids Setting.	24 hours.	
Length:Width Ratio.	Maximize flow path and minimize short-circuiting.	Minimum 3:1.	4:1 to 5:1.
Pond Depth.	Safety and control of weed growth.	• Bottom to NWL: 0.30 m average, 0.50 m maximum, 25% maximum area. • Inlets/Outlets: 1.0 m minimum, 3.0 m maximum • NWL to HWL: 1.0 m maximum • Freeboard: 0.30 m minimum. Refer to ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	
Overland Routes.	Safety.	Meets Alberta Environment Depth-Velocity guidelines.	
Escape Route.	Safety.	Minimum 1.0 m^3/s. Refer to also ***6.1.3 Overland Drainage and Escape Routes*** (Item iii).	Maximum possible.
HGL.	To prevent backup.	Surcharging 1.20 m below surface, except for last pipe segment into the forebay.	HGL impact confined to pipe adjacent to pond.

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Landscaping.	Public amenity and safety.	Approval of Water Resources and Parks.	
Recreational Activities.	Public safety.	Refer to list in ***6.4.2.16 Landscaping & Vegetation***.	
Side Slopes (pertains to pond and forebay areas).	Drainage and safety.	• Above HWL: No steeper than 4H:1V to 5H:1V. • Outward/Exterior facing: No steeper than 3H:1V. • NWL to HWL: No steeper than 5H:1V. • Below NWL: No steeper than 10H:1V. • Terraced: 7H:1V and 3H:1V. • Benches: 150 mm to 300 mm drop. • For forebays: - Below NWL: 2.0 m wide band 3H:1V. - Remainder: No steeper than 5H:1V to 7H:1V.	
Bottom Slope.	Promote sheet flow.	0.5% to 1%.	
Geotechnical.	Infiltration.	Maximum 1 x 10^{-6} cm/s.	
Inlet.	Safety and maintenance.	• Submerged: - Obvert 0.80 m below NWL - Invert: 100mm above bottom. • Unsubmerged: obvert @ HWL • Skimmer MH required (to remove floatables, oil/grit).	
Outlet.	Safety and maintenance.	1.20 m x 1.20 m per chamber.	1.80 m x 1.80 m/ chamber
Orifice.	Avoid plugging.	50 mm diameter minimum.	100mm diameter minimum
Trash Rack (Exposed Outlet).	Protect orifice from plugging.	• Required when orifice $\leq$200 mm diameter. • No trash rack required when outlet is fully submerged.	
Gate Valve.	Bypass and maintenance.	Required (300 mm diameter).	
Maintenance Vehicle Access.	Access for equipment.	• Width: 3.0 m with additional consideration for width at turns or bends. • Turning Radius: 8.0 m • Access gate(s) from the main road is required. • Road structure must accommodate maintenance vehicle weight and loading. • Boat/Equipment ramp is required.	Width: 4.0 m
Fencing.	Safety.	Not generally required.	
Monitoring Equipment.	Safety and design.	Required (refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds***).	
Signage.	Safety.	Required (refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary Water Resources' *Standard Specifications Sewer Construction*).	
Note: Refer to detailed information provided in following sections.			

6.4.2.1 Overall Design Philosophy

Stormwater wetland construction in Calgary is still relatively new and design is continually evolving. Despite a large amount of research and published information, the optimal design of a constructed wetland has not yet been determined. Many systems have not been adequately monitored, or have not been operating long enough, to provide sufficient data for analysis. As a result, Mitsch (1992) suggests the following guidelines for creating successful constructed wetlands:

- Keep the design simple. Complex technological approaches often invite failure.
- Design for minimal maintenance.
- Design the system to use natural energies, such as gravity flow.
- Design for the extremes of weather and climate, not the average. Storms, floods and droughts are to be expected and planned for, not feared.
- Design the wetland with the landscape, not against it. Integrate the design with the natural topography of the site.
- Avoid over-engineering the design with rectangular basins, rigid structures and channels, and regular morphology. Mimic natural systems.
- Give the system time. Wetlands do not necessarily become functional overnight and several years could elapse before performance reaches optimal levels. Strategies that try to overmanage or short-circuit the process of system development often fail.
- Design the system for function, not form. For example, if initial plantings fail, but the overall function is intact, then the system has not failed.

6.4.2.1.1 Design Criteria

The design criteria for stormwater wetlands must be confirmed prior to design so that the resulting configuration meets the required stormwater quantity, quality, ecological, and amenity objectives. Minimum stormwater quantity objectives should include:

- Maximum inflows to reduce soil erosion and damage to vegetation.
- Maximum NWL and HWL with associated storage volumes (i.e., permanent depth and active storage depths).
- Retention times.

6.4.2.1.2 Hydrology

Hydrology is probably the most important factor in the establishment and maintenance of specific types of wetlands and processes[43]. This includes precipitation, surface water inflow and outflow, groundwater exchange, and evapo-transpiration.

Changes in the natural hydrology of a wetland can therefore affect many of the functions of a wetland. For example, defining the extent, depth, and duration of active storage used in an engineered natural stormwater wetland should be

43. Source: Mitsch and Gosselink 1986.

determined on a case-by-case basis to achieve a balance between preserving ecological function while achieving stormwater quality control. It is essential that natural wetting and drying cycles be preserved as closely as possible to minimize impacts on the ecological function of a natural wetland.

Actions that upset the established balance of the biological community, such as changes in volume of runoff or water quality, can lead to significant changes in the functions of a wetland. For example, increasing the volume of stormwater runoff that enters a wetland can stress indigenous vegetation and allow more flood-tolerant species of vegetation (i.e., typha) to take over. In addition, the chemical make-up of stormwater can alter the chemical characteristics of the wetland soil if the stormwater is not adequately treated prior to its discharge into the wetland. Over a period of time, pollutants that have accumulated in the soil can appear throughout the wetland environment through chemical transformations, vegetative uptake, and re-suspension.

6.4.2.1.3 Ecological Objectives

Ecological objectives should be developed jointly with Water Resources and Parks by considering stakeholder input and wetland assessment information. At a minimum, ecological objectives should focus on establishing an effective biotic wetland community to maximize water treatment effectiveness. Alternatively, ecological objectives could be developed to preserve a large portion of a natural wetland slated for change to an engineered natural stormwater wetland.

Potential ecological objective topics that should be considered include:

- Fauna diversity and productivity
- Flora diversity and productivity
- Habitat productivity and availability
- Soil composition and quality
- Water quality, and
- Hydrologic regime

To meet Parks' ecological objectives, it might be important to ensure sufficient undisturbed area is conserved to maximize habitat for a species, or to provide an additional area for expansion of a population that might become affected.

6.4.2.1.4 Amenity Objectives

Amenity objectives should be determined in conjunction with ecological and stormwater management objectives. The benefits of amenity objectives include opportunities for recreational and educational activities.

There are also some nuisance controls that should be considered:

i) Mosquito control can be abated by introducing or making habitat available for baitfish, dragon flies, swallows and other predators. Research has shown that certain conditions in stormwater wetlands can lead to high mosquito populations.

ii) To reduce breeding potential[44]:

- Incorporate deep pools (30") free from vegetation to provide predator habitat.
- Ensure shallow pools are connected to the general flow path.
- Ensure constant water flow is maintained to disrupt mosquito production.
- Avoid emergent macrophytes that develop dense mono-cultural stands (i.e., cattails).
- Limit emergent zone width to allow access for predators and mosquito control.
- Plant herbaceous species that attract mosquito predators (i.e., dragon flies).
- Meet a target planting density of 3-4 trees per 1,000 m^2 when planting in the wetland.
  Note: Greater density at higher elevations, including the wetland fringe and buffer, is acceptable.

iii) Nuisance wildlife will require monitoring, since they can destroy or consume wetland vegetation.

iv) Odour control is not usually required if stormwater wetlands are properly designed.

6.4.2.1.5 Construction

Construction timing and phasing for stormwater wetlands should be selected to minimize impact on existing habitats and promote rapid stabilization of the wetland and surrounding landscape. Existing information from the BIA should be used to determine sensitive fauna and associated life cycle activity periods. Sensitive life cycle periods (i.e., rearing and breeding) for these species should be used to determine restricted activity periods (RAPs) where construction activities should be minimized. Construction should be planned so that planting occurs in early spring; this will avoid issues associated with winter conditions and provide plants with the maximum growing season prior to fall.

6.4.2.2 Level of Service/Volumetric Sizing

Wet ponds must provide a storage capacity for a 1:100 year event before spillover is permitted; the corresponding water level is the HWL (refer to ***6.1.2 Level of Service*** (Item ii)). A lower level of service may be allowed for retrofit facilities subject to approval from Water Resources. However, the wetland must also be sized to provide a minimum 85% removal of TSS for particle sizes greater than (or equal to) 50 µm for water quality. The more conservative volume of the two criteria will dominate. Refer to ***CHAPTER 3: STORMWATER DESIGN*** for more information.

There is no set minimum sizing criteria for the permanent pool (bottom to NWL) or the active storage (NWL to HWL). A minimum detention time of 24 hours must be provided. Minimum design volumes should be based on generally accepted criteria.

44. Source: Cappiella 2008 (page 21).

Adequate area must be planned for a wetland. As a rule of thumb, Alberta Environment suggests that the wetland size be approximately 5% of the watershed area it services.[45] However, this is a planning tool only; **wetland size should be confirmed through modelling**. Depending on the type of wetland and requirements, sizing might be less than 5% of the watershed area. It is important to note that wetlands require a minimum amount of water to survive; while wetlands can usually tolerate temporary drawdowns, they cannot usually withstand complete drying. Therefore, water level control is important to maintaining a healthy wetland. Design can also provide for WLFs for habitat management.

Release rates from the wetlands must conform to the rates set out in the approved MDP report and/or approved SMDP report.

6.4.2.3 Land Dedication

Wetland locations must be integrated with the Natural Area Management Plan (NAMP) and approved by Parks. Refer to The City of Calgary Parks' *Open Space Plan* and the *Calgary Wetland Conservation Plan*, or contact Parks, for more information.

i) Wetlands that are to be ultimately operated by The City of Calgary are to be located on PULs.

ii) The use of MR and MSR lands for wetlands will not be supported. Land located adjacent to PULs may be designated MR if the design of the pond provides a pathway or visual amenity.

iii) Use of ER might be supported if the wetland can function as part of the natural drainage system and can be appropriately designed and managed. Approval from Parks is required.

iv) All forebays must be located on PUL lands outside of the MR.

v) Retrofit wetlands might be supported in Major Natural Area Parks when there is minimal disturbance to the natural system and they are in accordance with The City of Calgary's *Calgary Wetland Conservation Plan*. Approval from Parks is required.

vi) Wetlands should not be located in ravines or in the flood plain of the Bow River, the Elbow River, Nose Creek, West Nose Creek, Fish Creek, Pine Creek, **unless there are no other viable locations**. **At no time are constructed stormwater wetlands acceptable in the floodway!** Contact Water Resources for more information.

vii) Where a wetland is located on privately owned land, an easement is required to permit encroachment of water onto the property and to restrict development in areas subject to inundation. For ponds proposed on Provincial lands, approval is required from the Province of Alberta. Contact the appropriate provincial department.

45. Alberta Environment 2006.

viii) A maintenance agreement is required for any **public** (City owned) wetland that will be operated and maintained by a private owner. Contact Water Resources for more information.

ix) The maximum level of inundation, or HWL, must not encroach onto private property. Lots bordering the wetland are required to have abutting property elevations a minimum of 0.30 m above the design emergency overland flow elevation of the pond when the pond has an overland emergency escape route. This must be increased to a suitable higher elevation if the emergency escape route consists of a pipe; contact Water Resources for more information.

x) **Existing** wetlands that qualify for Environmentally Sensitive Area (ESA) status might have limited suitability for dual use in stormwater management. Such sites will be managed for habitat and long term sustainability.

xi) A BIA is required for wetlands identified as environmentally significant. Environmental Impact Assessments (EIAs) are required to determine whether an existing wetland is environmentally sensitive; this is normally done by the consultant/developer at the MDP stage (refer to ***1.4.13 Biophysical Impact Assessments (BIAs)***). For more information contact Parks.

6.4.2.4 Upstream Drainage Area

Wetlands require a minimum upstream drainage area to sustain vegetation and the permanent pool. Refer to ***APPENDIX F: Wetland Design Comparison*** for suggested minimum drainage areas. As a minimum, upstream drainage areas greater than, or equal to, 4 ha are recommended, with preference for 10 ha or larger. These minimum upstream drainage areas have been suggested as guidelines; however, the actual required upstream drainage area will be a function of the permitted release rate, water quality requirements, and the desired water level in the permanent pool. A water balance study must be carried out to verify the operation of the wetland.

6.4.2.5 Pond Area and Number of Ponds

The minimum area of a wetland must be 2 ha at the NWL. Smaller areas will only be considered by Water Resources on a site-specific basis. In such cases, the private owner might be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer, larger wetlands. The developer must make every effort throughout the planning process to limit the number of wetlands required.

6.4.2.6 Winter Operation

Due to its shallow depth, much of a wetland's permanent pool volume will be frozen during the winter. Therefore, treatment will be a function of the remaining active storage volume. In general, the performance of the wetland decreases when the wetland is covered with ice. While there are currently no requirements to compensate for the loss of volume due to ice cover, precautions should be taken to minimize the effects of freezing of pipes and orifices. It should also be noted that methane (H_2S) gas is more likely to build up under the surface of the ice in winter, which can then seep back into the adjacent pipe system and lead to odour complaints.

Salt loadings are also higher due to winter road maintenance. Elevated salt levels in runoff can detrimentally impact water quality, vegetation, and wildlife. Salt entering wetlands can result in a vegetation community shift toward more salt tolerant species (such as cattails an phragmites), leading to the reduced health and growth of salt-intolerant species, generally reducing the biodiversity of the wetland plant community.

6.4.2.7 Circulation

Narrow and/or dead bay areas are not permitted. Inlets and outlets should be located to maximize detention time and circulation, and to reduce short-circuiting through the wetland. Refer to ***6.4.2.9 Sediment Forebays*** for more information.

A minimum turnover rate of the permanent pool volume is required; this should be twice per year based on Calgary's average annual precipitation.

6.4.2.8 Water Quality

All wetlands are required to provide enhanced water quality. Wetlands are to be sized to provide a minimum 85% removal of TSS for particle sizes greater than, or equal to, 50 µm. For more information on particle size and settling velocities for modelling purposes, refer to ***7.5.3.2 Particle Sizes and Settling Velocities***.

The treatment capability of a stormwater wetland depends on effective detention volume and hydraulic efficiency of the wetland. Currently, there is no set **minimum** sizing criteria for the permanent pool volume (bottom to NWL) or the active storage volume (NWL to HWL). However, a minimum detention time of 24 hours must be provided. Minimum design volumes should be based on generally accepted criteria.

Short-circuiting within a wetland, due to zones of re-circulation and stagnation, reduce the effective treatment volume. Hydrodynamic performance can be evaluated using a hydraulic efficiency concept, where perfect 'plug flow' is assumed to have the highest hydraulic efficiency (equal to 1). Hydraulic efficiency for stormwater wetlands should be between 0.50 - 0.70.

Careful consideration should be taken when trying to achieve hydraulic efficiency in an engineered natural stormwater wetland. Undertaking in-wetland modifications can cause harmful alteration of habitat and should be carefully weighed against other options such as expanding the wetland. Fringe-only planting should be avoided, since it reduces hydraulic efficiency. Vegetation should be planted in bands perpendicular to flow or evenly throughout the wetland zone, consisting of open water and vegetated areas within the wetland.

Water quality monitoring might be required during the maintenance period (refer to ***7.8 Water Quality Monitoring Programs***). Contact Water Resources, Development Approvals for more information. Costs of the program are to be covered by the developer during the maintenance period.

There are several mechanisms that are available in a wetland to improve water quality, including:

- Settling of suspended solids.
- Filtration and chemical precipitation through contact of the water with the substrate.
- Chemical transformation.
- Adsorption and ion exchange on the surfaces of plants, substrates and sediment.
- Breakdown and transformation of pollutants by microorganisms and plants.
- Uptake and transformation of nutrients by microorganisms and plants.
- Predation and natural die-off of pathogens.
- Planting of dense emergent wetland vegetation for nitrogen removal (through denitrification and adsorption).
- Planting of woody vegetation as a sink for phosphorus (and carbon) through uptake.

Although phosphorus removal following wetland construction is relatively high, it steadily decreases with time as bonding sites within wetland soils become saturated.

Features that can increase pollutant removal rates include: [46]

- Wetland surface area greater than 3% of contributing drainage area.
- Multiple wetland cells.
- No extended detention in wetland.
- Flow path from inlet to outlet 3:1 length to width ratio or more.
- Diverse micro-topography.
- Mean wetland depth less than 0.30 m (12").
- No groundwater inputs to wetland.
- Woody and emergent wetland vegetation.
- Dense wetland plant cover.
- Deciduous and evergreen vegetation.
- Wetland bottom covered with organic matter/detritus.

46. Source: Cappiella 2008 (page 21).

6.4.2.9 Sediment Forebays

A sediment forebay facilitates maintenance and improves pollutant removal of larger particles near the inlet of the wetland. In a wetland, it is important to confine sedimentation to the forebay since vegetation in the wetland area restricts sediment removal maintenance. The forebay should be one of the deeper areas of the pond to minimize the potential for particle re-suspension and protect the wetland from sedimentation.

Sediment forebays are required on all wetlands. In the case of engineered natural stormwater wetlands, the forebay must be located outside of the footprint of the original, natural wetland. As well, each inlet must drain into the forebay; short-circuiting through the forebay should be avoided. Sedimentation vaults or oil/grit separators may also be considered, but are subject to approval by Water Resources.

6.4.2.9.1 Short-Circuiting

To avoid short-circuiting and to ensure that sediment has time to settle out in the forebay, minimize the number of outlets into the forebay and/or ensure that flow path length(s) are maximized.The resulting effective length to width ratio in the forebay should be 4:1 to 5:1, with a minimum ratio of 3:1. Three dimensional modelling with programs such as CFD can be used to determine flow and velocity patterns, and sedimentation patterns.

6.4.2.9.2 Sizing

Sizing of the forebay length and width is determined using the same method provided for wet ponds, except that **a target particle size of 75 μm should be used** (refer to ***6.3.2.8 Sediment Forebay***). The forebay area should not exceed 20% of the overall wetland area (including the forebay); the preferable forebay area is approximately 10%. Where possible, the sediment forebay should be sized to accommodate the amassed sediment for a minimum period of 25 years without affecting treatment capacity to minimize the frequency of major cleaning. The treatment capacity is considered to be maintained as long as the theoretical sediment accumulation is at least 0.30 m below the invert of the incoming storm pipe.

6.4.2.9.3 Depth

The minimum depth of the sediment forebay should be 1.50 m to minimize the potential for scour and re-suspension. The recommended minimum depth is 2.0 m.

6.4.2.9.4 Length:Width Ratio

The total length of the forebay should provide a length to width ratio greater than, or equal to, 3:1 for each inlet. A length to width ratio of less than 3:1 is undesirable, since the wet pool will not be utilized effectively. In this case, the addition of flow baffles, or other means of lengthening the flow path in the forebay, may be used, subject to approval by Water Resources. When lengthening methods are used, effective length is measured along the flow path.

6.4.2.10 Forebay Berms

An earthen berm should be used to separate the forebay from the rest of the pond. The berm height should be set between 0 and 0.30 m above the NWL to act as a level spreader during storm events. The berm should be constructed with a solid substrate to facilitate removal of accumulated sediment and debris. In addition, the core of the berm must be impermeable and the berm itself geotechnically stable under submerged conditions. Sloughing of the berm must be less than, or equal to,150 mm at the time of FAC.

Emergent vegetation should be planted along the berm to promote filtration of water as it passes over (refer to ***APPENDIX E: Recommended Plant Species*** for species). The plants should be established on the top and sides of the berm at a maximum planting depth of 30 cm.

If possible, a maintenance pipe should be installed in the forebay to allow drawdown of the forebay for maintenance purposes. The maintenance pipe should be connected to a bypass pipe around the pond, connected to the downstream storm sewer system. Otherwise, the forebay will have to be pumped out. If only the forebay is to be pumped out or drawn down during maintenance, the forebay berm must be designed as an impermeable small dam since the rest of the pond will not be drained. Care must be taken not to compromise the structural integrity of the berm or liner during drawdown conditions.

6.4.2.11 Detention Time

A minimum detention time of 24 hours is required to promote water quality enhancement for active storage. Detention time is approximated by the drawdown time. Refer to ***6.1.2 Level of Service*** for a definition of detention time.

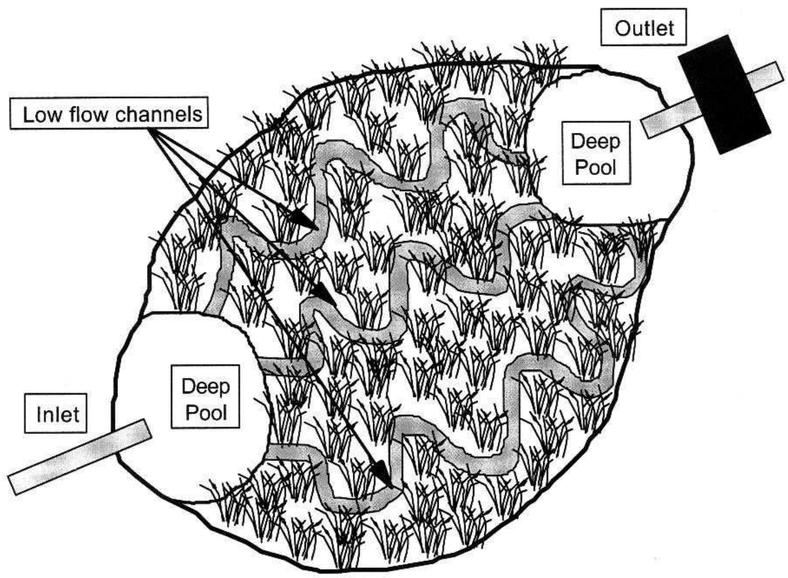
6.4.2.12 Length:Width Ratio

The flow path through a wetland is important to its overall performance. The flow path is dependent on the plantings and grading within the wetland due to the shallow depth of the permanent pool. The length should be based on the low flow path through the wetland, rather than the overall length dimension of the wetland. Low flow paths should be examined carefully in the wetland to ensure that short-circuiting does not occur.

The minimum length to width ratio is 3:1. However, the preferred length to width ratio is 4:1 to 5:1. Effective length excludes forebay length. Designs involving length to width ratios of 3:1 or less with point inflow and outflow will not promote good hydraulic efficiency unless steps are taken to distribute the inflow across the width of the wetland zone (the entire length of the wetland consisting of open water and vegetated areas).

In the case of engineered natural stormwater wetlands, care should be taken to ensure that the flow velocity associated with narrower cross sections does not exceed 0.05 m/s for a 1:5 year event and to minimize the potential for flow path obstruction due to accumulating debris.

Figure 6-21: Extending Flow Path through a Wetland.



Where possible, all stormwater servicing should be conveyed to one inlet location in the forebay. To provide the longest flow path though the wetland, the inlet should be located as far away from the outlet as possible. The provision of additional berms in the wetland to redirect flows and lengthen the flow path is also acceptable to ensure that short-circuiting will not occur.

The use of hydrodynamic models is recommended to assess flow, velocity, and sedimentation patterns. Refer to ***3.2.2.10 Other Models*** for more information.

6.4.2.13 Pond Depth

The depths of the permanent and active storage areas are important to the design and function of the wetland. Controlling water levels will help maintain a healthy wetland while providing water fluctuations in the design can provide habitat management.

6.4.2.13.1 Permanent Storage Areas

The **average** permanent pool depth measured from the pond bottom to NWL should be 0.30 m. The **maximum** permanent pool depth should not exceed 0.50 m. These permanent pool depths apply to the main cell(s) of the wetland; for the forebay depth refer to ***6.4.2.9 Sediment Forebays***.

Water depth at the inlets and outlets should be greater than, or equal to, 1.0 m to minimize sediment re-suspension. The maximum depth should be limited to 3.0 m.

Pockets of deep zones in the wetland up to 1.0 m are permitted for flow redistribution and submerged or floating aquatic vegetation. In general, the deep areas in a wetland should be limited to 25% of the total surface area to ensure that the majority of the wetland sustains emergent vegetation. Only the Pond-Wetland design will contravene this criterion due to its wet pond portion.

6.4.2.13.2 Active Storage Areas

The **maximum** active storage depth must be 1.0 m. The active storage depth is defined as the depth between NWL and HWL and is often referred to as the "extended detention" portion. In addition, a minimum freeboard of 0.30 m is required above the water level in the pond that corresponds to the design overland emergency discharge rate. Refer to ***6.1.3 Overland Drainage and Escape Routes*** for the definition of design overflow emergency discharge rate.

WLFs above the NWL should be of limited duration, and be designed to address the requirements of the chosen wetland plant communities; for engineered natural stormwater wetlands, WLFs should be determined based on the requirements of the natural wetland vegetation. Some plant species cannot withstand WLFs greater than 1.0 m. Although 1.0 m is sufficient for most wetland designs, the depth should be based on the plant species chosen.

6.4.2.14 Overland Drainage and Escape Routes

Overland drainage and escape route requirements include the following:

i) Overland drainage routes that direct flows from the 1:100 year storm event to the pond area must be provided. Overland flow design velocities (v) and depths (d) must be in accordance with *Stormwater Management Guidelines for the Province of Alberta (1999)*. Refer to ***Table 3-18*** and ***Figure 3-10*** in ***CHAPTER 3: STORMWATER DESIGN*** of this manual.

ii) Overland drainage routes entering the pond should be directed into the forebay. If this is not feasible, the runoff might need to be pre-treated before it is allowed to enter the pond. Trap lows adjacent to the pond may spill into the main cell(s) of the pond, provided that the trap lows fully contain the runoff from a 1:5 year event without spillover. Similarly, localized sheet flow from areas directly adjacent to the pond are permitted into the main cell(s) of the pond provided that flows are kept to a minimum.

iii) A designated continuous emergency overland escape route **from** all ponds is to be provided. In general, the design capacity of the escape route (refer to ***Figure 6-1***) from the pond is the greater of either:

- The resulting spillover rate for a 24 hour 1:100 year event assuming that the regular outflow is 0 m^3/s and there is a starting water level of NWL.
- 1.0 m^3/s.

The magnitude of the design capacity of the overland escape route should be determined at the time of pond design. The configuration and capacity must be adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route. Proper engineering design based on the local circumstances is required.

A minimum 0.30 m freeboard must be provided above the water level that corresponds to the design overland emergency discharge rate.

iv) Additional freeboard over and above what is required may be considered in cases where it is difficult to establish an overland escape route. The additional freeboard would provide a higher level of service overall; however implications to the HGL upstream of the pond must be considered.

v) Sanitary sewer MHs must be located outside of impoundment (pond) areas.

vi) Whenever possible, sanitary sewer MHs should not be located within the overland drainage route. When the situation is unavoidable, sanitary sewer MHs located within overland drainage routes must be sealed. Bolting is at the discretion of Water Resources

vii) Erosion control needs must be evaluated for both the overland drainage routes into the pond and the overland emergency escape route from the pond.

6.4.2.15 Hydraulics

The 1:100 year elevation will be established taking into consideration the adjacent footing elevations. When the wetland is at the 1:100 year elevation, water should not back up through the storm sewer system and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting HGL should be kept to a minimum. Free flow conditions are preferable; this is achieved when the obvert of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Water Resources. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

When free flow conditions are not achieved based on the HWL, HGL elevations in the storm sewer system must be determined based on the wetland at HWL and the appropriate losses taken into account (i.e. junction losses, pipe losses, etc.). Alternatively, a dynamic hydraulic analysis must be carried out to establish the HGL elevations. **Surrounding footing (or slab) elevations must be a minimum of 0.30 m above the HGL.** Other options to protecting weeping tile connections include a separate weeping tile drainage system connected downstream of the wetland, or sump pump to surface. Weeping tile drains connected to the sanitary system are not permitted in any circumstances.

Except for the last pipe segment into the forebay, sewer pipes should not surcharge for design or 1:100 year flows unless previously approved by Water Resources. **Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface (refer to *3.1.2.1 General Requirements*).** Also, proper aeration and venting must be considered as per ***5.5.2 Design***. Contact Water Resources for more information.

Backflow prevention devices are required on all weeping tile connections as per the National Plumbing Code of Canada.

All upstream storm piping below the HWL and HGL must be rubber gasketed as per The City of Calgary Water Resources' *Standard Specifications Sewer Construction*.

6.4.2.16 Landscaping & Vegetation

General wetland vegetation types, species lists and planting locations should be determined in coordination with wetland layout, water levels and bathmetry and water quality requirements. For example, the wetland outlet control structure could be designed to manipulate water levels to support specific plant species.

The biotic community is already established in engineered natural stormwater wetlands. However, this may change in response to altered hydrologic or water quality regimes associated with stormwater influxes. To manage these changes, optimal growing and reproduction conditions for desired individual plant species need to be determined, while still considering treatment requirements and the new hydrologic regime.

Landscaping and vegetation plans must be submitted with the construction drawings. The drawings must be reviewed and approved by Water Resources and Parks. All landscaping must be prepared by a qualified consultant and must conform to The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*.

In the case of engineered natural stormwater wetlands, the minimum buffer strip associated with upland areas is 8.0 m; greater than 16.0 m is preferred for wildlife purposes. Qualified consultants should also be knowledgeable in wetland ecosystems and restoration techniques. Refer to ***APPENDIX E: Recommended Plant Species*** for more information.

A planting strategy is required to provide shading, aesthetics, safety, enhanced pollutant removal, and waterfowl control. The purpose of the planting is to provide a sustainable community with a **naturalized treatment**. Plants native to Calgary should be used where possible. Planting density might not have to be high, as natural succession will ultimately make up the vegetation. As well, overall planting should be designed to minimize maintenance. Manicured and mown areas should be kept to a minimum or discouraged, since these areas can become a problem when they attract birds and geese,.

The recommended strategy for vegetating wetlands is to use nursery-grown seedlings for planting broad areas. Direct seeding and transplanting harvested materials can be used where opportunities arise. Sandbank material from wetland sediment is best suited to rehabilitating degraded wetlands, or where species selection is less critical. In general, planting diversity should achieve coverage of about 80% vegetation, meaning that plants should occupy 80% of each square meter of vegetated wetland zone. The benefit is that the 80% coverage value reduces the risk of weed invasion and avoids dominance of volunteer species, including cattails and phragmites, which flourish in disturbed conditions. For a list of plant species, refer to ***APPENDIX E: Recommended Plant Species***.

Planting strategies should focus on quick establishment of the preferred successional communities (that will compliment the surrounding landscape) before invasive species take over the site.

The primary difference between wetlands and wet ponds, in terms of landscaping and vegetation, is the proportion of shallow areas to deeper areas. Therefore, the planting strategy for the different types of areas (i.e. deep, shallow, fringe, and upland) for wetlands is the same as for wet ponds. Refer to ***6.3.2.15 Landscaping and Vegetation*** for design information.

6.4.2.17 Recreational Activities

Constructed stormwater wetlands can enhance the environmental features in an urban area. Although wetlands provide some recreational benefits, these benefits are quite different from those of wet ponds; and as with wet ponds, there are also risks associated with these activities.

Contact with stormwater in a wetland can cause skin irritation (swimmer's itch) and ingestion can make people and pets ill. Since the water quality in a wetland does not generally meet Alberta's *Environmental Protection and Enhancement Act (EPEA)* water quality guidelines, activities that involve direct water contact are prohibited.

Swimming and wading are **prohibited** activities; this includes pets (animals). Also prohibited are non-motorized (canoeing, kayaking, paddle boating, rafting, etc.) and motorized boating activities. Motorized boating is a potential source of noise, nuisance, and petroleum product spills. The exception is the use of motorized boats for emergency or maintenance purposes.

Ice related activities, such as skating and cross-country skiing, are not permitted since the ponds are not monitored for ice thickness. As well, protruding wetland vegetation will interfere with these types of activities.

Activities that are **permitted** include:

- Photography
- Bird watching
- Bicycle riding
- Jogging
- Walking
- Outdoor picnicking
- Arts and crafts

Contact Water Resources for more information.

6.4.2.18 Grading/Slopes

Grading and landscaping of the wetland and adjacent areas is important for public safety and the functionality of the wetland. Due to evolving wetland design, flexibility in grading will be permitted, subject to the approval of Water Resources. In general, though, the following requirements will apply:

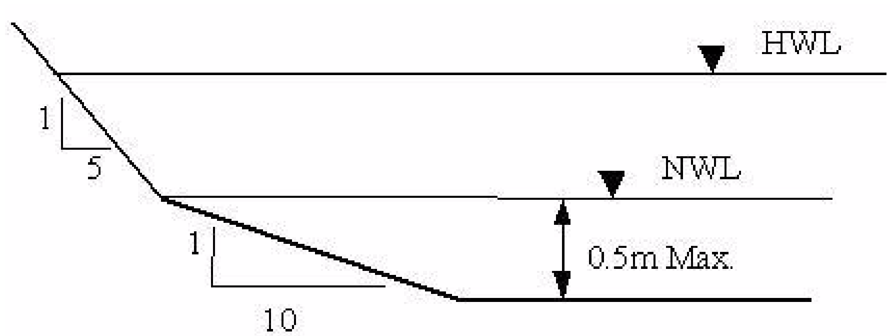
i) Due to the nature of the permanent pool and extended detention depths, grading in a wetland should be reasonably flat.

ii) Grading above the HWL must be no steeper than 4H:1V to 5H:1V. Subject to the approval of Water Resources, steeper side slopes in localized areas may be allowed above the inundated area for a limited distance, provided that a 2.0 m wide safety bench is provided above the freeboard elevation. For outward facing slopes, grading must be no steeper than 3H:1V.

iii) Grading between pond bottom and NWL should be no steeper than 10H:1V. Refer to ***Figure 6-22***.

iv) Grading between NWL and HWL (extended detention area) should be no steeper than 5H:1V. Refer to ***Figure 6-22***.

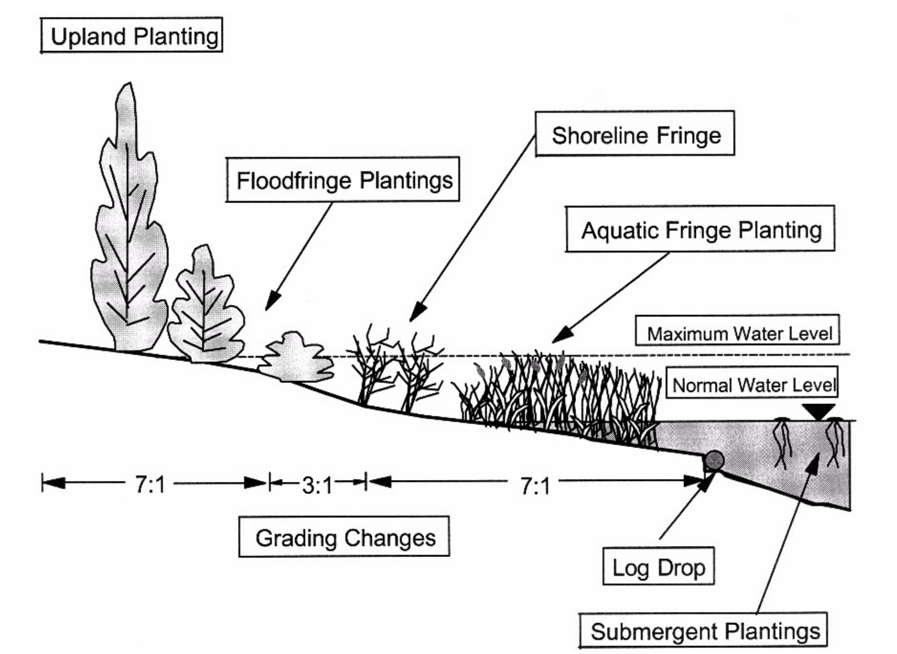
Figure 6-22: Typical Side Slopes for Wetlands.



v) Terraced grading is recommended to minimize the potential for the public to fall into the wetland. For terraced grading, alternating sections of 7H:1V and 3H:1V should be used in the vicinity of NWL, as shown in ***Figure 6-23***.

vi) For forebays in wetlands, below NWL, a 3H:1V slope is required for a horizontal distance of 2.0 m to discourage weed growth and public access. The remainder of the slope below NWL must be between 5H:1V and 7H:1V.

Figure 6-23: Terraced Side Slopes for Wetlands.



vii) Alternatives to side slope designs will be considered, including aquatic benches to enhance vegetation and naturalization. Small drops of 150 mm to 300 mm can be incorporated to deter the public from accessing deeper water. Contact Water Resources for approval.

viii) Where possible, grading should be designed to replicate the natural landform.

ix) In general, the bottom slope should promote sheet flow through the system, in order to achieve positive flow toward the outlet.

6.4.2.19 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of the wetland. The purpose of the report is to determine criteria such as dam safety (as required), underdrainage design (i.e. toe drains), liner requirements (infiltration), and any special design conditions (such as slope stability or groundwater). Refer to ***6.1.6 Water Quality*** for more information. Other considerations could include exfiltration (from pond to aquifer), construction dewatering, and possible liner uplift.

Pond bottom material is to be composed of impervious material with a suitable low permeability (permeability coefficient in the order of 1 x 10^{-6} cm/s). Preference should be given to using clay, where possible, or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Organic soils are not permitted for use as a liner; however, they are permitted along the edge of benches for establishing vegetation.

Due to the natural variability associated with engineered natural stormwater wetlands, extra emphasis should be put on the groundwater and soil portions of the geotechnical assessment.

The report must be submitted to, and approved by, Water Resources prior to submission of the construction drawings. The geotechnical report should be submitted with the Pond Report, the MDP report, or the SMDP report, whichever is the most practicable. Required details must be indicated on the construction drawings.

A dam safety assessment, including supporting geotechnical reports, must be submitted to Water Resources at the pre-design stage for stormwater ponds that could be classified as having a dam (refer to ***2.3.3.2 Dam and Canal Safety***); approval under the *Water Act* is required. Drawings of the pond must also be submitted. After internal review, Water Resources will forward the information to Alberta Environment's Dam Safety Branch as part of the review process.

6.4.2.20 Inlets

Due to the design and function of a wetland, an inlet is the only type of structure that permits the inflow of stormwater into the wetland. In order to provide water quality treatment, the flow must go through the wetland to the opposite end.

Inlet requirements include the following:

i) Inlets should **not** be located close to the outlet control structure to minimize short circuiting.

ii) Ideally, there should only be one discharge location, or inlet, into the wetland. Multiple inlets should be avoided where possible. However, at the transition from the forebay into the main cell(s) of the wetland, flow should be distributed using islands, weirs, vegetated benches, and aquatic benches installed perpendicular to the flow.

iii) All inlets and outlets are to be fully submerged, with the obvert of the pipe a minimum of 0.80 m below NWL (refer to ***Figure 6-13***). Partially submerged inlets are not permitted, due to concerns with ice formation.

iv) Inlet and outlet pipe inverts are to be a minimum of 100 mm above the pond bottom; depths in excess of 100 mm are recommended to prevent sedimentation from blocking the inlet pipe. Erosion control measures must be provided at the bottom of the inlet structure(s) to control erosion and scour.

    Erosion control measures should include the installation of a hard-bottomed surface, interlocking stone, or an approved concrete revetment/armouring system near the inlet pipe. Other enhancements such as dissipators or deflection structures will help to minimize scour and re-suspension. Erosion protection must extend along the side slope to the bottom of the forebay to a distance where the velocity is no longer erosive.

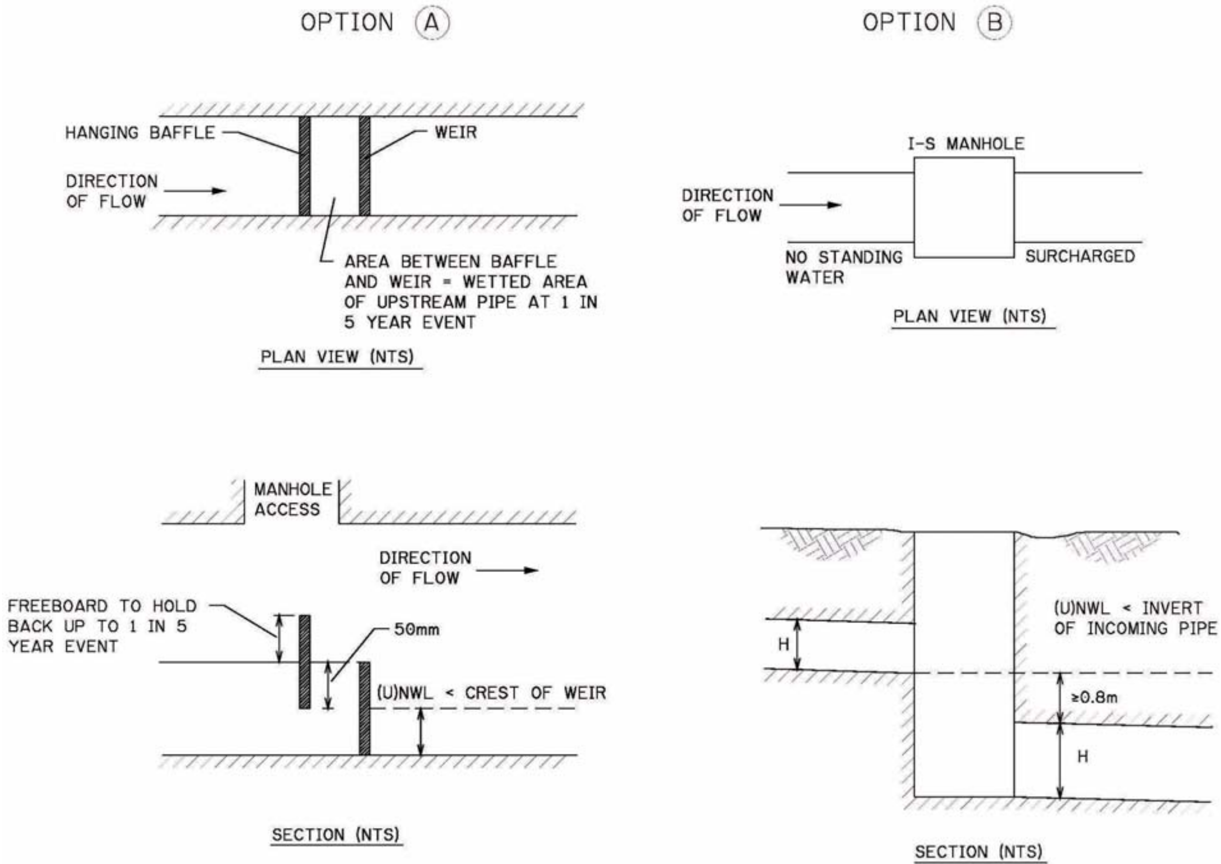
v) Clay plugs are required around all inlet and outlet pipes.

vi) Inlet velocities (at the end of the incoming pipe) should be limited to 1.50 m/s where possible to minimize erosion and scour, as well as re-suspension of sediments.

vii) The invert elevation of the inlet pipe(s) to the first MH upstream from the wetland must be at or above the NWL of the pond to avoid deposition of sediments in the inlet and freezing problems.

viii) A skimming type MH or approved equivalent (refer to ***Figure 6-24***) must be constructed on the first MH upstream of the inlet(s). The purpose of the skimming MH is to collect floatables (hydrocarbons, paint, etc.) and debris prior to entering the pond. The hydraulic losses associated with the incorporation of a skimming MH must be included in the modelling of the storm sewer system upstream of the pond.

Figure 6-24: Skimming Manhole



ix) Gratings are not required on submerged inlets.

x) Rock lined channels that convey stormwater from a pipe outlet to the wetland should be avoided.

xi) For engineered natural stormwater wetlands, a high flow bypass might be required to divert flow greater than a specified design flow (and/or volume) downstream to other stormwater management facilities. In most cases, flows and/or volumes associated with storms greater than a 24-hour, 1:5 year storm event should be routed downstream through the high flow bypass.

The chosen bypass design should be based on the design intent and local constraints of the site. In general, the design flows and volumes that can be accepted by an engineered natural stormwater wetland will be lower than those proposed for a constructed stormwater wetland due to its pre-defined characteristics and the sensitivity of an existing natural system. Acceptable design flows for engineered natural stormwater wetlands should be determined using information from the BIA.

6.4.2.21 Outlet Control Structures

Typically, the outlet control structure (also referred to as the “control structure” or the “outlet structure”) serves as the source of control for the release of stormwater from the wetland and the preservation of the normal water level elevation. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. A properly designed riser outlet consisting of multiple outlet holes provides the smallest range of detention times, and therefore the greatest treatment efficiency.

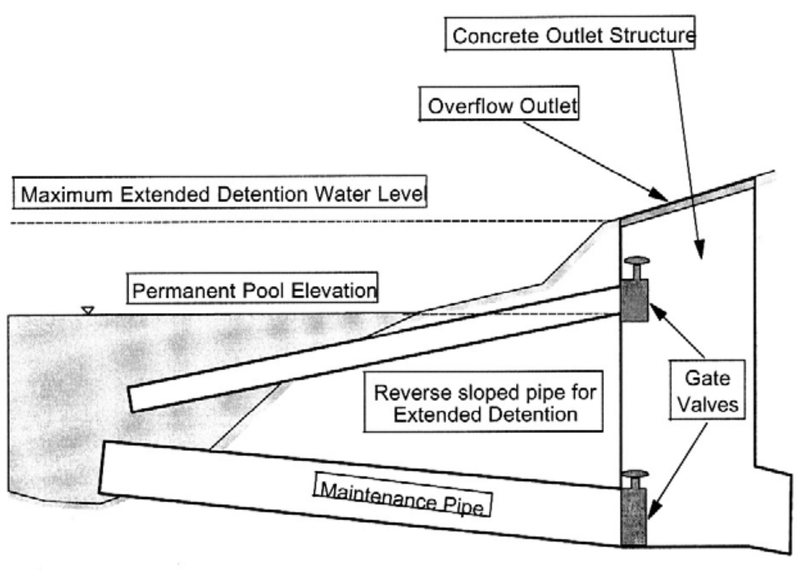
In addition, when designing for wetland water level fluctuations, riser outlets incorporating small holes, multiple orifice/weir outlets, and siphon outlets provide the best solution for mimicking a natural hydrologic regime. In the case of engineered natural stormwater wetlands, single weirs, orifices, and culverts are not preferred for the control of wetland water level fluctuations due to their inability to promote a range of fluctuations required for proper wetland function.

Design of the outlet control structure must be approved by Water Resources. Refer to ***5.3 Special Structures*** and ***5.4 Stage-Discharge Curves*** for additional design information. Clay plugs are required for all inlet and outlet pipes. Different types of control structures can be used for a wetland:

i) Three-chamber Structure - In this type of structure, there are usually two weir walls, one to control the NWL and one to control the HWL. While some outlet control structure designs include only two chambers, a three-chamber structure is preferred. For maintenance purposes, the size of each chamber should be a minimum of 1.20 m, but the preferred size is 1.80 m.

ii) Reversed Slope Pipe - The reversed slope pipe should drain to an outlet chamber located in the embankment. It is recommended that a gate valve be installed at the outlet end of the chamber to allow the drawdown time to be modified for future operating conditions.

Figure 6-25: Reversed Slope Pipe Outlet.



6.4.2.21.1 Orifices

Usually an orifice provides control for the permitted release rate for the wetland. The recommended minimum orifice diameter is 50 mm, to minimize the occurrence of clogging at the outlet. The preferred minimum diameter is 100 mm.

Subject to approval by Water Resources, orifices configurations other than circular openings can be considered. However, circular configurations with a slot are preferred for orifices along the floor bottom, because they better promote swirling flow and scour of deposited sediment at the bottom of the orifice. Supporting information, including hydraulic calculations for the proposed configurations, are to be provided to Water Resources as part of the Pond Report submission.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event of blockage of the primary orifice.

The orifice plate should preferably be constructed of stainless steel (306); however, galvanized steel or an approved equivalent are acceptable. The minimum gauge shall be 3 (1/4”).

6.4.2.21.2 Weir Walls

The three-chamber outlet control structure will typically have two weir walls: one to control the NWL, and one to control the HWL and to provide a source of overflow for the pond in the event of an orifice blockage. The weir wall controlling the overflow should be set at the HWL elevation, or the calculated HGL elevation.

6.4.2.21.3 Trash Racks

A trash rack could be required, depending on the design of the outlet pipe and/or outlet control structure. A submerged outlet pipe and/or outlet control structure will not require a trash rack.

For an exposed outlet control structure, a trash rack must be installed to protect the orifice when its diameter is less than (or equal to) 200 mm. The trash rack must be galvanized, and access to the orifice for maintenance purposes must be provided. The openings in the trash rack must be large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Vegetation can contribute to the potential for clogging. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable. Since the drainage area to a wetland is usually large, the diameter of the orifice is usually large enough that a trash rack is not required.

6.4.2.21.4 Gate Valves

All wetlands require a gate valve. The gate valve is used as a bypass for the orifice in the event the orifice plugs, as well as for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. Consideration should be given to not exceeding the design flow in the downstream storm pipe, except in emergency situations.

With the three-chamber design, two bypass gate valves are required: one in the NWL weir wall and one in the HWL weir wall.

In the reversed slope pipe design, the maintenance pipe should drain to the outlet chamber. A gate valve is required on the end of this pipe. Outlet flows can be controlled by setting and fixing in-place gap openings.

All gates should have non-rising stems that are operated either mechanically or manually (with a T wrench). The T wrench should be located on the downstream end of the outlet control structure in an easily accessible location.

The use of automatic control gate systems is not advocated, but Water Resources will consider these designs on a site-specific basis. An O&M manual is required for all automatic control gate systems.

6.4.2.21.5 Hydraulics

The hydraulic performance of the outlet control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to ***CHAPTER 5: HYDRAULIC DESIGN*** for more information.

6.4.2.22 Maintenance Vehicle Access

Maintenance vehicle access requirements include the following:

i) Maintenance vehicle access from an adjacent street or lane must be provided to:
   - The outlet control structure.
   - The inlet structure(s).
   - The skimming weir(s) or skimming manhole(s) in the upstream storm trunks.
   - The forebay.

   Operations staff using 1 tonne trucks must be able to access all areas of the pond. In addition, a boat ramp must be provided to the main cell of the pond or to the forebay; in case of the latter, at all times, (a) the berm must be submerged by 300 mm and (b) a 3.50 m wide passage must available from the forebay to the main cell of the pond. The boat ramp must extend to at least 1.0 m below the NWL.

ii) To ensure proper access to the outlet control structure and associated electronic equipment, the entire maintenance vehicle access road (including the top of the control structure and any associated electronic equipment) must be at or above the freeboard elevation.

iii) At the inlet, maintenance vehicle access shall be provided to the first manhole upstream of the forebay or pond inlet.

iv) Access to the forebay (for sediment removal and weed control) must be provided to the NWL. If a pond has multiple forebays, access must be provided to each forebay.

v) The first manhole upstream of the pond inlet, as well as the skimming weir/ skimming manhole, should preferably be located in a public roadway. If this roadway is subject to high traffic volumes (i.e. a primary collector and major/ arterial roadways), a turnout should be provided.

vi) Transportation Infrastructure or Roads should be consulted prior to pond design to ensure that the pond access road location is not an issue when the pond is located adjacent to, or accessed from, a major roadway and/or freeways/expressways. Access from major roadways or freeways should be avoided where possible due to safety concerns. Access should be designed to minimize interference with pedestrian activity and public safety. Pathways should not be used as a means of accessing pond maintenance areas (except by 1 tonne trucks) where possible, and maintenance areas should not impede or interfere with pedestrian activity and public safety.

vii) The vehicle access route must be a minimum of 3.50 m wide, but preferably 4.0 m wide. Additional consideration for width at turns and bends is required. The surface must be driveable, and the entrance must be gated with a bollard or equivalent at the property line (or at any location where a public vehicle could otherwise access the pond site) to prevent unauthorized access.

viii) Sharp turns must be avoided; the minimum turning radius is 12.0 m. Turnarounds must be provided at the outlet control structure, the inlet(s), and skimming weir/skimming manhole(s) if they are situated more than 30.0 m from the adjacent roadway. No turnaround is required for access to the forebay(s).

ix) Suitable surfacing material must be used (i.e. pavement, gravel, etc.). The subgrade for the access route to the outlet control structure, inlet structure(s), and skimming weir/skimming manhole(s) must be able to withstand a 23 tonne tandem truck; the boat ramp must be able to withstand a 1 tonne truck. The subgrade must conform to a "Lane" road standard as per The City of Calgary Roads' *Standard Specifications Roads Construction*. Alternatives will be considered, and are subject to approval, by Water Resources.

x) The slope of the access route to the control or outlet structure, inlet structure(s), and skimming weir/skimming manhole(s) (using a 23 tonne tandem truck) should be less than 5%, with a maximum slope of 8%. The slope for the boat ramp and access around the pond (using a 1 tonne truck) must be flatter than or equal to 5H:1V.

6.4.2.23 Fencing

In general, full perimeter fencing is not preferred, unless required by Parks or other business units. If there is a concern for safety due to the wetland being in a remote location, fencing might be requested, but most wetlands provide amenities that must be accessible to the public. Alternatives, such as the strategic planting of vegetation to provide effective barriers, are advocated. However, some facilities might be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern. This includes areas where the vertical drop is greater than, or equal to, 1.0 m. Chain link fence is less desirable than safety railings. and is only acceptable when the attached fencing does not protrude above the top rail.

Required fencing must be in accordance with The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*.

6.4.2.24 Monitoring Systems

Remote water level monitoring equipment is required at all wetlands to allow level monitoring by Water Services, Field Services when the pond is being used for storage. The use of solar panels for power supply is discouraged; pre-approval for use is required from Water Resources. The equipment will be installed at the developer's expense. Refer to ***6.1.10 Monitoring Systems*** and ***APPENDIX C: Monitoring Equipment for Ponds*** for details.

6.4.2.25 Signage

All wetlands must have appropriate signage. Signage is required at all public entrances to the wetland, at other critical points, and/or where there are long distances between signs. Locations should be identified on the Site/Overall pond drawing. Refer to ***APPENDIX D: Signage for Ponds*** and The City of Calgary Water Resources' *Standard Specifications Sewer Construction* for sign requirements. The developer is responsible for the cost of sign purchase and installation. Arrangements can be made with Water Services to order and/or install the signs.

As well, an informational sign (refer to ***APPENDIX C: Monitoring Equipment for Ponds***) is required at the most prominent entrance to the wetland. The purpose of the sign is to inform people about the function of the wetland, and to provide a contact number for more information or to report problems. It is the responsibility of the developer to supply and install the sign.

Signs promoting public education are encouraged. Signs may include information regarding the operation and purpose of the pond, protection of the environment, water conservation, native landscaping, the impact of chemicals, and interpretative trails. Contact Water Resources and/or Parks for more information.

6.4.2.26 Public Education

It is the responsibility of the developer to provide an educational brochure on stormwater wetlands during the marketing of an area that includes a wetland. The purpose of the brochure is to educate residents about:

- The specific function of stormwater wetlands.
- The water quality inherent with the function of the wetland and the impact of water quality resulting from fertilizers (which indirectly feeds into the sewer system by surrounding residents).Ppermitted recreational uses.
- Maintenance concerns and the potential for increased maintenance charges to residents to increase the level of maintenance deemed necessary.

6.4.2.27 Enhancements

In general, Water Resources will not fund any enhancements outside of the design specified above, including water fountains, aerators, waterfalls, etc. Stormwater wetlands should be kept in as natural a state as possible. However, Water Resources might support the enhancements if they are funded and permanently maintained by the Developer or others, and if they do not negatively impact the design of the system. Contact Water Resources for more information.

CHAPTER 7: WATER QUALITY

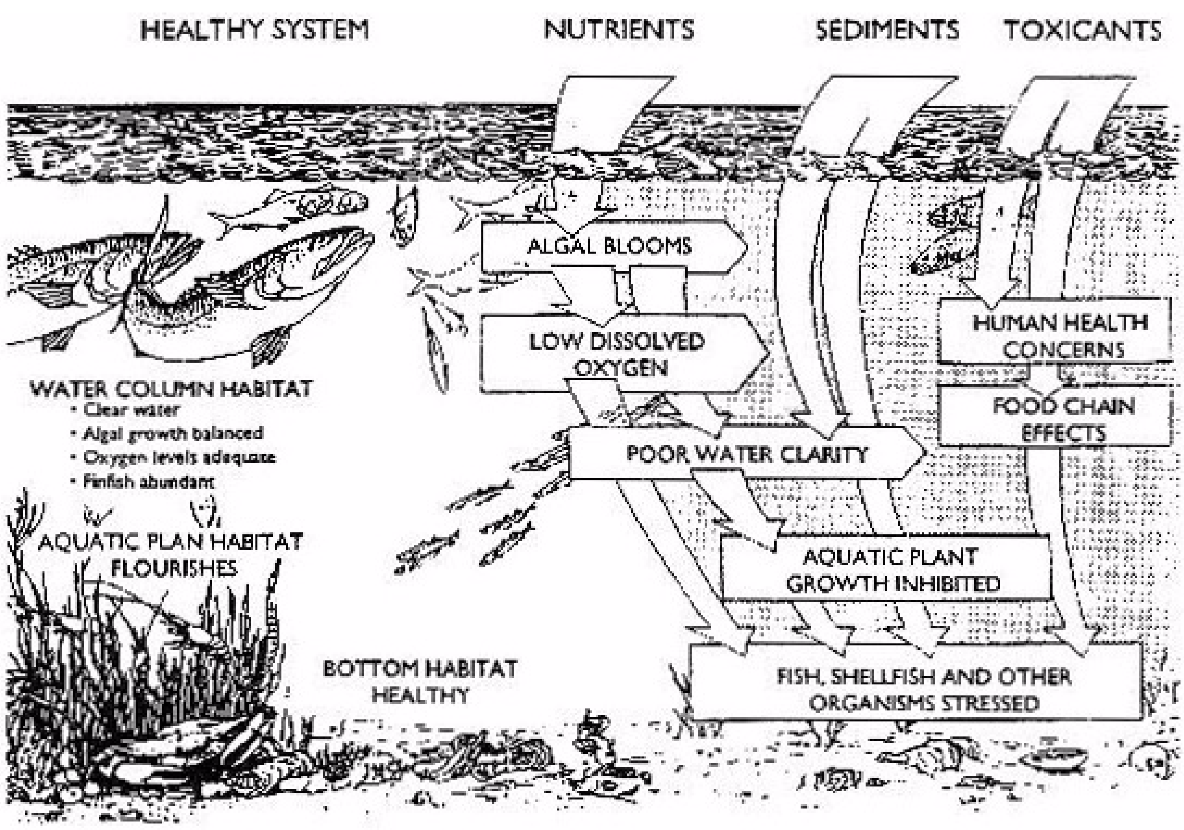
7.1 General

In the past, there has been a tendency to regard stormwater as a relatively minor source of pollution. However, numerous recent studies have indicated that there can be significant pollution within stormwater runoff. In fact, the annual loadings from urban runoff have been found to be similar to those found in wastewater effluent and industrial discharges.

As a result, the *2008 Calgary Total Loading Management Plan* was developed to help protect river health by setting targets for managing sediment and the amount of aquatic growth resulting from nutrients. Through the various Water Management Plans (WMPs) and Watershed Plans (WPs), additional water quality objectives and targets are being developed to maintain, and where possible improve, water quality.

Urban runoff is typically high in suspended solids and Biochemical Oxygen Demand (BOD). It can contribute significant concentrations of toxic metals, salts, nutrients, oils and grease, bacteria, and other contaminants to receiving waters, which can impact the potable water supply, aquatic habitat, recreation, agriculture, and aesthetics.

Figure 7-1: Effects of Pollutants on Aquatic Habitat



Although the environment has some inherent natural ability to mitigate and adapt to the impacts of pollution, urban runoff management is required. Generally, urban stormwater is a controllable source of pollution which can be managed with the implementation of Best Management Practices (BMPs). It is important that BMPs include both Source Control Practices (SCPs) and end-of-pipe approaches. SCPs are the first practical step to be taken to enhance urban runoff quality. End-of-pipe BMPs, such as wet ponds and wetlands, will be required when the runoff quality does not meet design specifications; on a smaller scale, vegetated swales and filter strips can be considered. Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** and/or The City of Calgary's *Stormwater Source Control Practices Handbook* for more information.

7.2 Declining Water Quality

The discharge of uncontrolled stormwater impacts and alters the hydrological, chemical, and biological condition of receiving water bodies. Stormwater runoff can contain a wide variety of contaminants, often at concentrations exceeding water quality objectives and guidelines.

Common pollutants found in stormwater include:

i) **Suspended Solids**:

Sediment loading is the most predominant pollutant associated with stormwater runoff. Typically, the major source of suspended solids in urban runoff is eroded soil from construction activities. However, sediment deposited on impervious surfaces and highway/road runoff also contributes to the problem. These sediments, both suspended and deposited, can have adverse effects on aquatic life and wetlands; the larger sediment can smother spawning grounds while finer sediments can be ingested by fish. In addition, sediments can alter the conveyance and storage capacities in streams, lakes, and rivers, and can also transport other attached pollutants. Some receiving streams are more sensitive to sediment loading than others.

ii) **Nutrients**:

Urban runoff has elevated concentrations of both phosphorus and nitrogen. High nutrient loadings can lead to the eutrophication of receiving waters; the excess nutrients promote algal growth and reduce the dissolved oxygen in the water body. The primary sources of phosphorus and nitrogen in urban runoff are decaying organic matter, originating from vegetation and animals, and fertilizer applications.

iii) **Organic Contaminants**:

Organic pollutants in urban runoff include pesticides, herbicides, fossil fuel combustion by-products, plastic products, and automobile-related activities. Industrial activities can contribute to these organic pollutants. The most commonly studied organic contaminant in urban runoff is hydrocarbons, particularly polyaromatic hydrocarbons (PAHs). Primary sources of PAHs are related to the operation of motor vehicles, mainly combustion byproducts, tire wear particles, and used crankcase oil. Organic contaminants can be toxic to aquatic life.

iv) **Trace Metals**:

Metal contaminants in stormwater can be toxic to aquatic life at certain concentrations; the contaminants can also accumulate in the sediments of streams, rivers, and lakes. Major sources of metals (zinc, copper, chromium, cadmium, nickel, and lead) are related to the operation of motor vehicles, including exhaust emissions, oil and grease, corrosion, and the breakdown of road surfaces. As well, pigments in paint and stain contain chromium, lead, and zinc. Various industries can also be sources of metals.

v) **Microorganisms and Pathogens**:

Pathogenic microorganisms in stormwater can often be found at levels above water quality objectives. The major sources of these organisms could be cross-connected sanitary systems or combined sanitary systems, or from animal and bird waste. Elevated levels of fecal coliform bacteria such as E. Coli can result in recreational impairment or closure of water bodies.

vi) **Road Salt**:

The application of road salt to roadways during winter is a major source of sodium and chloride ions. In Calgary, this typically includes NaCl (standard road salt) for de-icing purposes and calcium chloride brine for anti-icing/direct liquid application. In turn, this can affect the water chemistry of the receiving water in terms of alkalinity, hardness, pH, and salinity. Although the salt concentrations are not generally high enough to be directly toxic to fish and invertebrate species, sensitive species (such as frogs) and the growth of aquatic plant species can be negatively affected.

vii) **Water Temperature**:

Stormwater runoff from impervious surfaces can increase the temperature in receiving waters, which could adversely limit the habitat viability of aquatic fish and invertebrates that require cool and cold water temperature conditions.

The chemical makeup of stormwater runoff is primarily dependent on the land use within the catchment and the location of atmospheric pollution caused by major industries or large developments. In general, the quality of stormwater discharge will deteriorate when the percent imperviousness and runoff volume increases. Refer to ***Table 7-1*** for typical pollutant concentrations found in urban stormwater.

Table 7-1: Typical Pollutant Concentrations Found in Urban Stormwater.

Typical Pollutants Found in Stormwater Runoff	Units	Average Concentration [1]	Concentration Limits for Protection of Aquatic Life [2]
Total Suspended Solids[a]	mg/L	80	Not to be increased by more than 10mg/L over background value [Alberta]
Total Phosphorus[b]	mg/L	0.30	0.05 [Alberta]
Total Nitrogen[a]	mg/L	2	1 [Alberta]
Total Organic Carbon (dissolved oxygen)[d]	mg/L	12.70	6.50 [Alberta]
Fecal Coliform Bacteria[c]	MPN/100ml	3600	1000 [h]
E. Coli Bacteria[c]	MPN/100ml	1450	100 [h]
Petroleum Hydrocarbons[d]	mg/L	3.50	no data
Cadmium[e]	µg/L	2	0.047 [CCME]
Copper[a]	µg/L	10	7 [Alberta]
Lead[a]	µg/L	18	4 [CCME]
Zinc[e]	µg/L	140	30 [CCME]
Chlorides[f](winter only)	mg/L	230	860 [USEPA]
Insecticides[g]	µg/L	0.10 to 2	no data
Herbicides[g]	µg/L	1 to 5	no data

Notes: (1) These concentrations represent mean or median storm concentrations measured at typical sites and could be greater during individual storms. Also note that mean or median runoff concentrations from stormwater hot spots are 2 to 10 times higher than those shown here. As well, the values in this column are largely based on information from the United States. Concentrations in northern climates are often higher as demonstrated in the prior table for event mean concentrations for Calgary.

(2) Concentration limits for protection of aquatic life is based on a receiving water hardness of 150 mg/L $CaCO_3$. (Typical average hardness found in the Calgary region is approximately 155 mg/L $CaCO_3$ for the Bow River and 205 mg/L $CaCO_3$ for the Elbow River. A lower range of 150 mg/L $CaCO_3$ is used since it provides a stricter limit.)
Concentration limits identified by (USEPA), (Alberta), and (CCME) are reported in Alberta Environment's *Surface Water Quality Guideline for Use in Alberta (*1999).

(3) Units: mg/L = milligrams/liter µg/L = micrograms/liter MPN = Most Probable Number

(4) Value Sources:
(a) Schueler. 1987.
(b) Schueler. 1995.
(c) Schueler. 1997.
(d) Rabanal and Grizzard. 1996.
(e) USEPA. 1983.
(f) Oberts. 1995.
(g) Schueler. 1996.
(h) Alberta Environment. *Surface Water Quality Guideline for Use in Alberta.* 1999 (Table 2.0: Water Quality Guideline for Agricultural Uses).

(5) General Sources:
Alberta Environment. *Surface Water Quality Guideline for Use in Alberta.* 1999. and
Maryland Department of the Environment. 1998.

In 2001 and 2002, The City of Calgary conducted a stormwater monitoring program in support of the *Bow River Impact Study*[47], which was used to develop the *2008 Calgary Total Loading Management Plan*. This stormwater monitoring program resulted in Event Mean Concentration (EMC) values representing stormwater runoff, snowmelt, and baseflow pollutant concentrations for various land uses in Calgary. Refer to ***Table 7-2*** for local results.

Table 7-2: Event Mean Concentrations in Calgary, AB[48]

Land Use	TP (mg/L)	TDP (mg/L)	NH_3 (mg/L)	TKN (mg/L)	NO_2NO_3 (mg/L)	TSS (mg/L)	BOD (mg/L)	COD (mg/L)
Commercial	0.51	0.130	0.88	3.50	1.20	180	32.5	177
Industrial	0.80	0.180	0.73	3.70	0.92	369	34.2	261
On-Going Development	2.43	0.085	0.45	5.23	0.58	1896	17.6	258
Residential	0.74	0.130	0.62	3.77	0.91	444	26.7	188

where: TP = Total Phosphorus
TDP = Total Dissolved Phosphorus
NH_3 = ammonia
TKN = Total Kjeldahl Nitrogen
NO_2NO_3 = nitrite/nitrate
TSS = Total Suspended Solids.
BOD = Biochemical Oxygen Demand
COD = Chemical Oxygen Demand

47. Source: Golder 2004.
48. Source: The City of Calgary. *The City of Calgary Stormwater Runoff*, 2004. Table 5: EMC Concentrations. Data Documentation for the Generation of Daily Pollutant Loading Contributions (1990-2002).

7.3 Improving Water Quality

Due to the site-specific nature and inconsistent quality of urban runoff, accurate long-term characterization of discharge is difficult. However, it is clear that runoff from urban areas and highways contain relatively high concentrations of pollutants that can pose a threat to the health of organisms in receiving waters. Therefore, there is a need to implement water quality controls and to treat urban stormwater. Goals and objectives reflect the threat to resources and the receiving water uses, and contain site-specific, measurable targets. Monitoring and analysis of the existing environment will be required to evaluate the need for action, as well as the type of action required to meet the goals and objectives. Existing conditions can then be used as a baseline for comparison to ongoing monitoring data.

Detention ponds, in particular wet ponds and wetlands, are the most common methods used to enhance the water quality of stormwater runoff. The buffering and attenuation of stormwater flows contributes to the level of pollution control provided. However, it should be noted that the mechanisms that control pollutant removal, and in effect water quality, can be complex and numerous. In general, treatment ponds are effective in removing solids, but less effective for removing BODs, phosphorus, and nitrogen. SCPs, which are becoming more commonly used, aid in the improvement of stormwater quality and reduce the volume of urban runoff.

Other BMPs can be utilized to enhance water quality (refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** and/or The City of Calgary's *Stormwater Source Control Practices Handbook* for more information.). However, the use of treatment BMPs for urban stormwater is a relatively young technology, and the long-term effectiveness and impacts remain largely unknown.

7.4 Regulatory Requirements

7.4.1 Present

Since November 1998, The City of Calgary and Alberta Environment agreed to provide improved water quality treatment for urban runoff. The current objective is to provide a minimum of 85% removal of total suspended solids (TSS) for particle sizes 50 µm. All new Master Drainage Plans (MDPs) are required to address water quality enhancement. Water quality enhancement is also required at the site-specific level, including (but not limited to) industrial, manufacturing, and commercial sites (refer to ***4.11 Lot Grading and Drainage*** and ***4.12 Water Quality*** for details). Contact Water Resources for more information.

Under Alberta Environment Approval No. 17531-01-00, The City of Calgary is required to maintain the *2008 Calgary Total Loading Management Plan*, which includes annual total loading objectives for total phosphorus (TP), TSS, and any other substances that could be added to the plan from time to time. These loadings include wastewater treatment plant effluent and storm sewer discharges during the clear flow period between August and May. Planning trigger values (not regulatory limits) were outlined in the plan for TP (340 kg/day) and TSS (52,920 kg/day). A trigger was not generated for CBOD, as it was found to be of minor importance in maintaining dissolved oxygen levels in the Bow River[49]. No nitrogen triggers were set either, as it was found that dissolved oxygen levels in the Bow River were mainly controlled by phosphorus.

Also refer to the WMPs and WPs for the Bow River, Elbow River, and Nose Creek and Pine Creek Basins, where further recommendations regarding pollution limits might be identified.

7.4.2 Future

As part of The City of Calgary's *Stormwater Management Strategy*, which was updated in April 2007 (originally approved by Council in 2005), The City has committed to reducing sediment loading from Calgary's drainage system to the Bow River to or below the 2005 level by 2015, despite continued new development.

49. Source: Golder 2004.

7.5 Water Quality Modelling

7.5.1 Objectives

The main objective of water quality modelling is to meet regulatory requirements for stormwater quality, which is currently a minimum removal rate of 85% of TSS for particle sizes greater than, or equal to, 50 µm. Refer to ***7.5.3.2 Particle Sizes and Settling Velocities*** for information regarding particle size and fractions to be included. For treatment-type SCPs, such as bioretention areas, bioswales, and permeable pavement (excluding stormwater ponds), all runoff generated by the Water Quality Design Event must be treated without spillover. Refer to ***3.2.4.4 Water Quality Design Event*** for more information.

Good data collection is required to characterize the contaminant loadings contributing to receiving waters and/or the effectiveness of water quality treatment facilities. As well, data collection, analysis, and monitoring programs can be costly. However, the data collected from a spatially and temporally less extensive but more intensive sampling program can be used to calibrate computer models that can be used to estimate contaminant loadings. There are a number of computer models available, which are described in the following section. The selection of an appropriate model and the complexity of the analysis is determined by the nature of the problem, the type of drainage system, the objective(s), and the data and budget available.

7.5.2 Urban Runoff Water Quality Models

When choosing a computer model, it is important to consider the data and model limitations. Water quality computer models are relatively complex and require experienced personnel for their application. As well, quality models tend to be less accurate than quantity models, so expectations must reflect these limitations to avoid high modelling costs that do not yield the anticipated results.

The following points should be kept in mind for water quality modelling:

- Modelling efforts should be kept as simple as possible. When detailed modelling is planned, coarse screening models should still be used to determine whether or not the detailed simulation will yield useful results.
- Lumped catchment modelling is advised, as the quality of the available runoff and contaminant loading data normally limits the accuracy of the modelling.
- Continuous simulation is required. The rate of contamination buildup and antecedent moisture conditions have a major effect on loadings.
- Once continuous simulation has been conducted, selected design storms can be of use for testing treatment facility design and the impact on receiving waters.
- Calibration procedures should establish a good match of runoff volumes and peaks through single event models followed by continuous simulation comparisons. Calibration of contamination buildup and washoff can be undertaken with a continuous simulation model.
- It is generally advisable to limit contaminant simulation to a few parameters such as TSS, Total Dissolved Solids (TDS), BOD, and Total Nitrogen (TN).

Note: Studies that model in-stream impacts and contaminant transport are considerably more complex and require careful planning and execution.

There are currently four computer models that Water Resources has approved for **stormwater quality simulation**. They are as follows:

7.5.2.1 SWMM

The Stormwater Management Model (SWMM), is widely used for single event or long-term (continuous) simulation of runoff quantity and quality from urban areas. Water quality constituents can be simulated at selected storage nodes from subcatchments through a hydraulic network with optional first order decay and linked pollutant removal through use of BMPs and Low Impact Development (LID). Furthermore, the model provides a user friendly graphical environment for editing watershed input data, running hydrologic, hydraulic, real time control and water quality simulations, and viewing the results in a variety of graphical formats. Refer to ***3.2.2.3 EPA SWMM*** for more information.

7.5.2.2 XP-SWMM

XP-SWMM is a state-of-the-art hydrologic and hydraulic tool for modelling stormwater flows and pollutants. XP-SWMM also models flows and pollutant transport in natural systems including rivers, lakes, and floodplains with groundwater interaction. As well, XP-SWMM can simulate point and non-point pollution including the build-up and wash-off of contaminants in catchments, transport through collection and conveyance systems and treatment of stormwater by natural processes, BMPs and LIDs. Refer to ***3.2.2.6 XP-SWMM*** for more information.

7.5.2.3 QUALHYMO

QUALHYMO is a planning-level model that simulates water quality and quantity, capable of both continuous and single event simulations. The basic structure of QUALHYMO is based on the HYMO and OTTHYMO models, with a number of alternate commands incorporated that expand the scope of the model, making QUALHYMO distinct in its ability to simulate the generation and routing of pollutants, snowmelt, and instream erosion potential. QUALHYMO is one of the simpler simulation models available. Refer to ***3.2.2.7 QUALHYMO*** for more information.

7.5.2.4 QHM

QHM is a Windows-based watershed quantity and quality simulation model that is intended for watershed management and stormwater design. QHM was derived from the QUALHYMO model and therefore has similar features to QUALHYMO. QHM is capable of simulating rainfall-runoff, soil and groundwater effects on baseflow, evapo-transpiration, snowmelt and snow removal/disposal, soil erosion, and urban runoff quality (pollutants). Although QHM is primarily used for continuous simulation, single event simulation is also possible. Refer to ***3.2.2.8 QHM*** for more information.

7.5.2.5 Other Models

Historically, the majority of computer models used and accepted in Calgary have been based on the HYMO and SWMM families of models. Currently, SWMM (and XP-SWMM), QUALHYMO, and QHM are the models recommended for simulating urban runoff water quality, and in particular, sediment removal. However, computer modelling technology is evolving and new models have (and could continue to) become available. Refer to ***3.2.2.10 Other Models*** for more information.

7.5.3 Modelling Criteria

7.5.3.1 Continuous Simulation

Continuous simulation is required to model urban runoff water quality from all wet ponds and wetlands to estimate overall sediment removal rates (TSS). It is important that reasonable input parameters be used in the simulation. Currently, little calibration information is available to verify the accuracy of the parameters.

7.5.3.2 Particle Sizes and Settling Velocities

It is necessary to consider the particle size distribution for soils and their settling velocities. Although the relative distribution of the particles is seasonal, and dependent on location, a general distribution should be used for modelling purposes.

To estimate the total suspended solids removal rate from wet ponds, wetlands, and other devices or technologies requiring sediment removal (i.e., oil/grit separators), ***Table 7-3*** should be used as input into the model.

Table 7-3: Particle Size and Settling Velocities for Sediment Removal

Updated Parameters for City of Calgary				
Size Range (μm)	Density (kg/m^3)	Fraction (%)	Cumulative Total (%)	Settling Velocity (m/s)
<10	1500	23	23	0.00000592
10 - 20	2000	9	32	0.00004730
20 - 50	2500	13	45	0.00028300
50 - 150	2650	23	68	0.00195000
>150	2650	32	100	0.01240000

Notes: **a)** Densities are estimated.
b) Settling velocities are based on 15 degree Celsius temperature.
c) Settling velocities are based on the lower end of the size range.
d) A size of 5 μm is used for the <10 μm size range.

Parameters for Forebay				
Particle Size (μm)	Density (kg/m^3)	Size Range (μm)	Fraction (%)	Settling Velocity (m/s)
50	2650	>50	55	0.00195
75	2650	>75	46	0.00438
150	2650	>150	32	0.01240

Notes: **a)** The particle size distribution follows the New Jersey Department of Environmental Protection curve. This curve, which reflects the presence of more fine particles than originally assumed, falls within the wide range of particle size data acquired.

b) The settling velocities are largely based on Stokes Equation or Newton's Law of settling for larger particles. This reflects the findings by Sansalone and others. These velocities are significantly greater than what was assumed in the 2000 manual, which, at the time, reflected the 1994 Ontario MOE stormwater guidelines. The latter data was removed in the 2003 Ontario MOE stormwater guidelines as it was no longer felt to be appropriate.

c) Refer to ***6.3.2.8.2 Sizing*** for more information.

7.5.3.3 Rate of Sediment Accumulation

The rate of sediment accumulation must be used in the modelling to verify the sediment storage capacity of the forebay. The forebay must be able to accommodate the amassed sediment for a minimum of 25 years. Refer to ***6.3.2.8.2 Sizing*** for more information.

Based on a study undertaken in 1992 by J.N. MacKenzie Engineering Ltd. for QUALHYMO and QHM:

- The washoff method must be 2, with washoff rates of 6,000 and 3,000 grams per cubic metre, for impervious and pervious areas respectively, and a washoff coefficient equal to 1.20.
- The pollutant build-up method is 1, representing a power linear build-up method. The equivalent initial accumulation is 30 days, maximum accumulation is 0.20 kg per ha, and build-up equals 0.00055 kg per square metre per day.

A new version of QUALHYMO is under development. Contact Water Resources prior to using this new version, since both the operational commands and units of input parameters are understood to have changed.

Contact Water Resources when SWMM type models are expected to be used for water quality modelling purposes.

7.5.3.4 Technical Requirements

A technical stormwater report is required indicating the following water quality information:

- Model used.
- Input parameters, including build-up and washoff rates.
- Input and Output computer files.
- Proposed Water Quality Monitoring Program.
- Results (sediment removal rate, rate of accumulation, frequency of cleaning, size and volume of forebay and pond required to meet water quality requirements, BMP or SCP design parameters)

For further report requirements refer to ***CHAPTER 11: TECHNICAL REQUIREMENTS***.

7.6 Pond and BMP Sizing (Water Quality Perspective Only)

To provide the necessary water quality enhancement, the pond must be sized to provide a minimum 85% removal of TSS for particle sizes greater than, or equal to, 50 µm. As well, a minimum volume equal to 25 mm over the entire catchment area times the overall catchment imperviousness ratio (25 mm x catchment area x overall catchment imperviousness ratio) is required for the permanent pool for wet pond water quality requirements. The more conservative volume of the two shall govern. A minimum detention time of 24 hours must also be provided. Refer to ***6.3 Wet Ponds*** and ***6.4 Wetlands*** for more information on pond sizing requirements.

Release rates from the ponds must conform to the rates set out in the approved MDP report and/or approved Staged Master Drainage Plan (SMDP) report.

For treatment type SCPs, such as bioretention areas, bioswales, and permeable pavement (excluding stormwater ponds), all runoff generated by the Water Quality Design Event must be treated without spillover. Refer to ***3.2.4.4 Water Quality Design Event***. Contact Water Resources when other water quality modelling of SCPs is being considered.

For snow dump sites, special considerations might apply. Contact Water Resources, Development Approvals for more information, and refer to Alberta Environment's *Snow Disposal Guidelines for the Province of Alberta* for additional general information.

7.7 Cold Climate Impacts

Most stormwater treatment ponds are negatively affected by the winter season. Smaller ponds will tend to freeze, and any vegetation in the ponds will be relatively ineffective during this period of time. The effectiveness of other BMPs and SCPs will likely be reduced. Some BMPs are less affected by winter conditions (refer to *Performance Matrix for Suitability for Calgary Climate and Soils* and cold climate information on each of the specific SCPs (in ***8.1 Introduction*** and ***8.8 Operation and Maintenance***)). As the effects of chinooks are even less understood, more research is required in this area.

During winter months, anaerobic conditions can be created due to the thermal stratification of the ponds which may result in odours, and remobilization of previously deposited contaminants, especially in the presence of high concentrations of chlorides.

An extensive review of cold climate design considerations was undertaken by the Center for Watershed Protection in *Stormwater BMP Design Supplement of Cold Climates*[50]. Use of the following recommendations made in that document is encouraged:

- Increasing storage volumes to account for volume reductions due to ice and the effects of spring melt.
- Sizing and locating inlets and outlets to avoid ice clogging and freeze-up.
- Prohibiting early spring drawdown for maintenance to avoid discharge of anoxic or high chloride concentrated water.

50. Caraco 1997.

7.8 Water Quality Monitoring Programs

Water quality monitoring might be required for wet ponds and wetlands, and possibly other BMPs, during the maintenance period. Costs of the program are to be covered by the developer during this time period. Contact Water Resources for more information or changes to the program.

The analysis of urban runoff quality can be a valuable tool for assessing the effectiveness of treatment ponds and BMP design, and serves as a tool for determining any corrective steps required to effectively manage these facilities. The water quality monitoring program should include the following:

i) Sampling Locations and Frequency:

For storm ponds, both the inlet and outlet should be sampled. Sampling frequency is to be determined with the approval of Water Resources.

ii) Parameter Analysis:

All samples should be analyzed for the following parameters*:

Nutrients and Others (mg/l):	**Metals (mg/l):**	**Major Ions:**
• Total Suspended Solids (TSS)	• Aluminum (Al)	• Sodium (Na^{2+})*
• Total Dissolved Solids (TDS)	• Cadmium (Cd)	• Potassium (K^{+})*
• Biochemical Oxygen Demand (BOD)*	• Chromium (Cr)	• Magnesium (Mg^{3+})*
• Chemical Oxygen Demand (COD)	• Copper (Cu)	• Calcium (Ca^{2+})*
• Total Kjeldahl Nitrogen (TKN)	• Iron (Fe)	• Chloride (Cl^{-})*
• Ammonia-Nitrogen (NH_3-N)	• Nickel (Ni))	• Sulfate (SO^{4-})
• Nitrate (NO_3)	• Lead (Pb)	
• Nitrite (NO_2)	• Zinc (Zn)	
• Total Phosphorus (TP)		
• Dissolved Reactive Phosphorus (TDP)	**Microbiological:**	
• Ortho-Phosphate*	• Total Coliform*	
• pH	• Fecal Coliform*	
• Dissolved Oxygen (DO)*	• Fecal Streptococcus*	
• Conductivity	• E. Coli*	
• Turbidity		

* Parameters analyzed only in baseflow samples

Note: Monitoring parameters are subject to change. Monitoring of pesticides and Particle Size Distribution (PSD) could be required in the future.

When required, a monitoring report is to be prepared annually and submitted to Water Resources. Contact Water Resources for more information.

CHAPTER 8: BEST MANAGEMENT PRACTICES

8.1 Introduction

Stormwater Best Management Practices (BMPs) are activities or practices that divert, detain, or retain stormwater runoff and/or break down pollutants. The purpose of implementing Stormwater BMPs is to reduce or eliminate the impacts that stormwater runoff has on the environment, particularly the aquatic environment (refer to ***CHAPTER 7: WATER QUALITY***).

Large rain events tend to be the focus of most drainage design practices, because they represent the most significant conveyance problems and property damage potential. However, the bulk of annual urban runoff volume is actually the result of smaller, more frequent rain and melt events. In terms of water quality, it is the smaller rain and melt events that represent the largest pollutant loading problems to the receiving water bodies.

The selection and design of stormwater BMPs must incorporate both water quantity and water quality concerns. Current stormwater quality criteria for the City of Calgary requires the removal of a minimum of 85% total suspended solids (TSS) for particle sizes greater than, or equal to, 50 μm. As time goes on, additional pollutant loading criteria might be established that will identify additional pollutant controls required. If a single BMP is unable to fully meet these criteria, a combination of BMPs in series could be required.

Care should be exercised in selecting the appropriate BMP or combination of BMPs. Overall education is an integral component of successful design and implementation. It is the designer/consultant's responsibility to ensure that all BMPs are properly designed according to site conditions or constraints, and that details are provided on the design drawings. **All BMPs require the approval of Water Resources.**

Good planning and design integrates the design of a site with stormwater management facilities. The integration of BMPs into the planning and design process is essential for an effective stormwater management plan. Although site-specific conditions or characteristics will govern the stormwater management solutions used to some extent, the designer must use his/her own experience and judgement, and the requirements of the municipality, to successfully implement stormwater controls.

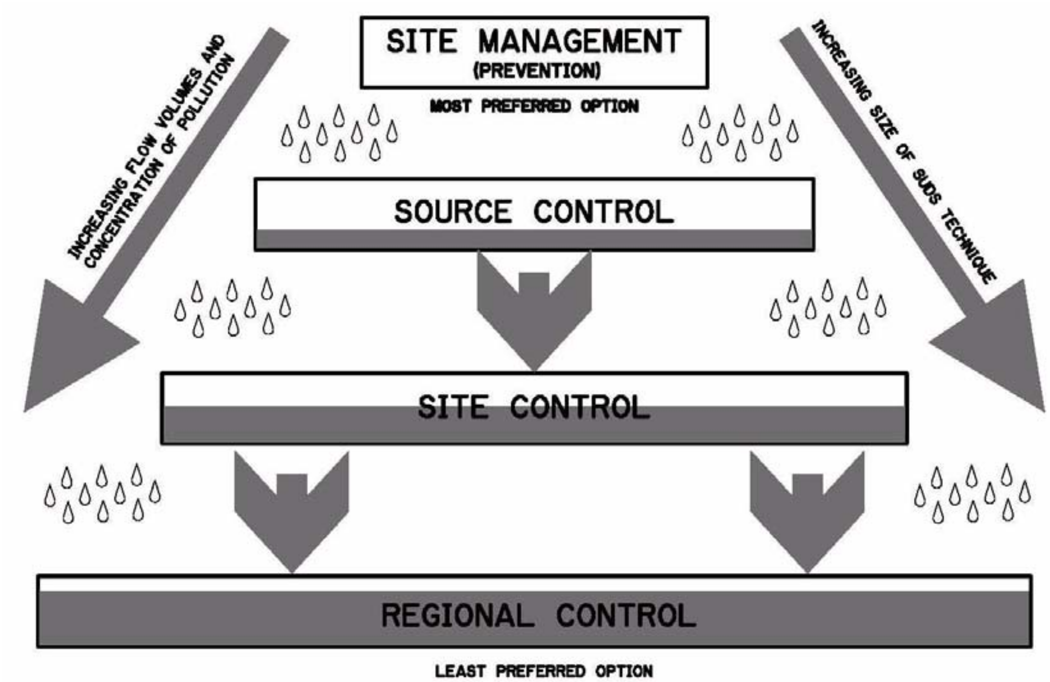
There are many types or classifications of BMPs that can be implemented to reduce stormwater pollutants. This chapter details the most common BMPs used, but is by no means a complete list. As well, some BMPs might be better suited to Calgary's climate and conditions than others, and some site specific conditions may allow the use of BMPs that might not be implementable on other sites. These limitations should be considered during the design process.

The BMPs chosen for Calgary are based on the following classifications:

- Pollution Prevention Strategies.
- Source Control Practices (SCPs).
- Site Control BMPs.
- End-of-Pipe BMPs.

The above classification mimics the treatment train analogy (refer to ***Figure 8-1***) presented in stormwater literature. BMPs can also be further classified as structural or non-structural. These terms and classifications are described further on in this chapter. For more information, refer to Alberta Environment's *Stormwater Management Guidelines for the Province of Alberta (1999)* and/or *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*.

Figure 8-1: Treatment Train Hierarchy[51]



51. Source: Wilson et al 2004.

8.2 Pollution Prevention Strategies

Environment Canada[52] defines pollution prevention as “various practices that reduce the creation of pollutants and waste”. Pollution prevention “focuses on removing the causes of pollution rather than on managing it after it has been created.”

There are several opportunities to implement pollution prevention (P2) strategies, though it is essential to include those who generate pollutants (or are affected by pollution) to give them a sense of ownership. A sense of ownership of the problem allows those who generate pollutants to be made aware of the problem, the consequences, and the implications, as well as how to reduce or prevent the problem. The most effective programs include public and private sector awareness and education regarding household, recreational, and work activities, as well as information about alternative practices and ways to reduce or prevent pollutants. Opportunities to promote education can include partnering with groups such as the Bow River Basin Council, the Calgary River Forum Society, and the Alberta Low Impact Development Partnership. Developers can also help promote pollution prevention by educating home builders and home owners where possible.

Pollution prevention strategies can include a number of activities, such as using alternative methods for controlling pests, following Good Housekeeping Practices, controlling construction activities, street sweeping, catchbasin (CB) cleaning, and animal waste removal to name a few. Refer to ***APPENDIX G: Pollution Control Strategies*** for more information.

8.2.1 Pesticide and Fertilizer Use

Pesticide and fertilizer use is associated with a wide range of household, business, and governmental activities. Pesticide use can be minimized by the amount and timing of applications, by using alternatives, and through Integrated Pest Management (IPM), which promotes:

- Using natural predators and pathogens.
- Mechanically removing of weeds, eggs, larvae. and insects.
- Changing habitat to minimize pest insect breeding.
- Timing applications to the most vulnerable phase of the pest's life cycle.
- Concentrating efforts on the most widely affected areas.
- Using site-specific methods.
- Using degradable and non-carcinogenic pesticides.

The City of Calgary Parks has developed and implemented its own IPM plan, which has been in effect since 1998. For more information, refer to The City of Calgary Parks’ *website* and the *Integrated Pest Management Plan*.

52. Source: Environment Canada’s “Pollution Prevention” website.

Chemical fertilizers are a significant source of nutrients (mainly phosphorous and nitrogen) in urban runoff. However, the use of fertilizers can be minimized by controlling the amount and timing of the application, and through use of other alternatives, which should include:

- Incorporating fertilizers directly into the soil (avoid surface applications).
- Using slow-release fertilizers.
- Substituting compost and peat for chemicals.
- Confining applications to seasonal periods that minimize losses to surface and ground waters.
- Avoiding applications during extended dry periods.
- Avoiding excessive watering of lawns.

8.2.2 Good Housekeeping Practices

General Good Housekeeping Practices are also beneficial in pollution prevention strategies. These practices can be applied to household, commercial, industrial, and construction activities:

- Promptly contain and clean up solid and liquid pollutant leaks and spills, including oils, solvents, fuels, and dust from manufacturing operations. Absorbent materials, such as clay and peat, can be used where practicable.
- Do not hose down or discharge pollutants to storm drains, conveyance ditches, or receiving waters.
- Promptly repair or replace all leaking connections, pipes, hoses, valves, etc. that can contaminate stormwater.
- Sweep handling and storage areas on a regular basis and, if needed, dispose of dust and debris that could contaminate stormwater.
- Recycle materials such as oils, solvents, coolants, waste, etc. as much as possible.
- Cover and contain materials, equipment, waste, and compost piles that could cause leachate contamination of stormwater.
- Use drip pans to collect leaks and spills from industrial/commercial equipment, or repair the equipment.
- Use environmentally safer raw materials, products, additives, etc.

8.2.3 Household, Industrial, and Commercial Activities

Household activities can be altered to reduce stormwater contamination. This includes controlling the use of hazardous products (or using non-hazardous products), preventing disposal of hazardous materials into storm sewers, reducing fertilizer and pesticide use, and managing pet, kitchen, and yard wastes. Public education of homeowners is the key component to controlling source pollution; they need to be made aware of the consequences of polluting stormwater runoff, and how they can help mitigate these impacts. Driveways and sidewalks should be swept, not hosed, to avoid oil, grease, and solids from washing into the storm sewer. Fluid leaks from vehicles and equipment should be repaired, and spills absorbed with the appropriate absorbent material. Hazardous wastes should be collected and dropped off at facilities or depots that handle these types of waste.

Industrial and commercial activities can generate significant metal and organic contaminants. Manufacturing and disposal practices can be changed to promote the recycle and re-use of materials that cause pollution. Generated pollutants that cannot be altered or changed should be enclosed or covered. Any contaminated runoff should be treated on-site or routed to the sanitary sewer, if permitted. Spill prevention and control plans should be in place, and staff should have proper training and education. Refer to ***APPENDIX G: Pollution Control Strategies***, *Drainage Bylaw 37M2005*, and *Sewer Service Bylaw 24M96* for more information.

8.2.4 Automobile-Related Activities

Automobile-related activities can generate a wide range of pollutants, in particular metals and hydrocarbons. This includes the wear and corrosion of parts, as well as leaking and disposal of oils and lubricants. Some SCPs that can be implemented include:

- Using unleaded gasoline.
- Cleaning heavily used parking and commercial lots.
- Using oil and grease recycling centres.
- Inspecting and repairing vehicle fluid leaks.
- Reducing vehicle use.

As well, roadway de-icing during the winter contributes to heavy metal, cyanide, and high salt concentrations in runoff. High salt concentrations can exert stress on roadside vegetation and in receiving waters. By reducing the use of de-icing salt, using alternative de-icers, or substituting sand and gravel for salt, the impact of de-icer pollutants can be minimized. Unfortunately, there is currently no practical method of roadway de-icing that is completely environmentally satisfactory.

8.2.5 Construction Activities

Soil erosion caused by construction activities has been identified as a primary source of suspended solids in urban runoff. Construction activities generate pollutants from pesticides, petroleum products (fuels and lubricants), nutrients (mainly from fertilizers used in revegetation), solid waste (trees, shrubs, wood, paper, scrap metals), garbage (food wrappings, cigarette packages and butts, etc.), construction chemicals (paints, cleaners, etc.), and other sources such as concrete wash water.

Frequent collection and proper disposal of petroleum wastes, cleaning materials, and site debris/garbage is effective in minimizing pollutant transport. Erosion and sediment controls must be implemented to control soil erosion and to retain eroded soils on-site. Refer to ***CHAPTER 9: EROSION AND SEDIMENT CONTROL*** and The

City of Calgary's *Guidelines for Erosion and Sediment Control* for information. Temporary sedimentation controls, such as sedimentation traps and basins, will aid in pollutant control. Erosion and sediment controls should always be developed as an integral part of the construction planning process. Erosion and sediment controls are also paramount in protecting SCPs such as bioswales, bioretention areas, and permeable pavement while construction takes place in the upstream catchment area. Water quality should be monitored before, during, and after construction activities to determine the effectiveness of mitigation techniques. Refer to ***APPENDIX G: Pollution Control Strategies*** for more information.

8.2.6 Street Sweeping

Street sweeping removes a portion of the pollutants deposited on roads and parking lot surfaces, thereby reducing pollutant runoff to storm sewers and receiving waters. However, the effectiveness of street sweeping is dependent on the time of year, frequency, length of time between rainfall events, type of sweeping equipment (vacuum, wet, dry, etc.), and the type of road surface. Early spring is typically the most effective time to remove accumulated winter pollutants. To significantly reduce pollutant loadings, street sweeping must be done frequently.

8.2.7 Catchbasin (CB) Cleaning

CBs, with and without sumps, can collect debris and sediment. The cleaning of accumulated sediments in CBs can reduce the amount of pollutants discharged to receiving waters. While CBs with sumps are more effective in trapping the larger runoff particles than those without sumps, fecal bacteria control is not effective with either type.

8.2.8 Animal Waste Removal

Fecal bacteria in animal waste is a significant pollutant source. By prohibiting littering and controlling disposal of animal wastes, the pollutants deposited on the ground surface can be reduced, thereby reducing pollutant contamination of stormwater. Public education is essential to raising awareness.

8.3 Source Control Practices (SCPs)

The City of Calgary has typically managed its stormwater largely through the use of end-of-pipe treatment systems that are largely designed to attenuate high stormwater flow rates and reduce (large) TSS loadings. There is now a shift in how The City manages and controls stormwater and its pollutant contributions to the receiving bodies of water. Though stormwater wet ponds, wetlands, and dry ponds will continue to be important components of the drainage system in Calgary, The City is encouraging industry to include SCPs in their planning and development in an effort to control stormwater before it is introduced into the storm sewer network.

The information in this section is adapted from The City of Calgary's *Stormwater Source Control Practices Handbook* and is intended only as a basic overview. Water Resources is authoring an SCP Manual that contains specific design guidelines, standards, and specifications, but until its release the reader is encouraged to review and utilize the information provided in the design, inspections, and operations and maintenance sections of the *Stormwater Source Control Practices Handbook*.

Many SCPs exist, though some are better implemented in certain climates, regions, soil types, and land uses than others. There are **seven** SCPs that are best suited for Calgary:

i) Better Planning Practices.
ii) Vegetated swales.
iii) Absorbent landscapings.
iv) Bioretention areas.
v) Porous pavement.
vi) Rainwater harvesting.
vii) Green roofs.

Each of these SCPs can be utilized in a variety of development types, though some are better suited for specific development types than others (refer to ***Table 8-1***). Selection of an appropriate SCP for a specific site also depends on the performance criteria required (i.e., volume reduction, pollutant removal, etc.). ***Table 8-2*** shows the performance (or importance) of these criteria with respect to the various SCPs. Contact Water Resources to discuss acceptable analysis and design methodologies prior to design of envisioned SCPs.

Table 8-1: Applicability Matrix[53]

Source Control Types	Development Types					
	Ultra Urban	Infill Redevelopment	Industrial	Commercial and Multi Family	Residential	Parks and Open Space
Better Planning Practices	✓	✓	✓	✓	✓✓	×
Vegetated Swales	×	✓	✓✓	✓✓	✓	✓✓
Absorbent Landscaping	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Bioretention Areas	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Porous Pavement	✓	✓	✓	✓✓	✓✓	✓✓
Rainwater Harvesting	✓	✓✓	✓✓	✓✓	✓✓	×
Green Roofs	✓✓	✓✓	✓	✓✓	✓	×

✓ Somewhat Applicable
✓✓ Highly Applicable
× Not Applicable

Table 8-2: Performance Matrix[54]

		Suitability for Calgary Climate and Soils [1]	Environmental Performance			Maintenance	Community Acceptance	Cost [3]
			Pollutant Removal	Peak Flow Reduction [2]	Volume Reduction			
Types	**Better Planning Practices**	N/A	Medium	Medium	Medium	N/A	High	Low
	Vegetated Swales	High	High	Medium	Medium	Low	Medium	Low
	Absorbent Landscaping	High	High	Medium	High	Low	High	Low
	Bioretention Areas [1]	High	High	Medium	Low	Medium	High	Medium
	Porous Pavement [1]	Medium	Medium	Medium	Low	Medium	Medium	High
	Rainwater Harvesting	N/A	N/A	Medium	High	Low	High	Low
	Green Roofs	N/A	N/A	Medium	High	Low	Medium	Medium

1 Subdrain system may be required.

2 The source control practices listed above are typically designed for smaller storms and the "peak flow reduction" should be considered in that context.

3 In many cases, costs can be offset by savings (e.g. reduced potable water use, smaller end-of-pipe facilities, etc.)

53. Adapted from: The City of Calgary. *Stormwater Source Control Practices Handbook*, 2007 (Table I-2).
54. Adapted from: The City of Calgary. *Stormwater Source Control Practices Handbook*, 2007 (Table I-3).

Water Resources, Development Approvals provides checklists to help developers properly implement SCPs; they are available on the *Development Approvals Submissions* page on The City of Calgary's website. **It is recommended that the reader contact Development Approvals for guidance before using these checklists.**

- *Checklist #5: Water Quality BMP (Oil-Grit Separator)*
- *Checklist #13: Stormwater Source Control Practices - Absorbent Landscapes*
- *Checklist #14: Stormwater Source Control Practices - Bioretention Areas*
- *Checklist #15: Stormwater Source Control Practices - Bioswales*
- *Checklist #16: Stormwater Source Control Practices - Green Roofs*
- *Checklist #17: Stormwater Source Control Practices - Permeable Pavement Systems*
- *Checklist #18: Stormwater Source Control Practices - Rainwater Harvesting and Reuse*

8.3.1 Better Planning Practices (BPPs)

Better Planning Practices (BPPs) are designed to accomplish three goals at development sites:

i) Reduce the amount of impervious cover.

ii) Increase natural lands set aside for conservation.

iii) Use pervious areas for more effective stormwater treatment.

To meet these goals, The City of Calgary encourages designers to scrutinize all aspects of a site plan (streets, parking spaces, setbacks, lot sizes, driveways and sidewalks) to determine if any of these can be reduced in scale. At the same time, creative grading and drainage techniques reduce stormwater runoff and encourage more infiltration and/or evaporation.

Stormwater BPPs are one aspect of sustainable development, which is widely described as land development that is more economically, environmentally, and socially responsible. The intent of the approach is to build and/or rebuild communities that are in balance with the natural environment. Sustainable development aligns with The City of Calgary's triple-bottom-line approach to all municipal operations and decision-making.

A BPP development philosophy based on **sustainability** focuses on:

i) Compact, complete communities that provide:
   - Increased transportation options.
   - Reduced loads on water, waste and energy systems.
   - Protection and restoration of urban green space.
   - A lighter 'hydrologic footprint'.
   - Increased stream and wetland protection.

ii) Integrating stormwater and environmental management elements into a development in addition to incorporating street layout, housing type, and architectural design. These management elements include:

- Hydrology - Water sensitivity is a guiding principle during initial site assessment and planning phases.
- Application of BPPs - Individual BPPs are distributed throughout the project site and influence the configuration of roads, lotting, and other infrastructure.
- Multi-functional approach - The development includes amenities that fulfil multiple functions, such as aesthetic landscaping, visual breaks that increase a sense of privacy within a variety of housing densities, and a design element (of equal importance to architectural design and street plan layout) that promotes neighbourhood identity.

iii) Reducing imperviousness to improve source control efficiency. Traditionally, runoff from green or open space has been dealt with separately from runoff generated by roadways or other impervious surfaces. Since runoff from impervious surfaces is the primary cause of drainage-related concerns (such as stream degradation and flooding risks), limiting impervious coverage and redirecting runoff into pervious areas is an important means of reducing runoff flow rates and runoff volume. A reduction in effective impervious coverage on lots and roads can improve the efficiency of source controls by reducing the amount of runoff the controls are designed to manage.

8.3.2 Vegetated Swales

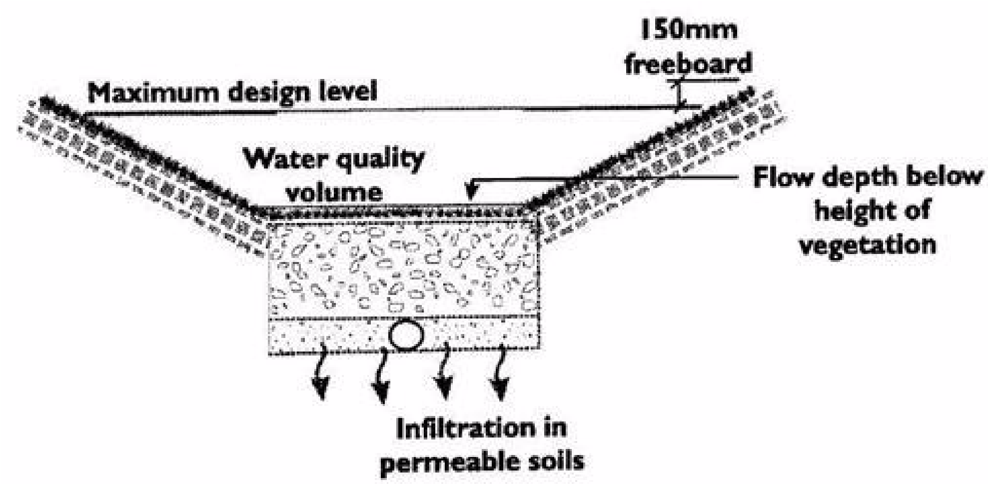
Vegetated swales are open, densely vegetated drainage ways with low-pitched side-slopes that can be used as an alternative to the conventional curb and gutter system and underground storm sewer system along roadways. This SCP is used to treat and attenuate the runoff volume from the water quality design event, as well as to convey excess runoff from more severe events downstream. Vegetated swales incorporate the same design features as bioretention cells; however, they are designed as part of a conveyance system and have relatively gentle side slopes and flow depths that are generally less than 300 mm. Vegetated swales represent a viable SCP for the Calgary region, as they are suitable for areas where subsoil permeability is generally poor.

There are two types of vegetated swales:

i) Dry Swales - Dry swales allow the entire runoff volume generated by a water quality design event to be temporarily stored in a pool or series of pools created by permanent check-dams or ditch-blocks. Their relatively flat design facilitates a slow and shallow flow, thereby allowing sedimentation and filtration to occur while limiting erosion. The runoff volume held back in the pools either infiltrates into the subsoils or evaporates.

ii) Bioswales - Bioswales combine aspects of dry grassed swales and infiltration trenches. The surface component of a bioswale is a shallow grassed channel, accepting flows from small areas of adjacent paved surfaces such as roads and parking. The bioswale is designed to allow the runoff volume from the water quality design event to slowly infiltrate into the porous space of the underlying fine media layer. During and between runoff events, the media layer gradually dewaters into an underlying gravel or drain rock reservoir system. Where needed, a subdrain pipe also maintains drainage of adjacent road base courses. A surface swale provides conveyance for larger storm events to a surface outlet. Culverts are typically provided for roadway and driveway crossings.

Figure 8-2: Typical Bioswale[55]



Bioswales provide flow attenuation as well as treatment of stormwater through settling, fine filtration, extended detention, and some biological uptake. Bioswales are preferred over dry swales as their water quality performance is vastly superior.

Alternatives to gravel/drain rock, such as “milk crate” configurations, are commercially available. The subdrain system can be connected to a flow control consisting of an orifice, or equivalent, in a CB or manhole (MH). Depending on the overall grading of the site, at times a secondary overflow inlet is provided at adjacent CBs.

8.3.3 Absorbent Landscaping

Preserving and/or restoring the moisture storage and infiltration capacities of soils can significantly reduce stormwater runoff. Prior to development, native soils act like a sponge, soaking up, storing, and slowly releasing runoff. In undeveloped areas of the Calgary region, over 90% of precipitation either percolates into the soils or evapotranspires. Landscape soils typically store from 7% (in sandy soil) to 18% (in loamy soil) of their volume as water before becoming saturated to field capacity and generating percolation or runoff.

55. Source: Wilson et al 2004.

Construction activity removes the upper layers of soil from a site and compacts exposed sub-soils low in organic matter. Compacted, unamended soil in landscaped areas functions like an impervious surface, allowing considerable stormwater runoff.

Figure 8-3: Stormwater Variables of Absorbent Landscaping[56]

The ability of soil to effectively store and slowly release water is dependent on soil texture, structure, depth, organic matter content, and biota. Plant roots, macro fauna, and microbes tunnel, excavate, penetrate, and physically and chemically bond soil particles to form stable aggregates that enhance soil structure and porosity. Micro-pores and macro-pores improve water-holding capability and increase infiltration capacity and oxygen levels.

Organic matter is a critical component of a functioning soil system. Mixed into the soil, organic matter absorbs water, physically separates clay and silt particles, and reduces erosion. Vegetation enhances surface infiltration rates, prevents erosion, reduces the amount of rainfall directly impacting the ground surface, and decreases runoff velocity.

56. Source: Lanarc Consultants Ltd. et al 2005.

8.3.4 Bioretention Areas

A bioretention area, also known as an (infiltration) rain garden or porous landscape detention, is an SCP that consists of depressed, landscaped areas underlain by a fine media layer and, depending on the permeability of the subsoils, a granular or equivalent subbase with a subdrain pipe. Bioretention areas facilitate attenuation of runoff flow, as well as treatment of stormwater, through settling, fine filtration, extended detention, and some biological uptake. This SCP is generally incorporated into the landscaping of a site.

Figure 8-4: Bioretention Area

A shallow ponding layer, similar to traplow ponding along roadways, in parking lots, or in green space, exists above the bioretention area for temporary storage of excess runoff from roofs or paved areas. During a storm event, runoff accumulates in the vegetated zone and gradually infiltrates into the underlying fine media layer, filling up the pore space in the media. On subsoils with low infiltration rates, which are prevalent in the Calgary region, bioretention areas often have a gravel/drain rock reservoir and a perforated subdrain system to collect excess water. Between runoff events, the media layer gradually dewaters into the native subsoils, or if a subdrain is provided, into a nearby channel, swale, or storm sewer.

Alternatives to gravel/drain rock, such as “milk crate” configurations, have become commercially available. Depending on the desired hydrologic functionality of this SCP, the subdrain system can be connected to a flow control consisting of an orifice, or equivalent, in a CB or MH. Depending on the overall grading of the site, a secondary overflow inlet is sometimes provided at adjacent CBs. The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable sub-watersheds that help control runoff close to the source. Runoff can enter either as sheet flow or via a curb and gutter collection and conveyance system.

8.3.5 Permeable Pavement

Permeable pavement systems are ideal for small sites where surface detention and stormwater treatment are hampered by space constraints, or where runoff treatment is an important design parameter. These systems can be used in new developments, retrofits and redevelopment areas.

Permeable pavement is suited to low-speed and low-volume traffic areas, such as:

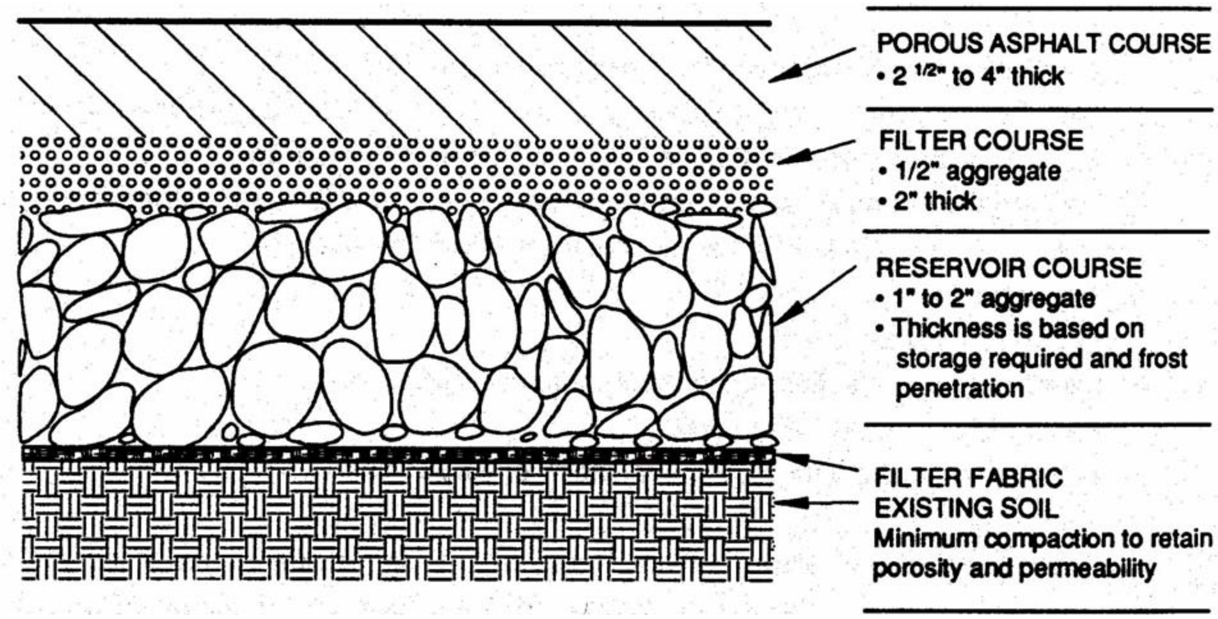
- Driveways.
- Parking lots.
- Residential street parking lanes.
- Roadway shoulders.
- Storage yards.
- Bike and pedestrian paths.
- Walkways.
- Recreational vehicle pads.
- Service roads or fire lanes.
- Low vehicle movement airport zones such as parking aprons and maintenance roads.
- Crossover/emergency stopping/parking lanes on divided highways.

In addition to being used to manage direct precipitation, permeable pavements can provide a drainage path for water discharged from adjacent areas, such as roofs or impermeable parking areas. They are also suitable for rainwater re-use projects.

Permeable (also called pervious or porous) pavement consists of one or more of the following:

- A permeable surface, which allows precipitation and runoff from adjacent areas to percolate into the ground beneath.
- An underlying open-graded reservoir base where rainfall is stored.
- An underlying subgrade through which water is exfiltrated.
- A subdrain that removes infiltrated stormwater.

Figure 8-5: Porous Pavement



8.3.6 Rainwater Harvesting

The capture and re-use of rainwater is a viable SCP that can reduce the volume of stormwater runoff and help diminish the demand on our potable water supply as part of integrated water management planning.

Rainwater harvesting re-use effectively reduces the volume of runoff discharged to receiving water bodies, which in turn results in reduced pollutant loadings, reduced erosion, and an improvement in the overall hydrologic balance of the watershed.

Rainwater harvesting is typically defined as the collection of runoff from a roof area or other impermeable surface before it discharges onto the ground or drains into a storm sewer system. The rainwater collected can be re-used for sub-surface irrigation and (potentially) toilet/urinal flushing.

Any building, residential, commercial, or industrial, can be used for rainwater harvesting purposes, as long as appropriate provisions for the collection, storage, treatment, and distribution of the harvested rainwater can be made. Given the risk of contamination, untreated rainwater cannot be used for any potable purposes. Rainwater re-use practices are governed by the Province. Installed systems must comply with municipal and provincial standards and guidelines, including *Alberta Guidelines for Residential Rainwater Harvesting Systems*, and the *National Plumbing Code of Canada.*

8.3.7 Green Roofs

Green roofs are veneers of living vegetation installed on top of buildings, from small garages to large industrial structures. Green roofs (also called eco-roofs, vegetated roofs, and rooftop gardens) help to manage stormwater through a variety of hydrologic processes that otherwise take place at ground level. Plants on green roofs capture rainwater on their foliage and absorb it in their root zone, encouraging evapo-transpiration and reducing the volume of stormwater entering receiving water bodies. Water that does leave the roof is slowed and kept cooler, which benefits downstream water bodies. Green roofs are especially effective in controlling intense, short-duration storms, and have been shown to reduce cumulative annual runoff by over 50 percent in temperate climates, depending on the composition and thickness of the growing media.

Vegetation used in this application should be appropriate for Calgary's climate.

Figure 8-6: Green Roof

8.4 Site Control BMPs

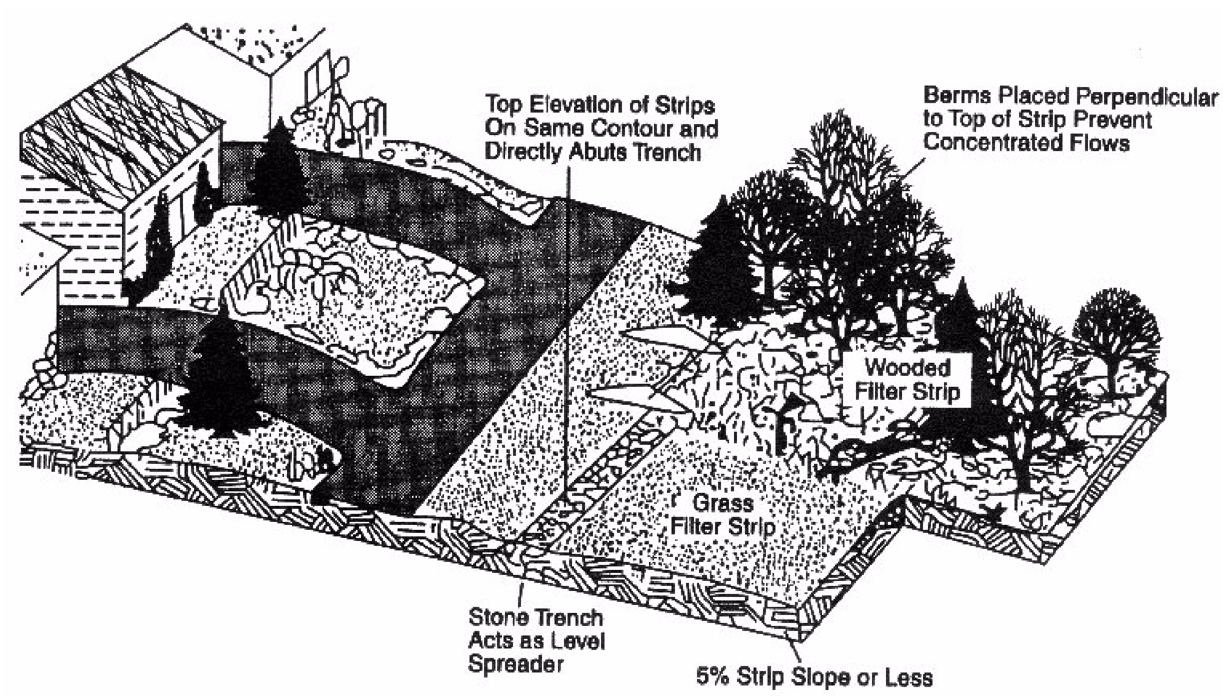
8.4.1 Filter Strips

Filter strips are engineered conveyance systems that are designed to remove pollutants from overland sheet runoff. Generally, filter strips treat small drainage areas (less than 2 ha). A typical filter strip consists of a level spreader (to ensure uniform overland flow) and vegetation. It is the vegetation that filters out the pollutants and promotes infiltration of the stormwater.

There are generally two types of filter strips: grass filter strips, and forested filter strips. Further research is still required to compare the efficiency of these two types of filter strips for water quality enhancement. Filter strips are best utilized adjacent to buffer strips, watercourses or drainage swales since sheet flow from the filter strip is difficult to convey in a traditional conveyance system such as pipes or swales. They may be used along overland escape routes and in parks and other landscaped areas. Filter strips also serve as pre-treatment systems to other BMPs such as bioswales and bioretention areas.

Filter strip performance data is limited, although it is generally thought that properly designed filter strips are capable of removing a high percentage of stormwater pollutants. **However, it is difficult for them to maintain sheet flow through the vegetation.** Stormwater volume might also be reduced slightly through the infiltration provided.

Figure 8-7: Grassed and Wooded Filter Strips[57]



57. Source: Alberta Environment 2006 (page 6-56).

Design considerations include the following:

- Filter strips typically treat small drainage areas (less than 2 ha).
- A level spreader should be used to convey the runoff as sheet flow. Storage behind the spreader is required to regulate the discharge rate and the depth of flow through the filter strip.
- Filter strips should be located in flat areas (flatter than 10%) to promote sheet flow and to maximize filtration. The ideal slope is flatter than 5%.
- Filter strips should be 10.0 to 20.0 m long, in the direction of flow, to provide sufficient water quality enhancement. The slope of the filter strip should dictate the actual length.

8.4.2 Buffer Strips

Buffer strips are natural or landscaped areas between development and receiving waters. They are designed to protect the stream and valley corridor system, and to protect vegetated riparian areas within the valley system to minimize the impact of development on the stream itself (i.e., provide shade and bank stability). Although buffer strips might only provide limited benefits in terms of stormwater management, they are an integral part of the overall environmental management for development. The protection of stream and valley corridors provides significant benefits to wildlife, aquatic habitat, terrestrial habitat, and linkage between natural areas.

There are currently no specific design considerations required for buffer strips, except that no untreated concentrated stormwater flow is allowed to enter buffer strips. Preferably, buffer strips should be preceded by a filter strip to minimize water quality impacts on the buffer strip and stream or wetland. Vegetation should be suited to the adjacent habitat and land uses. Use of Municipal Reserves (MRs) and Environmental Reserves (ERs) as buffer strips is possible, subject to the approval of Parks. Width of buffer strips should be reviewed with Parks and Water Resources.

8.4.3 Oil/Grit Separators (OGSs)

Oil/grit separators (OGSs) are a variation of the traditional settling tanks that are designed to capture sediments and trap hydrocarbons (oils) in stormwater runoff. An OGS is an underground retention structure that takes the place of a conventional MH in the storm sewer system. There are various types of OGSs, including:

- Flow-Through separators.
- Swirl (Hydrodynamic) separators.
- Coalescing (Oil/Water separators).

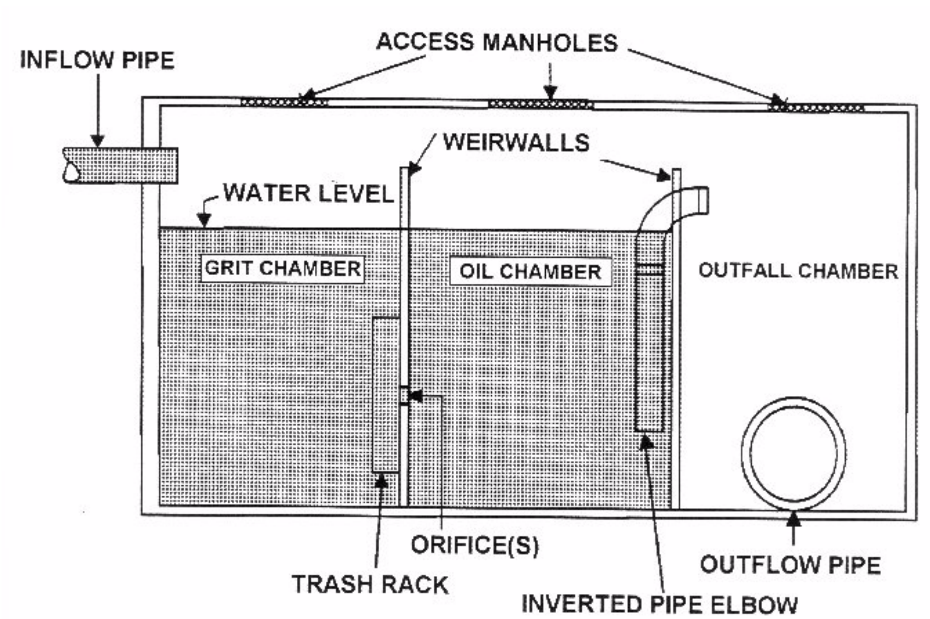
Both flow-through and swirl type OGSs are used in Calgary. Use of one or more chambers helps to remove sediment, screen debris, and separate oil from stormwater. The major benefit of OGSs is improved water quality and effective treatment of stormwater runoff when used at the source or as pre-treatment. Effectiveness of the units can vary.

Water Resources has developed a checklist that must be submitted for each oil/grit or oil/water separator submission. *Checklist #5: Water Quality BMP (Oil-Grit Separator)* is available on the *Development Approvals Submissions* page on The City of Calgary's website. **It is recommended that the reader contact Development Approvals for guidance before using this checklist.**

8.4.3.1 Flow-Through Separators

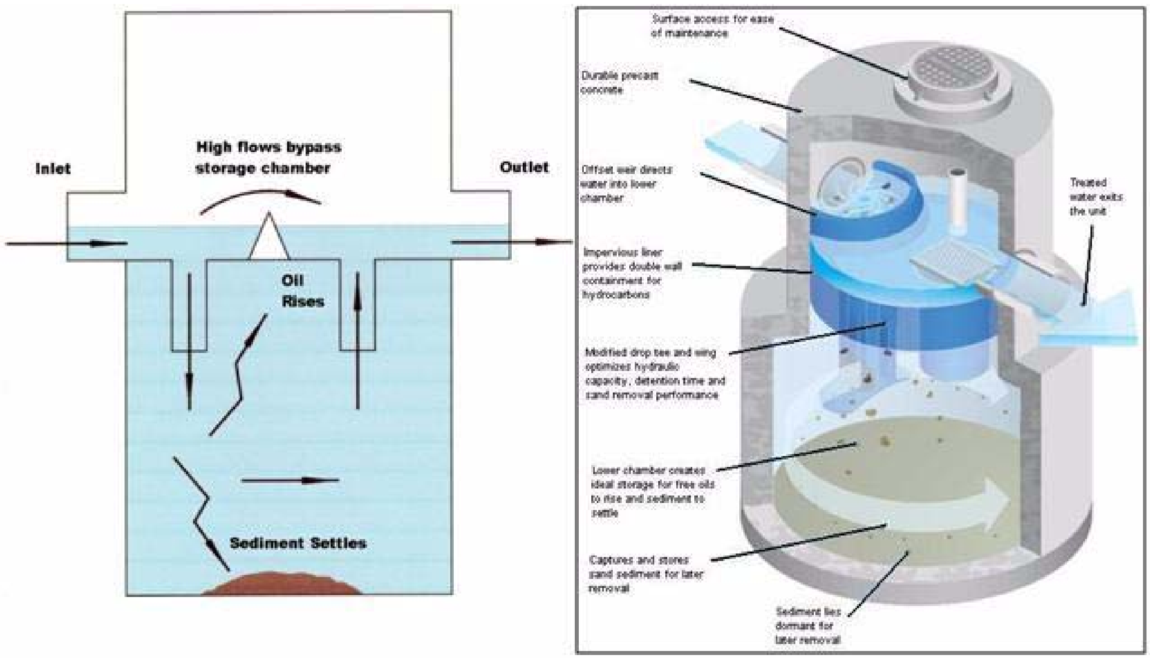
Flow-Through separators are based on conventional settling philosophy, where particles are removed by gravity from a fluid that moves in a straight line from inlet to outlet. Refer to ***Figure 8-8*** and ***Figure 8-9*** for examples.

Figure 8-8: Multi-Chamber Oil/Grit Separator



The multi-chamber OGS is a type of Flow-Through separator that operates most effectively when constructed off-line; only low flows should be directed to the separator.

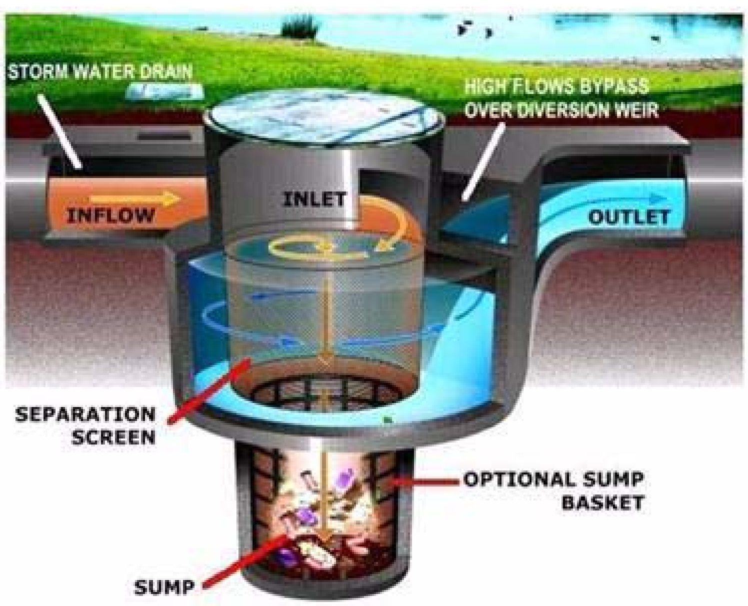
Figure 8-9: Flow-Through Oil/Grit Separator[58]



8.4.3.2 Swirl Separators

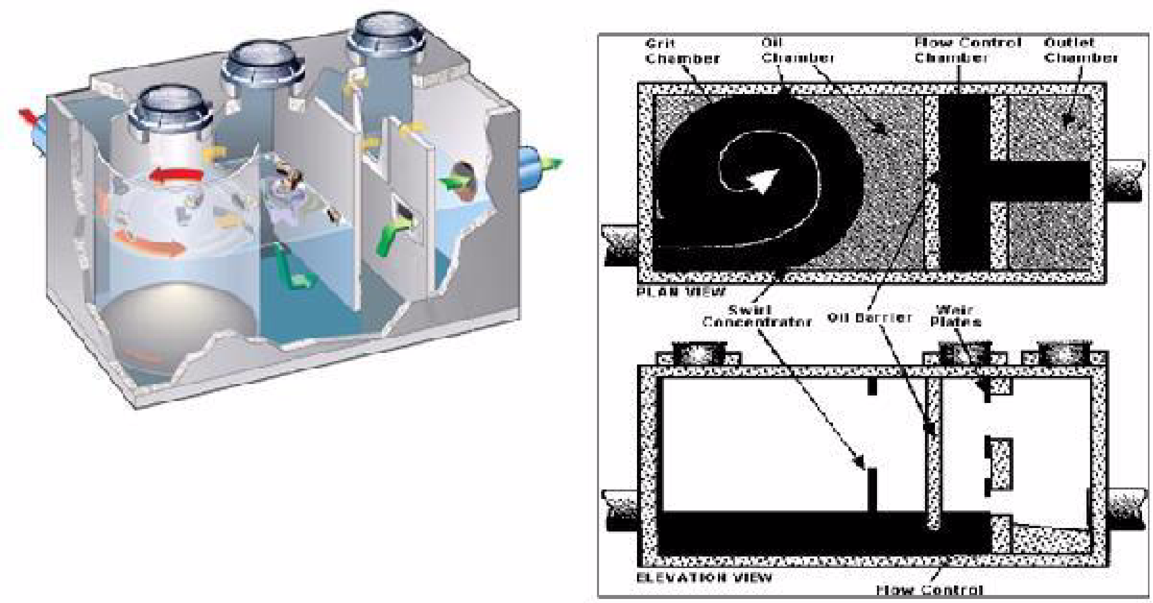
Swirl separators feature a swirling mass of water forming a vacuum in the center, into which anything caught in the motion is drawn inward by the whirl or powerful eddy. This is known as hydrodynamic separation. Refer to ***Figure 8-10*** and ***Figure 8-11*** for examples.

Figure 8-10: Swirl (Hydrodynamic) Oil/Grit Separator[59]



58. Source: Imbrium Systems.
59. Source: Adapted from Jago 2003.

Figure 8-11: Hybrid Swirl and Multi-Chamber Oil/Grit Separator[60]



OGSs vary in design and performance. They tend to be more effective capturing particulates (such as sediment), hydrocarbons, and floating debris from relatively smaller drainage areas; larger areas generally employ a pond for water quantity and quality control. OGSs are best applied in areas where there is potential for hydrocarbon spills and polluted sediment discharges, which generally includes:

- Parking lots (commercial and industrial sites).
- Heavy industrial and manufacturing sites.
- Gas stations (including lube and oil change facilities, vehicle maintenance and mechanical shops including adjacent parking lots, and sites with on-site fuel storage).
- Sites subject to runoff volume targets.
- Larger sites (greater than 2 ha if pre-treatment is required).

Refer to ***4.13 Best Management Practices (BMPs)*** for more information.

OGSs that do not incorporate a flow bypass have generally been found to be ineffective in removing and containing sediments and oils due to continuous re-suspension. Only when internal bypasses are used, or the maximum flow rate into the separator is smaller than the recommended treatment flow rate, can separators be installed on-line. Otherwise, the separator should be installed using an off-line arrangement. **In order for these devices to be effective, proper maintenance, regular inspections, and cleaning must be done.** Regularly scheduled maintenance is required to maintain performance and is a requirement according to *Drainage Bylaw 37M205*. For a list of approved oil/grit and oil/water separators refer to The City of Calgary Water Resources' *Standard Specifications Sewer Construction*.

60. Source: US Department of Transportation 2002.

Key design considerations include:

i) The unit must be readily accessible to personnel and equipment for maintenance.

ii) The hydraulic design of the OGS with respect to backwater conditions meets the manufacturer's specifications (some OGSs are designed to operate under free flow conditions).

iii) Units should treat a minimum of 90% of the total runoff volume over the period of record before a bypass is allowed. A bypass will remove excess high stormwater volumes.

iv) The following minimum information must be submitted:

- The manufacturer must submit a performance table showing average annual removal rates, total runoff volumes, treated volumes and sediment deposition volumes for ALL available years of Calgary Airport Meteorological rainfall data (i.e., 1960-2008). This typically means providing supporting modeling information.
- A minimum annual TSS removal rate of 85% for particle sizes 50 µm and greater is required **for each and every year**. Submit calculations/information showing how removal rates were achieved or modelled.
- The unit must have a minimum of one year of adequate sediment storage capacity without scouring.
- ***Table 7-3*** from this manual must be used for particle size distribution and settling velocity.

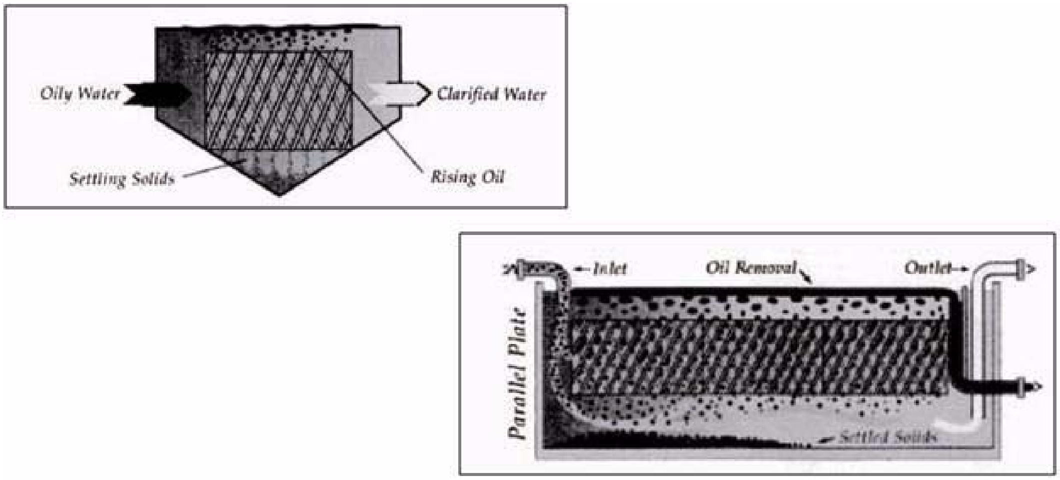
v) To limit the potential for scour, the hydraulic loading rate of oil/grit separators (excluding the bypass) must be restricted to a maximum rate of 27 $L/s/m^2$, or lower if recommended by the manufacturer. The area m^2 is defined as the horizontal cross-sectional area of the settling area of the unit.

vi) The developer/owner is responsible for the cost of maintenance and annual inspections. The unit must be maintained periodically per the manufacturer's specifications and instructions, with a minimum cleaning frequency of six months unless it can be demonstrated otherwise.

8.4.3.3 Coalescing Separators

Coalescing oil/water separators consist of rows of corrugated plates that are angled to incoming flows. This helps to slow down the inflow so that particulates and oil can be separated. For best performance, flows must be relatively small. As a result, the coalescing oil/water separators should be limited to gas stations with small drainage areas. Refer to ***Figure 8-12***.

Figure 8-12: Coalescing Plate Oil/Water Separator[61]

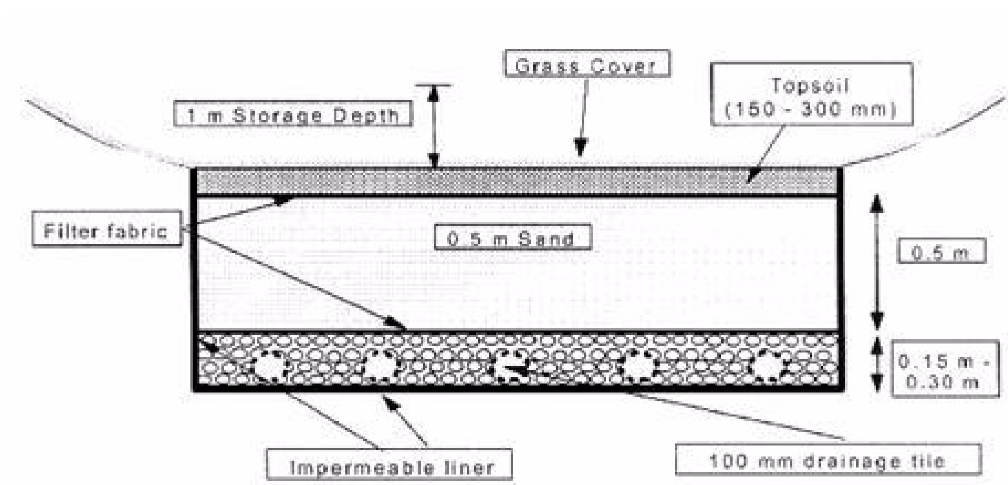


8.4.4 Filters

Filters are treatment BMPs that promote pollutant removal. They can be constructed as either surface or subsurface devices. The filter can be equipped with an impermeable liner to prevent the adjacent native material from clogging pore spaces, and to prevent filtered water from entering the groundwater. The infiltrated water is then collected into a pervious pipe system and conveyed to a downstream outlet. Surface filters are normally covered by a layer of grass.

Sand filters are the most common type of filter, but organic filters are also available. Organic filters can also be designed as surface or subsurface devices. In an organic filter, there is an organic layer of peat added to the sand that enhances the removal of nutrients and trace metals. In addition to the sand and sand-peat filters, over the last decade several cartridge type filter systems have become commercially available.

Figure 8-13: Sand Filter Cross Section



61. Source: PanAmerica Environmental

Figure 8-14: Sand-Peat Filter Cross Section[62]

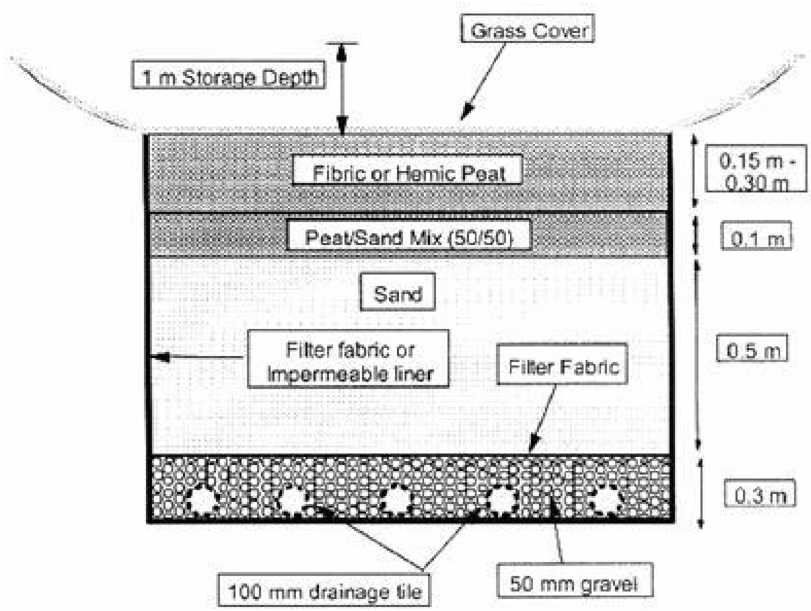
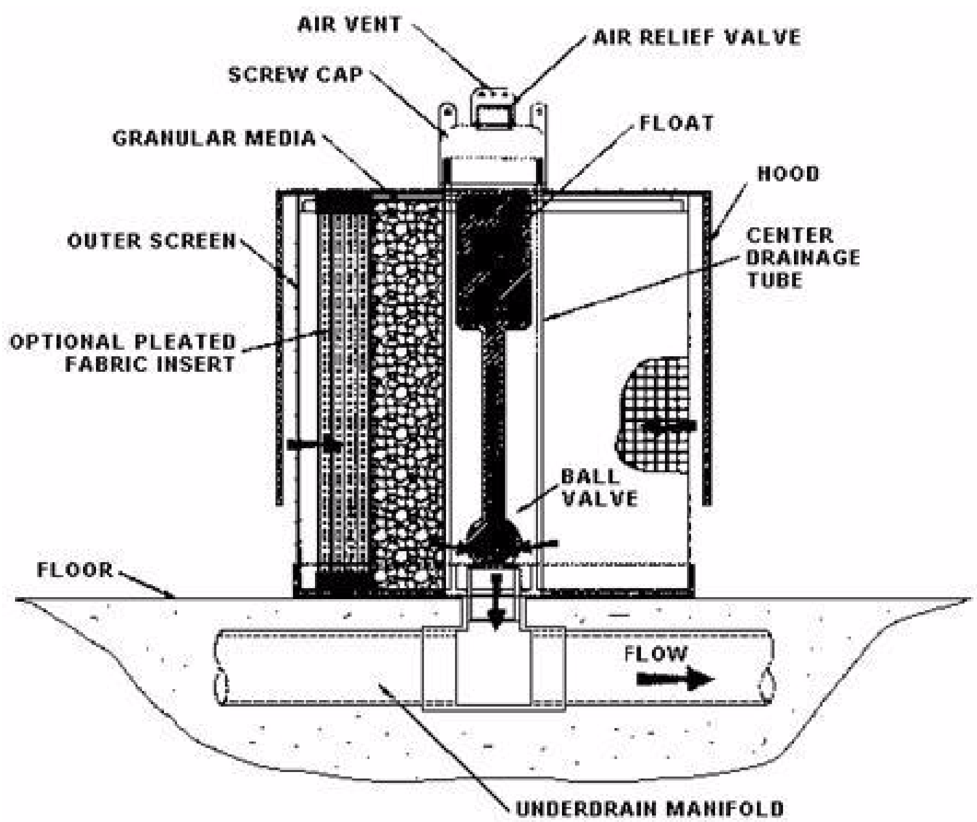


Figure 8-15: Siphon-Actuated Cartridge Filter Cross Section[63]



62. Source: U.S. Department of Transportation 2002.
63. Source: U.S. Department of Transportation 2002.

Filters are a water quality BMP and have no practical application for erosion or quantity control. Although sand filters have been found to be effective in removing pollutants, little is known about their performance in winter conditions.

Filters are generally suitable for drainage areas less than 5 ha. These filtration systems can be used in most parking lot areas and commercial sites. Otherwise, filters can be employed for any land use.

Design considerations include the following:

- Filters should include a pre-treatment system for solids removal to extend longevity of the filter.
- It is recommended that the storage depth above a sand filter be limited to 1.0 m maximum to reduce the potential for compaction of the sand layer.
- The recommended filter layer (media) depth for sand filters is 0.50 m. For organic filters, a depth of 0.15 to 0.30 m is recommended for the peat layer, 0.10 m for the peat/sand layer, and 0.50 m for the sand layer.
- Filter fabric or an impermeable liner should be used at the interface between the filter material and the native soil to prevent clogging the voids in the storage media.

Contact Water Resources prior to the analysis and design of any filter systems.

8.5 End-of-Pipe BMPs

End-of-pipe BMPs typically receive stormwater from conveyance systems such as ditches and sewers, and provide water quality enhancement of the stormwater prior to discharging into a receiving water body. These BMPs are often the "last line of defence" after other SCPs or BMPs have been applied. End-of-Pipe BMPs include wet ponds, dry ponds, and wetlands. Extended detention ponds and hybrid ponds are variations of wet ponds, dry ponds, or wetlands, and are included in these End-of-Pipe BMPs.

8.5.1 Dry Ponds

Dry ponds temporarily store stormwater runoff and can be effectively used for erosion and quantity control. However, dry ponds have no permanent pool of water. Therefore, removal of stormwater contaminants is primarily a function of the drawdown time of the pond. Modelling studies by Perreault et al and Adams (1996) have indicated that substantial improvement in removal efficiency can be achieved if a 48 hour detention time is used. With limited water quality benefits, dry ponds will largely be restricted to water quantity control or as part of an overall treatment sequence approach. For more information, refer to ***6.2 Dry Ponds***.

Design Considerations include the following:

- Dry ponds are suitable for large drainage areas. Use of dry ponds for combined water quantity and quality is discouraged without the use of sediment forebays that include a permanent pool.
- Dry ponds are designed to meet specific water quantity objectives. For design information, refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***.

8.5.2 Wet Ponds

Wet ponds temporarily store stormwater runoff in order to promote pollutant removal and to control discharge at predetermined levels to reduce downstream flooding and erosion. Wet ponds are one of the most common treatment BMPs used, and are very effective in controlling runoff and improving water quality when properly designed. For more information, refer to ***6.3 Wet Ponds***.

Wet ponds have a moderate to high capacity of removing most urban pollutants, and are particularly effective in removing sediments (TSS). The permanent pool in the wet pond is the primary source of water quality enhancement. Runoff entering the pond is slowed by the permanent pool and suspended pollutants are allowed to settle out. Other biological processes, such as nutrient uptake by algae, also help to reduce contaminants. The vegetation established in and around the pond provides shading, aesthetics, safety, and enhanced pollutant removal. The inclusion of a forebay helps facilitate sediment removal, as well.

Design Considerations include the following:

- Wet ponds are suitable for large drainage areas, and for residential, commercial, and industrial land uses. Wet ponds subject to water re-use are more effective in that the volume discharged to downstream systems is smaller (compared to wet ponds that have no re-use capability).

- Wet ponds are designed to meet specific water quantity and water quality objectives. For design information, refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***.

8.5.3 Constructed Wetlands

Constructed wetlands retain runoff for prolonged periods of time and provide water quantity and quality control. Wetlands consist of relatively shallow extended detention areas, with extensive plantings that make up the majority of the wetland's permanent storage. Sedimentation, filtration, and biological and chemical processes account for the water quality improvement. Although many communities across Canada have installed wetlands, limited performance monitoring has been conducted; therefore, the biological impacts and enhancements are still not well understood. The impact of Calgary's climate is also not known. For more information, refer to ***6.4 Wetlands***.

In general, wetlands have been found to lower Biochemical Oxygen Demand (BOD), TSS, and total nitrogen (TN) concentrations. For total phosphorous (TP), metals, and organic compounds, removal efficiencies vary widely and appear to be limited by substrate type, constituent forms, the presence of oxygen, and the chemical makeup of the water to be treated.

Design Considerations include the following:

- Wetlands are suitable for relatively large drainage areas, and for residential, commercial, and industrial uses. However, the influent must not contain high levels of industrial toxic pollutants, as this will adversely affect the wetland vegetation.
- Wetlands are designed to meet specific water quantity and water quality objectives. For design information, refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS***.

8.6 BMP Screening and Selection

To effectively implement a BMP system, it is essential for the designer to determine the most appropriate BMP based on the physical characteristics of the site and the intended usage of the site. A prudent designer will take advantage of a site's topography, and use his/her own experience and judgement, and the requirements of the municipality, to successfully design and implement these controls.

When selecting SCPs to be used at a particular site, refer to ***8.3 Source Control Practices (SCPs)***, in particular ***Table 8-1***.

8.6.1 Physical Site Constraints

8.6.1.1 Soil Suitability

Soil suitability is a major consideration when designing BMPs, particularly when designing infiltration facilities and wet facilities or ponds. A soil investigation is required to determine whether the soil is suitable. Soil surveys, where available, also provide useful soil type information.

Calgary has a high degree of clay and clay-type soils (i.e., silty clays) which affect soil infiltration rates. Typically, soils with less than a permeability of 6.80 mm/hr[64] are not suitable for infiltration BMPs. However, there are different areas in Calgary where the soils might be suitable (i.e., gravel beds near rivers), and infiltration BMPs could be appropriate.

Infiltration and/or percolation into the subsoil is not permitted if the runoff is contaminated with highly mobile constituents as assessed by an environmental specialist with The City of Calgary's Environment & Safety Management business unit. Any infiltration and/or percolation provisions must be designed by a professional Geotechnical Engineer. Any proponent that proposes to utilize deep infiltration and/or percolation to meet runoff volume targets must:

i) Assess the impact on the ground water table.
ii) Demonstrate that the assumed percolation rates are sustainable in the long run on a local and regional level.
iii) Demonstrate that the percolating runoff will have no detrimental impact on the adjacent road base or any downstream structures.
iv) Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

8.6.1.2 Depth to Water Table

The effectiveness of infiltration BMPs is impacted by the depth to the water table. High water tables affect the movement of water from the BMP to the underlying soil. The size and shape of the BMP, along with the hydrological properties of the soil, determine the impact of the water table elevation on infiltration performance. For

64. Source: Northern Virginia Planning District Commission 1992.

screening purposes, soils having high water tables less than 1.20 m below the ground surface are unsuitable for infiltration.

8.6.1.3 Depth to Bedrock

The depth of bedrock is an important consideration for infiltration BMPs. A shallow depth to bedrock can impede exfiltration of water from BMPs into the underlying soil. As well, the depth to bedrock might impact the excavation process for ponds.

8.6.1.4 Topography

The topography or slope of a site will limit the type of BMP that can be utilized on a particular site. Slopes for grassed swales and porous pavement should not be steeper than 5% to be effective. Infiltration trenches should be limited to flatter areas, and should not be used in fill sites due to the risk of slope failure.

8.6.1.5 Drainage Area

The size of the drainage area to be served by a BMP is an important consideration. If the drainage area is too large, the BMP will not be effective. In this situation, other BMPs or a combination of BMPs should be utilized to be more efficient and/or cost effective.

8.6.1.6 Site Usage

Site usage will also have an impact on the BMP selection. A BMP should be located where the expected zone of saturation will not affect building foundations, fill slopes, retaining walls, basements, or potable water supplies.

BMPs could also be affected by land availability being limited, or its purchase or construction being cost prohibitive. Therefore, the amount of land required by the BMP must be carefully considered. As well, recreational uses might have to be incorporated, since BMPs could utilize recreational space.

Finally, BMP locations can potentially impact aquatic and wildlife habitat. Sites with high wildlife habitat values should be avoided, and/or efforts should be made to minimize adverse impacts or disruption of the wildlife corridors. Opportunities to enhance or protect wildlife habitat should be pursued. Habitat values should be carefully considered during site screening, planning, design, preparation, and construction of BMPs.

8.6.2 Initial Screening

There is a wide range of BMPs available. Selection of the appropriate BMP or group of BMPs will be dependent on the stormwater objectives for the area and any physical site constraints. Overall effectiveness should include both water quantity and water quality objectives.

Each stormwater BMP has certain advantages and disadvantages that could reduce the number of options available for a particular area. ***Table 8-3*** summarizes these advantages and disadvantages.

Table 8-3: BMP Advantages and Disadvantages

BMP Advantages and Disadvantages		
BMP	**Advantages**	**Disadvantages**
Better Planning Practices (BPPs)	• Notable reduction in peak flow rates and runoff volume can decrease downstream flooding and erosion. • Higher chance of achieving predevelopment conditions than conventional drainage practices. • Most beneficial for day-to-day type storm events. • Provides significant water quality improvement.	• Success depends on the imagination and creativity of the planners, landscape architects, and engineers.
Vegetated Swales	• Bioswales can provide water quality enhancement. • Less expensive to construct than conventional curb and gutter and storm sewer systems. • Provides some reduction in runoff volume and protects against erosion.	• Could result in breeding area for mosquitoes. • Not suitable to treat runoff from large drainage areas. • Sensitive to any materials that might clog soils or the filter medium.
Absorbent Landscaping	• Efficient in reducing runoff volume. • Capable in removing sediments and pollutants. • Provides aesthetic and environmental values. • Can provide up to 99% erosion reduction.	• The amount of absorbent landscape on a site must be balanced with the amount of impervious area.
Bioretention Areas	• Suited for highly impervious areas. • Habitat, aesthetic, and recreation opportunities provided. • Very effective for removing fine particles, trace metals, nutrients, bacteria, and organics.	• Sensitive to any materials that might clog the filter medium. • Cannot be used to treat the runoff from large drainage areas. • Cannot be used in areas with high groundwater levels. • In general, 1.20 m to 1.80 m of elevation above the invert of storm sewer system is needed to accommodate the flow of stormwater through the bioretention media and subdrain system.
Porous Pavement	• Ability to reduce the peak flow and runoff volume. • Excellent technique for dense urban areas since permeable pavement systems do not require additional land. • Can also be used to effectively remove water from the driving surface and reduce hydroplaning. • High pollutant removal rates.	• Sedimentation can lead to the porous space becoming permanently clogged. • High cost depending on type of system utilized.
Rainwater Harvesting	• Reduce the depletion of water supply. • Rainwater quality exceeds that of ground or surface water.	• Storage might not be sufficient to significantly reduce the runoff volume. • Benefits depend on supply and demand amount and patterns.

BMP Advantages and Disadvantages		
BMP	**Advantages**	**Disadvantages**
Green Roofs	• Can be designed to reduce annual runoff by more than 50%. • Pollutants carried by the rain end up being bound in the substrate instead of being discharged. • Can increase biodiversity in urban areas.	• Additional loading needs to be considered for the roof. • Green roofs are 50% more expensive than conventional roofs. • Limitation on technology and supply. • Currently no technology standards or building code standards are in place.
Filter Strips	• Water quality benefits could be realized if part of an overall stormwater management plan (i.e., as a secondary facility). • Effective in filtering out suspended solids and intercepting precipitation. • Might reduce runoff by reducing overland flow velocities, increasing time of concentration, and increasing infiltration. • Can create wildlife habitat. • No thermal impact.	• Limited to small drainage areas (<2 ha) with little topographic relief. • Uniform sheet flow through vegetation difficult to maintain. • Effectiveness in freeze/thaw conditions questionable.
Filters	• Generally effective in removing pollutants. • Resistant to clogging. • Area easier/less expensive to retrofit compared to infiltration trenches.	• Not suitable for water quantity control • Generally applicable to only small drainage areas (<5 ha). • Do not generally recharge groundwater system. • Might cause aesthetic/odour problems. • O&M costs generally higher than other end-of-pipe facilities.
Oil/Grit Separators	• Effective in removing sediment load when properly applied as a source control for smaller areas. • Effective in trapping oil/grease from runoff.	• Only applicable for smaller drainage areas.
Dry Pond	• Not constrained by land area required by wet ponds. • Can provide recreational benefits.	• Potential re-suspension of contaminants. • More expensive O&M costs than wet ponds (batch mode). • Could be constrained by topography or land designations.
Wet Pond	• Capable of removing soluble as well as solid pollutants. • Provides erosion control. • Habitat, aesthetic, and recreation opportunities provided. • Relatively less frequent maintenance schedule.	• More costly than dry ponds. • Could have negative downstream temperature impacts. • Could be constrained by topography or land designations. • Sediment removal costly when required.
Wetlands	• Pollutant-removal capability similar to wet ponds. • Offers enhanced nutrient-removal capability. • Potential ancillary benefits, including aviary, terrestrial, and aquatic habitat.	• Requires more land area than wet ponds. • Could have negative downstream temperature impacts. • Could be constrained by topography or land designations. • Potential for some nuisance problems.

8.6.3 Final Screening

During the initial screening, the attractiveness of implementing some BMPs is restricted by particular disadvantages and site constraints. The remaining feasible BMPs should then be further screened with the application of specific objectives pertaining to water quality, water quantity (flooding), erosion, and recharge potential. These opportunities are identified in ***Table 8-4***. Long term operating and maintenance also needs to be considered (refer to ***8.8 Operation and Maintenance*** for more information. For more information on the effectiveness of BMPs to remove pollutants, refer to Alberta Environment's *Stormwater Management Guidelines for the Province of Alberta (1999)* and The City of Calgary's *Stormwater Source Control Practices Handbook*.

Table 8-4: BMP Opportunities and Benefits[65]

Stormwater BMP	Water Quality	Water Quantity (Flooding)	Stream Erosion	Groundwater Recharge
Source Control Practices				
Better Planning Practices	◆	●	●	◆
Dry Swales	◆	◆	◆	◆
Bioswales	●	◆	●	◆*
Absorbent Landscaping	◆	◆●	●	●
Bioretention Areas	●	◆	●	◆*
Porous Pavement	●	◆	◆	◆*
Rainwater Harvesting	◆	◆	●	◆
Green Roofs	◆	◆	●	◻
Site Controls				
Filter Strips	●	◻	◆	◆
Buffer Strips	*	◻	◆	◆
Oil/Grit Separators	◆	◻	◻	◻
Sand Filters	●	◻	◻	◆*
Cartridge Filers	●	◻	◻	◻
End-of-Pipe BMPs				
Dry Ponds	◆	●	◆	◆
Wet Ponds	●	●	◆	◻
Constructed Wetlands	●	●	◆	◻

● Highly effective (primary control).
◆ Limited effectiveness (secondary control.
◻ Not effective.
* Could have adverse effects.

65. Sources: MOEE 1994 and The City of Calgary's *Stormwater Source Control Practices Handbook* 2007.

8.7 Cold Climate Impacts

Designing effective stormwater BMPs is not an easy task. Cold climates present additional challenges that make some traditional BMP designs less effective or unusable. Care should be taken when designing BMPs for Calgary's cold climate and chinooks. Some of the challenges to be considered include those listed in ***Table 8-5***:

Table 8-5: Cold Climate Challenges

Climatic Condition	BMP Design Challenges
Cold Temperatures	• Pipe or flow control freezing. • Permanent pool ice-covered. • Reduced biological activity. • Reduced oxygen levels during ice cover. • Reduced settling velocities.
Deep Frost Line	• Frost heaving. • Reduced soil infiltration. • Pipe freezing.
Short Growing Season	• Short time period to establish vegetation. • Different plant species appropriate to cold climates than moderate climates.
Snowfall	• High runoff volumes during snowmelt and rain-on-snow events. • High pollutant loads during spring melt. • Impacts of road salt/de-icers. • Snow management could affect BMP storage.

8.8 Operation and Maintenance

All BMPs require inspection and maintenance to ensure proper operation. However, there can be a significant difference between BMPs in the degree of maintenance they require for efficient performance. Selection of a BMP should consider maintenance requirements in terms of cost, responsibility, feasibility, and access.

The first screening consideration should be the frequency of maintenance required for the BMP. Limited staff resources and lack of maintenance can result in ineffective BMP operation. In general, infiltration type SCPs will require the most maintenance to ensure that the media does not become clogged. Sediment control systems installed upstream of infiltration SCPs will help with their long-term maintenance. Regularly scheduled maintenance will also help alleviate problems.

Maintenance costs are the second screening consideration that should be considered. Currently, the City of Calgary does not have an adequate record of maintenance costs for BMPs, other than those for ponds. However, information from other municipalities can be used as a general guideline. Maintenance costs are borne by land owners for BMPs on private property.

Regular inspection and maintenance must be scheduled for all BMPs. Until maintenance data becomes more widely available, the frequency and scope of the inspections and maintenance will have to be developed by trial and error. Information from other municipalities, where available, can be used as a reference.

CHAPTER 9: EROSION AND SEDIMENT CONTROL

Note: The information provided in this chapter is intended to supplement, not replace, The City of Calgary's *Guidelines for Erosion & Sediment Control*, which is the governing manual for erosion and sediment control. Specific details regarding erosion and sediment control requirements, planning, implementation, inspection, and maintenance can be found in that document.

9.1 Introduction

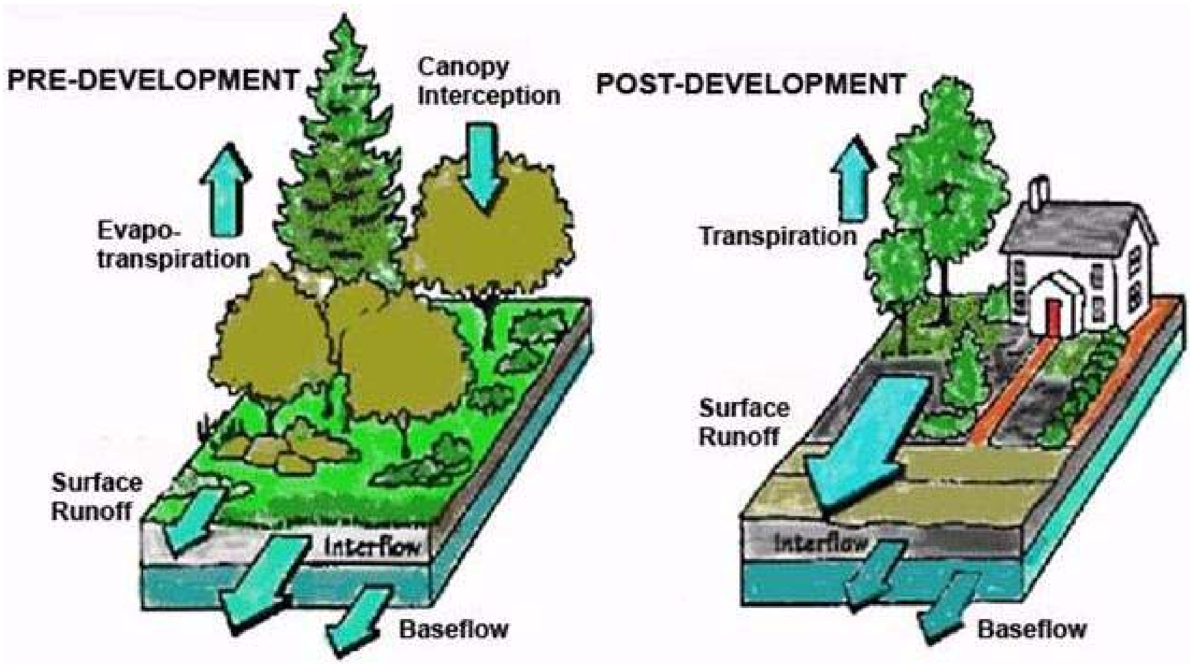
Stormwater runoff is part of the natural hydrological cycle. However, human activities, in particular urbanization, can have a profound impact on the quantity and quality of runoff.

The hydrology of a site changes during construction (refer to ***Figure 9-1***). Trees, meadows, grass and agricultural crops that once intercepted and absorbed rainfall are removed, and natural depressions that temporarily ponded runoff are graded over. Exposed subsoil is compacted by equipment, resulting in increased imperviousness (reduced infiltration of surface water) which leads to a further increase in the quantity and rate of surface runoff. Surface runoff (overland flow) occurs when the rate of rainfall or snowmelt exceeds the infiltration capacity of the soil; infiltration capacity is reduced by frozen, compacted, and saturated soils.

The removal of soil stabilizing vegetation, and the exposure and compaction of highly erodible sub soils, can result in soil erosion rates that are significantly greater than natural rates. The International Erosion Control Association (IECA) indicates that in the absence of practices and controls to manage runoff, erosion, and sedimentation, the production of eroded sediment is typically 200 to 400 times greater on construction sites versus undisturbed conditions.

Sediment transported in stormwater can settle out in infrastructure, damage public and private property, and negatively impact fish and fish habitat, water supply, flood control, navigation, and recreation. In addition, uncontrolled dust from construction activities can be harmful to public health, property, and the environment. Damage to infrastructure, property, and the environment can be extremely expensive and difficult to repair. Regulatory requirements are in place to protect infrastructure, property, health, and the environment.

Figure 9-1: Water Balance at Undeveloped and Developed Sites[66]



9.1.1 Erosion and Sedimentation Processes

9.1.1.1 Erosion

Soil erosion is the removal and loss of soil by the actions of water, ice, gravity, or wind. In construction activities, the force of falling and flowing water can result in the detachment and transport of soil particles.

The force of raindrops falling on bare or sparsely vegetated soils detaches soil particles, which are then picked up and transported in runoff as raindrop and sheet erosion. As the runoff gains velocity and becomes laden with sediment, more soil particles detach, cutting rills and gullies into the soil surface. Sheet, rill, and gully erosion all have the potential to carry significant amounts of sediment off site into storm infrastructure, water bodies and sensitive areas during and immediately after rainfall events. In addition, heavy snowmelt over exposed, partially thawed soils can result in significant erosion during early spring and chinook conditions.

9.1.1.2 Sedimentation

Sediment refers to soil particles that have been detached and mobilized by soil erosion. Sedimentation (or deposition) is the settling out of these soil particles transported by water. When the velocity of the water, in which soil particles are suspended, is slowed for a sufficient period of time, particles will settle out depending on their weight. Heavier particles such as sand and gravel will settle out more rapidly than fine clay and silt size particles. Sedimentation can occur in storm

66. Source: Brown and Schueler 1987.

sewer infrastructure, quiescent waterbodies, or in treatment facilities such as stormwater ponds.

Often, clay particles will not settle out for extended periods of time due to their weight. As a result, settling by gravity is often ineffective and high turbidity can result, which can have detrimental effects on an aquatic environment (refer to ***Table 9-1***). Treating stormwater for turbidity can be an expensive and difficult process, so Source Control Practices (SCPs) and any prevention measures that reduce turbid water are beneficial.

Table 9-1: Impact of Suspended and Deposited Sediments on the Aquatic Environment[67]

Suspended Sediments	Deposited Sediments
• Abrades and damages fish gills, increasing risk of infection and disease. • Scouring of plants attached to rocks. • Loss of sensitive or threatened fish species when turbidity exceeds 25 NTU (nephelometric turbidity units). • Decline in sediment tolerant fish species when monthly turbidity exceeds 100 NTU. • Reduces sight distance for trout, with reduction in feeding efficiency. • Reduces light penetration causing reduction in plankton and aquatic plant growth. • Reduces filtering efficiency of zooplankton in lakes and estuaries. • Adversely impacts aquatic insects which are the base of the food chain. • Slightly increases stream temperature in summer • Suspended sediments are a major source of nutrients and heavy metal pollution in water bodies. • Turbidity increases the probability of boating, swimming and diving accidents. • Increased water treatment costs to meet drinking water standards.	• Physical smothering of benthic (bottom-dwelling) insect community. • Reduced survival rates for fish eggs. • Destruction of fish spawning areas and redds (fish nests). • Sensitive or threatened fish species could be eliminated. • Depletion of dissolved oxygen in water bodies due to decomposition of organic sediment and debris. • Significant contributing factor in the decline of freshwater mussels. • Reduced channel capacity, exacerbating downstream bank erosion and flooding. • Reduced flood transport capacity under bridges and through culverts. • Loss of storage and lower design life for reservoirs, impoundments and ponds. • Increased dredging costs to maintain navigable channels and reservoir capacity. • Spoiling of sand beaches. • Deposits diminish the scenic and recreational value of waterways.

The erosion and sedimentation processes can be characterized by four basic stages: detachment, entrainment, transportation, and deposition. Once sediment is detached from the land surface and entrained by moving water (or wind), the transportation and deposition stages will determine how far the sediment is moved and where it will be deposited.

67. Modified from: Scheuler 1997.

9.1.1.3 Types of Erosion

There are generally four types of erosion that result from water:

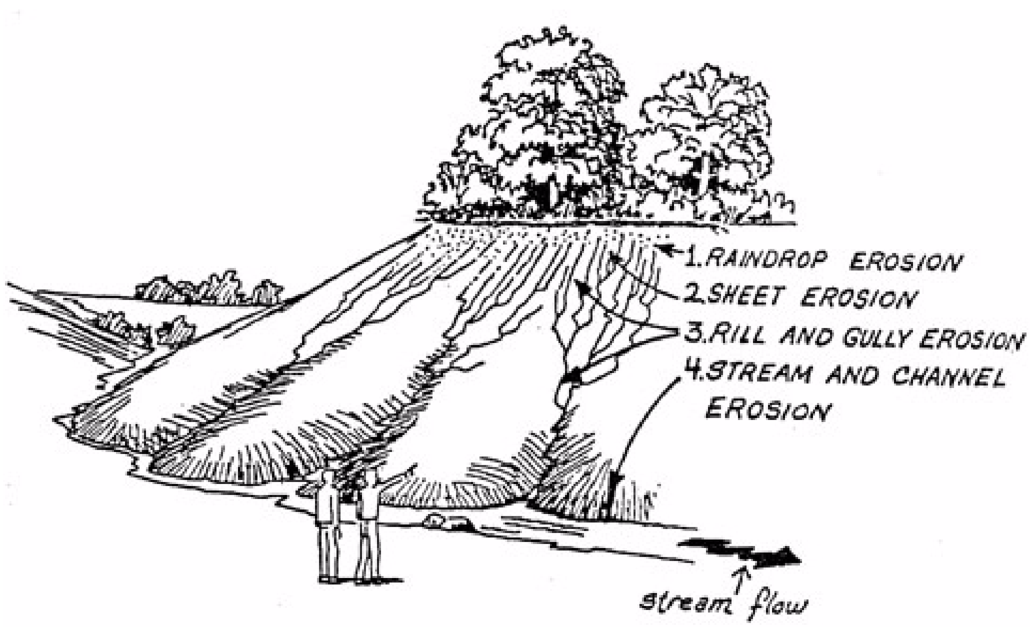
i) **Raindrop Erosion:** The direct impact of falling drops of rain on soil causes the dislodging of soil particles so they can be easily transported by surface runoff. This could be caused by failing to provide temporary cover on exposed soils (such as tackifier/mulch, temporary vegetation, or erosion control blankets).

ii) **Sheet Erosion:** This type of erosion is caused by the removal and entrainment of exposed soil particles by the action of raindrop splash and runoff as water moves in broad sheets over the land.

iii) **Rill and Gully Erosion:** On hill slopes, runoff generally only occurs as sheet flow for a small distance before surface irregularities or turbulence causes runoff to concentrate, cutting grooves (called “rills”) into the soil surface. As the flow of runoff concentrates into channels, the friction between flowing water and the soil surface is reduced, resulting in increased flow velocity, increased erosion, and large quantities of sediment transport. If water flow is sufficient, rills will develop into larger gullies.

iv) **Stream and Channel Erosion:** Increased volume and velocity of runoff in an unprotected, confined channel could cause stream meander instability, scouring, and erosion of stream or channel banks and bottom.

Figure 9-2: Types of Erosion



Soil erosion can also occur from wind, creating a water quality problem if dust is blown into water. The lack of dust control during construction can be a significant problem, since it can affect nearby sensitive habitat and wildlife areas, contribute to the accumulation of sediments and sediment transport in adjacent developed areas, and exacerbate dust and pollutant allergies in humans.

9.1.1.4 Factors Influencing Erosion

The erosion potential of soil is influenced by five general variables. These variables are represented in the Revised Universal Soil Loss Equation (RUSLE), which is commonly used to estimate erosion potential for disturbed land (agricultural, forestry, mining, and urban development). The information contained in this section is intended to be general information only. Some variables in the RUSLE equation require specific site and product/technique data. For more information, refer to The City of Calgary's *Guidelines for Erosion & Sediment Control*.

RUSLEFAC is an adaptation of the RUSLE model "For Application in Canada" (hence the "FAC") with different factors that reflect the different regional climatic conditions and soil textures in Canada; it is used to estimate soil erosion magnitudes in various Canadian agricultural and urban regions. The RUSLE (RUSLEFAC) equation is as follows:

Equation 9-1: RUSLE (RUSLEFAC) Equation

$$A = R * K * LS * C * P$$

where:
- A = Estimated Annual Rate of Erosion (typically expressed as tonnes/hectare)
- R = Rainfall Erosivity Factor
- K = Soil Erodibility Factor
- LS = Slope Length and Steepness Factor
- C = Cover Factor
- P = Management Practices

9.1.1.4.1 Rainfall Erosivity Factor (R)

Erosion potential climbs as rainfall duration and intensity increases. Although there is no way to directly control rainfall duration and intensity, it is possible (and necessary) to manage the effects of rainfall on exposed soils. Erosion potential is also very dependent on the volume and velocity of runoff flowing across exposed soil surfaces. Stopping or slowing the flow of runoff across exposed soil surfaces can significantly reduce erosion.

Rainfall erosivity factor is derived from average annual rainfall, rainfall duration, and intensity and is therefore area-specific (the value provided for RUSLEFAC for Calgary is typically 320).

9.1.1.4.2 Soil Erodibility Factor (K)

Soil erodibility is the ease with which soil is detached by splash during rainfall or by surface flow, or both. It is influenced by soil properties such as particle size, organic content, soil structure, and soil permeability. These factors affect the infiltration capacity of a soil and the resistance of the soil particles to detachment and transportation. Soils containing high proportions of silt and very fine sand are usually the most erodible. Erodibility is decreased as the percentage of clay or organic matter increases. However, once eroded, clays are easily transported.

Organic matter, particle size, and gradation affect the soil structure by the arrangement, orientation, and organization of particles. In general, well-drained and well-graded gravels and gravel mixtures with little or no silt are the least erodible soils.

The K value can be estimated from soil texture (percentage of sand, silt, and clay) and organic matter, and the estimate can be further refined by determining soil permeability and structure in the field. Therefore, representative soil sampling and texture analysis (sieve and hydrometer) is an important consideration. Field examination of soil structure and permeability can further refine estimates of soil erodibility.

9.1.1.4.3 Slope Length and Steepness Factor (LS)

Disturbed area and the topographical characteristics of the land influence erosion potential. Larger project sites have the potential to generate more runoff. As slope steepness increases, there is a marked increase in erosion potential; increased velocity of runoff and the effect of gravity increase the potential for particle detachment, entrainment, and transport. As uninterrupted slope length increases, soil particles can be increasingly entrained and transported long distances by water, and the potential for rill and gully formation increases.

The LS value is a combination of slope length and steepness (both of which have a significant effect on erosion potential).

9.1.1.4.4 Cover Factor (C)

Vegetative cover helps control erosion by shielding the soil surface from rainfall, slowing the velocity of runoff, maintaining the soil's absorption capacity, and holding soil particles in place. Soil erosion can be reduced by limiting the removal of existing vegetation and decreasing exposure time of denuded areas.

Stabilizing soil cover is the easiest and most cost-effective erosion control factor that can be managed on a construction site. Stabilizing exposed soil with temporary cover (including straw and other organic mulches and tackifier) provides very effective temporary erosion control. Timely permanent stabilization of final graded areas with vegetation and other erosion resistant covers is also critical.

Temporary and permanent stabilization of soils with cover practices such as mulch, vegetation, and erosion control blankets can provide significant reduction in erosion potential. Many practices are well researched and have C values assigned to them.

9.1.1.4.5 Management Practices (P)

The timing and duration of construction projects must be considered when assessing erosion risk. Scheduling short construction projects or disturbing high risk areas during drier seasons is a good practice for reducing risk. Other management practices such as diverting clean runoff away from exposed areas, conveying sediment-laden runoff to sediment basins or traps, and installing and maintaining perimeter controls where sediment could leave the site or enter critical areas are also important.

Practices such as fibre wattles/rolls, compost socks, slope terracing, soil roughening, and contour furrowing provide erosion and sediment control benefits. Again, many such practices are well-researched and have P values assigned to them.

9.1.2 Objectives

Given the urbanization occurring within Calgary, a critical objective is to protect storm infrastructure, watercourses, and public and private property from the impacts of erosion and sedimentation. These areas can be protected by limiting the amount and rate of erosion occurring on disturbed sites, and by capturing eroded soil before it leaves construction sites.

Ensuring proper planning, implementation, inspection, and maintenance of erosion and sediment controls is the responsibility of everyone involved in the construction process (i.e., landowners, developers, consultants, project managers, contractors, and homebuilders). **The best strategy for managing sediment and erosion is to direct efforts towards minimizing erosion at the source by controlling runoff and providing temporary stabilization of exposed soils.** Sediment controls (methods implemented to detain runoff and filter or settle-out sediment on-site) used in combination with SCPs are necessary during construction, but must be considered as a last defence that provides additional insurance against off-site impacts.

9.1.3 Responsibilities

Erosion and sediment control is ultimately the responsibility of the property owner, which is typically the developer or landowner. Although the developer/land owner has prime responsibility, **erosion and sediment control is everyone's responsibility!**

Everyone has a role in protecting our watercourses through erosion and sediment control. This includes:

- The City of Calgary.
- Developers/Land Owners.
- Consultants.
- Contractors.
- Road Builders.
- Home Builders.
- Homeowners.

Training and public education are essential to making planning, implementation, inspection, and maintenance of erosion and sediment controls work.

- Ensure that Erosion and Sediment Control (ESC reports and drawings are developed by (or under the supervision of) qualified, experienced professionals specializing in erosion and sediment control/construction stormwater management.
- Allocate the responsibility of timely implementation, inspection, and maintenance of controls and practices to properly trained personnel on-site.
- Maintain records (reports, photos, etc.) detailing the implementation, inspection and maintenance of all temporary and permanent controls and practices.
- For all projects, implement standard Best Management Practices (BMPs) to protect stockpiles, prevent mud-tracking, contain runoff on-site, control dust, etc. (known as Good Housekeeping Practices).
- Plan contingency practices and be prepared to implement them.
- Ensure all employees (including sub-contractors) are properly trained and aware of their responsibilities.
- Immediately report releases/incidents as per legislative requirements.

For more information, refer to The City of Calgary's *Guidelines for Erosion & Sediment Control*.

9.2 Regulatory Requirements

A number of federal, provincial, and municipal acts, legislation, guidelines, and codes of practice contain provisions requiring control of erosion, sediment, and sedimentation resulting from land disturbing activities. Some of these are discussed in more detail in ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES*** and in the The City of Calgary's *Guidelines for Erosion & Sediment Control*. Water Resources has also prepared a document which provides a more through review of regulations and responsibilities relating to erosion and sediment control (*Environmental Regulatory Review and Responsibilities: Calgary Construction Sites*). Failure to comply with legislation can result in substantial fines and/or imprisonment.

It is the responsibility of landowners and developers, as well as project managers, contractors, and erosion and sediment control designers and practitioners working on projects, to ensure that they are in compliance with all applicable statutes and regulations at all times.

Note: Legislation is subject to change. Please be sure to consult the applicable bylaw, regulation, act, or enactment. The City of Calgary is not responsible for the accuracy of the information contained in this section.

9.2.1 Federal Legislation

A number of federal acts have sections pertaining to erosion and sediment control, as shown in ***Table 9-2***.

Table 9-2: Summary of Applicable Federal Legislation (Government of Canada).

Regulatory Authority	Legislation	Relevant Sections	Key Points	Fines
Fisheries & Oceans Canada (Calgary) 403-292-5160 www.dfo-mpo.gc.ca	*Fisheries Act (F-14)*	Section 35(1)	No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.	• Up to $300,000 (first summary offence). • Up to $300,000 and/or 6 months in jail (subsequent offences). • Up to $1,000,000 (first indictable offence). • Up to $1,000,000 and/ or 3 years in jail (subsequent indictable offences). **Note:** Fines apply to Section 35(1).
		Section 35(2)	• The harmful alteration, disruption or destruction of fish habitat may be authorized under conditions authorized by the Federal Fisheries Minister. • No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act.	
		Section 36(3)	Do not deposit deleterious substances in waters frequented by fish. Deleterious substances are those that could potentially have a harmful, toxic, lethal or injurious impact.	N/A
		Sections 38(4), (5), and (6)	• (4) Duty to report deposits of deleterious substance. • (5) Person responsible for substance deposited shall remedy or mitigate any adverse effects. • (6) Inspectors may order to take remedial measures.	• Up to $200,000 (first offence). • Up to $200,000 and/or 6 months imprisonment (subsequent offences).

Regulatory Authority	Legislation	Relevant Sections	Key Points	Fines
Transport Canada 1-888-463-0521 www.tc.gc.ca	Navigable Waters Protection Act (NWPA)	Section 21	No person shall throw or deposit or cause, suffer or permit to be thrown or deposited any sawdust, edging, slabs, bark or like rubbish of any description whatever that is liable to interfere with navigation in any water, any part of which is navigable or that flows into any navigable water.	$5000 per offence.
		Section 22	No person shall throw or deposit or cause, suffer or permit to be thrown or deposited any stone, gravel, earth, cinders, ashes or other material or rubbish that is liable to sink to the bottom in any water, any part of which is navigable or that flows into any navigable water, where there are not at least twenty fathoms of water at all times.	
Environment Canada (Calgary) 403-292-5150 www.ec.gc.ca	Canadian Environmental Assessment Act (CEAA)	Section 14	Environmental Assessment Process may involve a screening, comprehensive study, mediation or panel review.	N/A
	Inclusion List Regulations (SOR/94-637)	Parts V and VII	Activities or Approvals under the Navigable Waters Protection Act (NWPA) or Fisheries Act (F-14) may require an Environmental Assessment.	N/A
	Canadian Environmental Protection Act (CEPA)	Section 64	Defines a toxic substance.	• Up to $300,000 and/or six month in jail (summary offence). • Up to $1,000,000 and/ or three years in jail (indictable offence).
		Section 95	Releases of toxic substances must be reported, prevented and mitigated to prevent any danger to the environment or human life or health.	

9.2.2 Provincial Legislation

A number of provincial acts, regulations, and codes of practice have sections pertaining to erosion and sediment control, as shown in ***Table 9-3***.

Table 9-3: Summary of Applicable Provincial Legislation (Province of Alberta)

Regulatory Authority	Legislation	Relevant Sections	Key Points	Fines
Alberta Environment *403-297-3362 Emergencies/ Complaints: 1-800-222-6514* *http://environment.alberta.ca/* ***Alberta Sustainable Resource Development (Calgary)*** *403-297-8800* *http://www.srd.alberta.ca/Default.aspx*	Soil Conservation Act	Section 3 - Duty of Landowner	Landowners shall take appropriate measures to prevent soil loss or deterioration from taking place or stop soil loss from occurring.	$500 per day up to a maximum of $10,000.
		Section 4 - Direction to Take Remedial Measures	An officer may serve a notice directing the landowner to take remedial measures to prevent or stop the loss or deterioration.	Up to $5000.
		Section 6 - Remedial Measures	Where a landowner does not comply with a notice, an officer may enter the land, carry out the remedial measures and demand payment for the expenses.	
	Public Lands Act	Section 54 - Prohibitions	No person shall cause, permit or suffer the disturbance of any public lands that may result in injury to the shore or bed of a watercourse or soil erosion.	$5000 per day.

Regulatory Authority	Legislation	Relevant Sections	Key Points	Fines
Alberta Environment *403-297-3362* *Emergencies/ Complaints:* *1-800-222-6514* *http://environment.alberta.ca/* ***Alberta Sustainable Resource Development (Calgary)*** *403-297-8800* *http://www.srd.alberta.ca/Default.aspx*	*Environmental Protection and Enhancement Act (EPEA)*	Section 108 & 109 - Releases	Do not release into the environment any substances in an amount, concentration, level or a rate of release that causes or may cause a significant adverse effect.	• Section 108 & 109 (1): Up to $100,000 and/or up to 2 years imprisonment; Corporations: fine of not more than $1,000,000. • Sections 108 & 109 (2), 110, 111, 112: Individuals: up to $50,000; Corporations: up to $500,000
		Section 110 - Duty to Report Releases	Immediately report releases of a substance into the environment where it has caused, is causing or may cause an adverse effect.	
		Section 111 - Manner of Reporting	Persons required to report to the Director pursuant to Section 110 shall report the location and time of releases, circumstances leading up to the release, the type and quantity of substance released, action taken and proposed at the release site and a description of the release location by telephone or in person.	
		Section 112 - Remedial Measures	The person responsible for a release shall ensure the substance is removed and/or remedied, as well as providing repair and restoration of the environment.	
	Release Reporting Regulation (AR117/93)	Section 3 - Substances Regulated by Federal Act	Reportable substances.	• N/A
		Section 4 - Written Report	Written reports are required within seven days of verbal report.	
	Wastewater & Storm Drainage Regulation (AR119/93)	Section 7 - Prohibited Substances and Releases	Do not release substances into the storm or wastewater (sanitary) systems that may impair the integrity or operation of the system.	• Individuals: up to $50,000; Corporations: up to $500,000
	Water Act and Water Act Codes of Practice	Section 36(2) - Approval Required	An Approval may be required for certain activities as defined in the Act.	• Individuals: Up to $100,000 and/or up to 2 years imprisonment; Corporations: fine of not more than $1,000,000.
	Water (Ministerial) Regulation (AR205/98)	Schedules 1 & 3	• *Schedule 1* lists activities exempt from requiring an approval. • *Schedule 3* lists activities exempt from requiring a licence.	• N/A

9.2.3 Municipal Legislation

A number of City of Calgary bylaws have sections pertaining to erosion and sediment control, as shown in ***Table 9-4***. For more information, refer to the *Bylaws* or *Erosion and Sediment Control* pages the on the City of Calgary's website or call 3-1-1.

Table 9-4: Summary of Applicable Municipal Legislation (The City of Calgary)

Legislation	Relevant Sections	Key Points	Fines
Sewer Service Bylaw 24M96	Section 6(1) - Storm Drainage	Do not allow any storm drainage to be placed in the wastewater collection system, except as authorized by a permit.	• $350 • Summary Conviction: up to $10,000 or not more than 1 year in jail.
	Section 8(1) - Prohibited Material	No person shall release or discharge, or permit the release or the discharge of any waste described in Schedule "A" into the wastewater collection system.	• $600 • Summary Conviction: up to $10,000 or not more than 1 year in jail.
Street Bylaw 20M88	Section 17 - Unauthorized Material on the Street	Do not store any material on any portion of a street. Material stored on private property must be stored so as not to enter the street.	• $500 (first offence) • Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.
	Section 18 & 18.1 - Material Entering Street	Material entering the street by natural forces from a person or a landowner.	• $250 (first offence) • Summary Conviction: up to $10,000 or not more than 90 days in jail.
	Section 19 - Tracking Mud onto Street	Mud and other construction debris may not be tracked by vehicles onto the street.	
	Section 20(1) - No Permit	Use of Street without permit.	• $300 (first offence) • Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.
	Section 20(2) - Permit Conditions	Failure to comply with permit conditions.	• $500 (first offence) • Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.
	Section 37 - Excavation	Excavation of street surface.	• Mandatory court appearance • Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.
Community Standards Bylaw 5M2004	Section 42 - Nuisances Escaping Property, Smoke and Dust	No owner or occupier of premises shall engage in an activity likely to allow smoke, dust or other airborne matter likely to disturb another Person, to escape the Premises without taking precautions to ensure that the smoke, dust or other airborne matter does not escape the premises.	• $300 • Summary Conviction: up to $10,000 or not more than 6 months in jail.
	Section 51(1) - Hazardous Excavation, Drain, Ditch or Depression	No owner shall allow a excavation, drain, ditch or other depression in the ground to become or remain a danger to public safety. This includes ponded water.	

Legislation	Relevant Sections	Key Points	Fines
Drainage Bylaw 37M2005	Section 4(1) - Discharges to Storm Drainage System, Prohibition	No person shall release or allow to be released any prohibited material into the Storm Drainage System unless permitted by the bylaw.	• $3000 • Summary Conviction: up to $10,000 and/or not more than 1 year in jail.
	Section 4(2)- Release Impounded Water	No person shall release impounded water either passively or actively into the storm drainage system.	• $1500 • Summary Conviction: up to $10,000 and/or not more than 1 year in jail.
	Section 4(3) - Discharges to Storm Drainage System, Permitted	Water may be discharged in accordance with a permit or written approval from the Director, Water Resources. A failure to obtain a permit is an offence.	• $1500 • Summary Conviction: up to $10,000 and/or not more than 1 year in jail.
	Section 5(4) - Unauthorized Discharges	Any person who releases, or causes or allows any prohibited materials to be released into the Storm Drainage System, shall immediately take all reasonable measures to notify the appropriate authorities and mitigate the discharge.	• $500 (failure to notify). • $3000 (failure to mitigate discharge). • Summary Conviction: up to $10,000 and/or not more than 1 year in jail.
	Section 7 - Directing Storm Drainage	Except in an emergency, no person shall direct impounded water from a parcel to the Storm Drainage System without the consent of the Director, Water Resources. A Drainage or Dewatering Permit is required from The City.	• $1500. • Summary Conviction: up to $10,000 and/or not more than 1 year in jail.
	Section 11 - Restricting access or flow or altering the storm drainage system	No person shall restrict access or flow to or within the storm drainage system or alter, remove or change the storm drainage system without prior approval.	• $1500 • Summary Conviction: up to $10,000 and/or not more than 1 year in jail
	Section 15 - Authority of Director	The Director, Water Resources has the authority to require testing, monitoring, reporting and water treatment of water released to the Storm Drainage System.	• N/A

9.3 Planning and Design Approach

Development of effective ESC report and drawings is important in protecting storm infrastructure, watercourses, and public and private property from impacts of erosion and/or sedimentation. An ESC drawing should be prepared for all construction projects and submitted to the City of Calgary's Development & Building Approvals business unit, Urban Development division, in order to obtain an approval for stripping and grading or construction. The ESC drawings and reports (as required) are circulated to Water Resources for review and approval. Refer to ***9.8 Technical Requirements for ESC Reports and Drawings*** for more information. Site and drainage planning should occur concurrently with site grading and erosion control planning. The process that should be followed for developing an effective ESC plan is illustrated in ***Figure 9-3***.

A number of measures can be implemented to mitigate the effects of urban development through careful planning and design. Consideration should be given to the following:

i) Limiting development and construction to the least critical areas. Therefore, shorelines, floodplains, natural drainage ways, steep slopes, and erodible soils should be avoided where possible.

ii) Efforts should be made to preserve and utilize natural drainage systems. Impervious surfaces should be minimized to enhance infiltration.

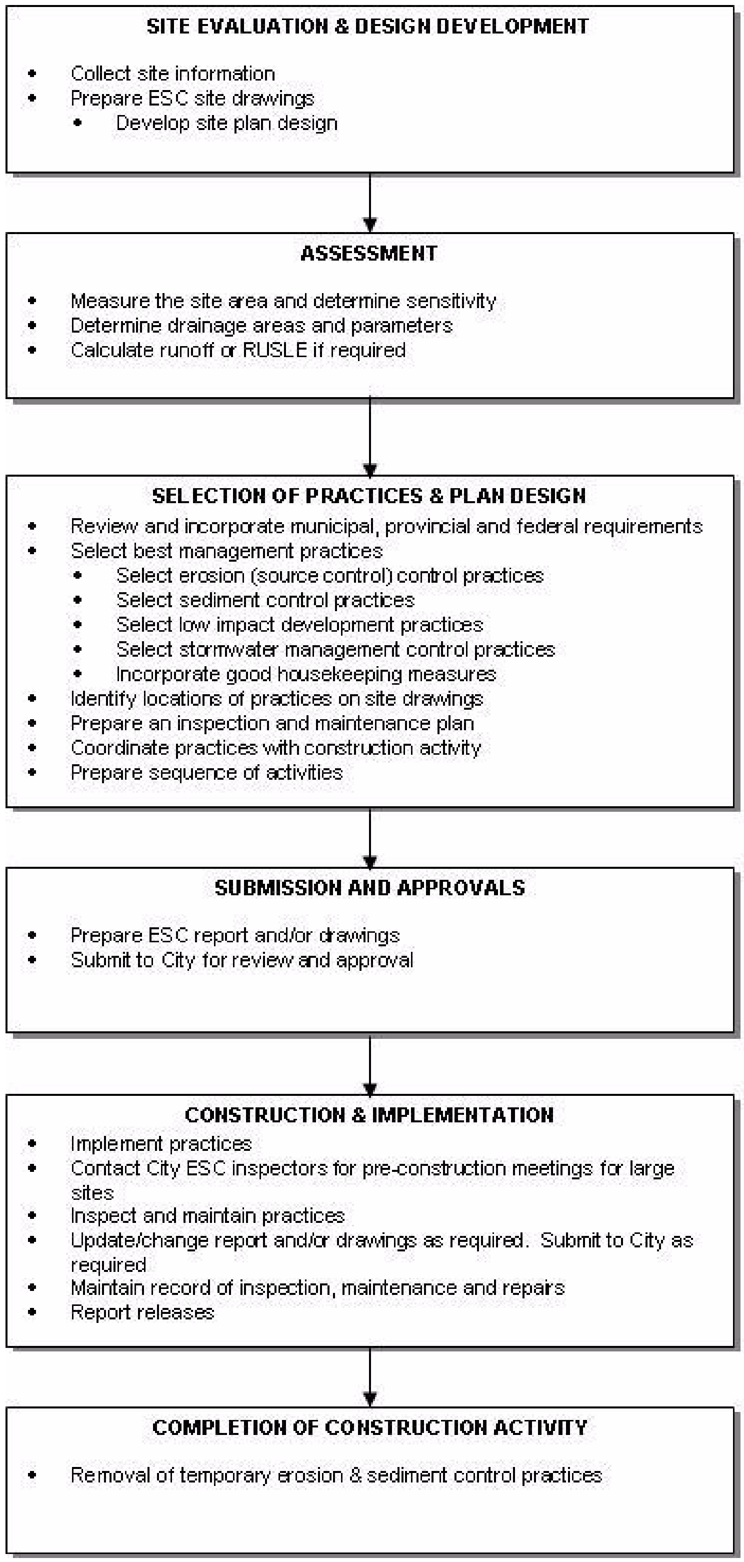
iii) Alternative methods of runoff and stormwater management should be considered to enhance infiltration. This will benefit the receiving streams by alleviating the need for additional stream alterations due to additional flows.

The following general design principles should be considered:

- Prevent pollutant release. SCPs should be selected as the first line of defense.
- Erosion and sediment control (ESC) Practices, or other BMPs, should be selected based on the site characteristics and the construction plan.
- Site drainage and soil conditions should be assessed to determine the most significant factors for the site and planned construction.
- Runoff should be diverted away from exposed areas when possible.
- Existing vegetation should be preserved.
- The extent of clearing should be limited and phased construction operations should be considered.
- Natural drainage features should be incorporated when possible. Adequate buffers should be used to protect areas where flow enters the drainage system. Keep clean water clean.
- Minimize slope length and steepness.
- Runoff velocities should be reduced to prevent channel erosion.
- Prevent tracking of sediment off-site.
- Select the appropriate practices for control of pollutants other than sediment. Examples include, but are not limited to: controlling concrete waste disposal,

ensuring safe and secondary containment of hazardous chemicals, and immediate reporting and clean-up of any spills of materials that are having, or could have, an adverse effect on the environment.

Figure 9-3: Erosion and Sediment Control Planning Process



9.3.1 Elements of Effective Planning

There are ten standard elements that must be considered when planning erosion and sediment control for construction projects:

i) Minimize needless clearing and grading:

Development should be planned to fit the site with minimal impact to the environment

ii) Protect waterways and stabilize drainage ways:

Many storm sewers discharge directly into waterways and can be a source of urban pollutants. In addition, stream channels, lake shores, river/lake beds, and riparian areas can be very sensitive to disturbance and could take a long time to recover.

iii) Phase construction to limit soil exposure:

Phased construction is typically more cost-effective than the expense of proper control of erosion and sedimentation over large areas.

iv) Stabilize exposed soils immediately:

Soils that are not being actively worked must be stabilized with suitable temporary cover prior to final stabilization. Where such temporary stabilization is not possible, it is necessary to ensure that sufficient sediment control measures (such as sediment ponds) are in place and functional.

v) Protect steep slopes and cuts:

Increasing slope steepness dramatically increases erosion potential and downstream sediment yield. Rilling and gullying can occur on erodible soils, or on slopes exposed to sufficient flow, which results in expensive and costly repairs for slopes and downstream areas. Where steep slopes do need to be disturbed, schedule work for a drier time of year, and minimize exposure time.

vi) Install perimeter controls to filter/settle sediment:

Perimeter controls must be considered a last line of defense that complements timely on-site soil stabilization

vii) Employ advanced sediment settling controls:

Properly designed sediment traps and ponds consider contributing area, runoff volumes, and soil type/texture.

viii) Train site personnel:

Ensure that contractors are trained and understand the site ESC report and drawings and Good Housekeeping Practices, and are familiar with the implementation, inspection, and maintenance of the required erosion and sediment control measures

ix) Continually inspect and maintain controls and practices:

Frequent inspection, maintenance, and modification of erosion and sediment controls is necessary to ensure their effectiveness throughout different stages of construction. The ESC report and drawings should be updated during construction.

x) Assess erosion and sediment control effectiveness during and after storms:

Rainfall events of greater than 12 mm over 24 hours can result in significant erosion and transport of sediment. Smaller precipitation events on saturated soils, as well as snowmelt over thawed soils, are also a significant source of erosion. Additional inspections must be conducted during or following such events or conditions, with any required maintenance completed and documented.

9.3.2 Planning for Success

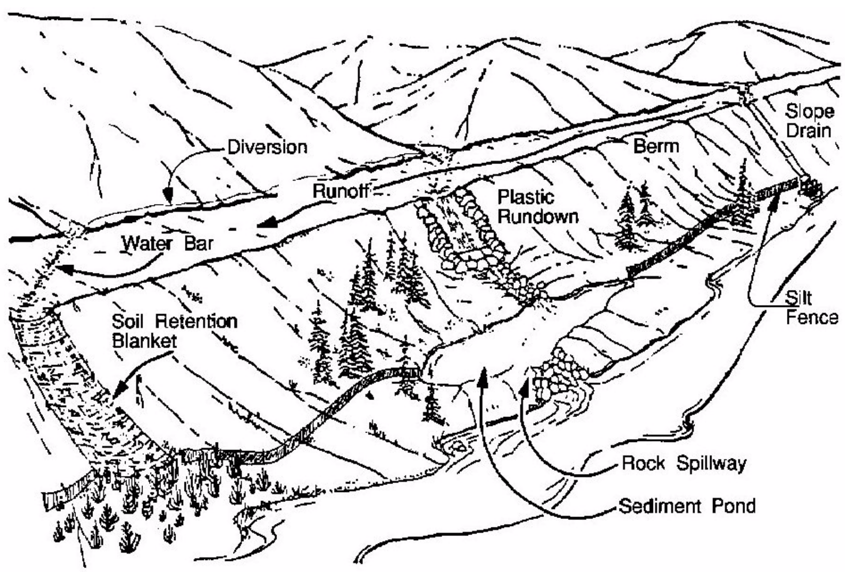
Construction site stormwater management and control of erosion and sedimentation is often poorly planned and/or implemented. Good communication between all stakeholders, good planning and implementation, and timely inspection and maintenance of effective practices is critical. To meet the goal of improved planning and implementation, the following objectives should be considered:

- Ensure that all stakeholders have a good understanding of erosion and sedimentation processes.
- Consider the importance of soil texture, site topography, and seasonal variations in climate as they affect stormwater run-off and erosion rates.
- Avoid using a ‘one size fits all’ approach to ESC report and drawings preparation. Except for the planning and implementation of simple housekeeping practices, planning is very site-specific.
- Always hold pre-construction meetings and invite the appropriate stakeholders, including regulatory agencies.
- Recognize that the ESC report and drawings prepared at the project planning stage only provide an initial appraisal of the site conditions, and prescribe practices which are based on that appraisal. Site conditions change, and practices need to be easily modified and updated as the project proceeds. This requires ongoing involvement and assistance from regulatory agencies, including City staff.
- Always plan and implement practices to control erosion at the source (this requires control of run-on and run-off, as well as provision of timely and effective soil cover/stabilization). Ensure that the sole focus is not on attempting to remove fine sediment from run-off using sediment controls (detention, settling, filtration); these practices are only effective as a secondary line of defence.
- Always identify and recognize the high value of environmental resources, infrastructure, and property within, and adjacent to, construction sites. Protect accordingly.
- Clearly understand the purposes and limitations of specific ESC Practices.
- Ensure that specifications and requirements for erosion and sediment control are clearly written into pre-tender documents and contracts. Ensure that the ESC reports and drawings will be easily understood by contractors.
- Ensure that a program of timely inspection and maintenance of ESC practices is in place. Almost all practices, especially temporary practices implemented during construction, require frequent inspection and maintenance.

9.4 Erosion and Sediment Control (ESC) Practices

An extensive array of erosion and sediment control BMPs (ESC Practices) are available. Therefore, the selection of specific controls is important to the overall cost, effectiveness, and success of implementation, inspection, and maintenance. Proper selection should consider the overall site evaluation, season, construction requirements, design requirements, and cost. An example of a typical application of ESC Practices is illustrated in ***Figure 9-4***. Where possible, erosion control and SCPs should be implemented first, since this minimizes soil detachment. Due to the fine/clay soil texture in Calgary, sediment control practices might not be as effective here as in other areas.

Figure 9-4: Example of Erosion and Sediment Control Features



The degree of control must also be assessed. When a site has low erosion potential and the impact on downstream water uses is also low, Good Housekeeping Practices might be sufficient for erosion and sediment control. When the impact and potential for erosion is greater, then further specific control practices will be required (refer to ***Table 9-5***). Frequent inspection of all practices is required to determine whether the degree of control used is sufficient.

Table 9-5: Degree of Erosion and Sediment Control

Site Erosion Potential	Impact on Downstream Water Uses	Degree of Erosion and Sediment Control Required
Low	Negligible	Good Housekeeping Practices only
	Yes	Consider sedimentation traps/basin(s)
Moderate	Negligible	ESC Practices
	Yes	Erosion controls and sedimentation traps/basin(s)
High	Negligible	ESC Practices
	Yes	All flows to on-site sedimentation traps/basin(s)

The City of Calgary requires that ESC practices used to manage erosion, sediment, and stormwater are planned and implemented on **all** construction sites. Many of these practices provide more than one function (i.e., check dams are primarily used to modify channel gradients and control erosion, but they could also provide some sediment control). A summary of the suitability of a variety of common ESC Practices for various stages of construction is presented in ***Table 9-6***. Detailed descriptions of these BMPs can be found in The City of Calgary's *Guidelines for Erosion & Sediment Control*.

Table 9-6: Suitability of ESC Practices for Various Construction Stages

BMP		Activity											
		Cleaning &Grubbing	Stripping & Grading	Borrow Areas	Excavation & Underground	Stockpiles	Cut & Fill Slopes	Channels & Site Drainage	Temporary Haul Roads	Stormwater Inlet/Outlet	Perimeter Controls	Small Sites: Commercial, Industrial, Multi-Family	Small Sites: Residential
Stripping, Grading, Site Preparation and Housekeeping													
1.	Construction Scheduling and Phasing	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔
2.	Preserve Existing Vegetation	✔	✔				✔	✔	✔		✔	✔	✔
3.	Surface Grading, Roughening & Texturing		✔			✔	✔	✔				✔	
4.	Topsoil Salvage & Placement	✔	✔	✔	✔	✔	✔	✔	✔			✔	✔
5.	Stabilized Construction Exits		✔						✔			✔	✔
Runoff Control													
6.	Temporary Berms and Diversion Channels	✔	✔				✔	✔	✔		✔	✔	
7.	Grass-Lined Channels		✔					✔			✔		
8.	Riprap-Lined Channels		✔					✔			✔		
9.	Temporary Slope Drains		✔				✔	✔	✔	✔			
10.	Energy Dissipaters		✔					✔		✔	✔	✔	✔
11.	Check Dams		✔					✔					
Erosion Control													
12.	Seeding and Sod			✔		✔	✔	✔			✔	✔	✔
13.	Mulching	✔	✔	✔		✔	✔	✔				✔	✔
14.	Hydromulching & Hydroseeding			✔			✔	✔				✔	✔
15.	Rolled Erosion Control Products			✔			✔	✔		✔		✔	✔

BMP		Activity											
		Cleaning &Grubbing	Stripping & Grading	Borrow Areas	Excavation & Underground	Stockpiles	Cut & Fill Slopes	Channels & Site Drainage	Temporary Haul Roads	Stormwater Inlet/Outlet	Perimeter Controls	Small Sites: Commercial, Industrial, Multi-Family	Small Sites: Residential
Erosion Control													
16.	Compost Blankets						✔	✔			✔	✔	✔
17.	Straw/Fibre Wattles		✔	✔		✔	✔	✔		✔	✔	✔	✔
18.	Aggregate Cover		✔	✔			✔	✔	✔	✔		✔	✔
19.	Riprap						✔	✔		✔			
20.	Cellular Confinement Systems						✔	✔		✔			
21.	Live Staking, Wattles & Brush Layering						✔	✔		✔			
Sediment Control													
22.	Dust Control	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
23.	Construction Drainage & Dewatering		✔		✔			✔				✔	✔
24.	Sediment Traps & Basins	✔	✔	✔	✔			✔	✔		✔	✔	✔
25.	Compost Berms & Socks		✔	✔		✔	✔	✔		✔	✔	✔	✔
26.	Silt Fence	✔	✔	✔		✔	✔	✔		✔	✔	✔	✔
27.	Storm Drain Inlet Protection	✔	✔		✔			✔		✔	✔	✔	✔
28.	Flocculants & Coagulants		✔	✔	✔	✔	✔	✔	✔			✔	

9.4.1 ESC Practices for Different Site Dimensions

9.4.1.1 Small Sites

Uncontrolled construction activity on relatively small sites can result in large quantities of sediment and other stormwater pollutants moving off-site and into storm sewers and water bodies. Sites with an overall area less than 0.40 ha are considered to be small construction sites. These sites include single family residential and duplex developments, as well as commercial, industrial and multi-family sites.

Even though The City might not require submission of ESC reports and/or drawings for small sites, ESC Practices must still be employed during construction to minimize erosion and sediment concerns, and to meet regulatory requirements.

However, if the small site possesses a risk (i.e., adjacent to a water body or sensitive area, highly erodible soil, etc.), an ESC report and/or drawing might be required. There are five general categories of practices for controlling erosion and sediment on small sites:

i) Good Housekeeping Practices.

ii) Stripping, Grading, Site Preparation.

iii) Runoff Controls.

iv) Erosion Controls.

v) Sediment Controls.

For more information on these practices, refer to ***9.4.2 Good Housekeeping Practices***, ***9.4.3 Stripping, Grading and Site Preparation Controls***, ***9.4.4 Runoff Controls***, ***9.4.5 Erosion Controls***, and ***9.4.6 Sediment Controls***, as well as The City of Calgary's *Guidelines for Erosion and Sediment Control*.

9.4.1.2 Medium Sites

All sites with an overall area between 0.40 to 2 ha are considered to be medium sites. The City exercises some discretion in requiring ESC reports and/or drawings for sites in this size category. Risk factors such as erodible soils, slopes that could erode to off-site areas or storm infrastructure, and adjacent water bodies are considered in determining submission requirements. In most cases, a drawing or set of drawings will suffice.

As with smaller sites, the five general categories of practices for controlling erosion and sediment should be used on medium sites. For more information on these practices, refer to ***9.4.2 Good Housekeeping Practices***, ***9.4.3 Stripping, Grading and Site Preparation Controls***, ***9.4.4 Runoff Controls***, ***9.4.5 Erosion Controls***, and ***9.4.6 Sediment Controls***, as well as The City of Calgary's *Guidelines for Erosion and Sediment Control*.

9.4.1.3 Large Sites

All sites with an overall area greater than, or equal to, 2 ha are considered to be large construction sites. The City of Calgary requires a submission of an ESC report and/or drawings for approval for large sites. For more information, refer to ***9.3 Planning and Design Approach*** and ***9.8 Technical Requirements for ESC Reports and Drawings***.

As with smaller sites, the five general categories of practices for controlling erosion and sediment should be used on large sites. For more information on these practices, refer to ***9.4.2 Good Housekeeping Practices***, ***9.4.3 Stripping, Grading and Site Preparation Controls***, ***9.4.4 Runoff Controls***, ***9.4.5 Erosion Controls***, and ***9.4.6 Sediment Controls***, as well as The City of Calgary's *Guidelines for Erosion and Sediment Control*.

9.4.2 Good Housekeeping Practices

There are many common erosion and sediment concerns that arise due to construction activities. These include, but are not limited to the following:

- Mud tracking from construction sites onto adjacent properties and streets.
- Silt and debris washed into the existing storm sewer (or drainage) system.
- Silt and debris transported to receiving watercourses by surface runoff and the sewer system.
- Wind-blown dust during dry weather and extensive stripping and grading work.

Good Housekeeping Practices will help minimize some of the erosion and sediment concerns. While some could be impractical under certain conditions, others should be considered based on suitability, practicality and cost effectiveness.

i) Dust control practices should be implemented to prevent wind transport of dust from disturbed soil surfaces. This can be accomplished in several ways. Vegetate or mulch areas that won't receive vehicle traffic, or construct wind breaks or screens. The site could also be sprinkled with water or a chemical dust suppressant to control dust; however, care must be taken to prevent the tracking of mud that might result. Another effective tool is to reduce vehicle speed limits to decrease the amount of dust stirred up from unpaved roads and lots.

ii) Stockpiles should be located away from watercourses, environmentally sensitive areas, drainage courses, ravines, and existing adjacent developments. Stockpiles should be stabilized against erosion immediately following stripping/excavation and stockpiling operations. Stabilization of larger stockpiles can include periodic application of mulch (such as wood or recycled newsprint fibre) and tackifier or the establishment of a vegetative cover.

iii) All construction vehicles should leave the site at a **designated** point or points. Gravelling or paving of frequently used access roads will help ensure that minimal material, such as mud, is tracked off-site. Other options include installation of rumble strips or application of coarse, woody mulch at site exits. In situations where mud tracking becomes a major problem, a washdown facility for truck wheels should be considered.

iv) When sewers have been installed or are existing, practices should be undertaken to ensure sediment and debris does not get into the municipal sewer system. This is generally done by controlling runoff and implementing erosion controls to protect catchbasins (CBs) and manholes (MHs). In some circumstances, CBs and MHs can be protected by sealing the openings, or by providing appropriate inlet protection (such as silt fence boxes, sediment traps, etc.). This should be considered as a last line of defence, since filtering of fine sediment through these means is generally not successful, and only work best when used in a treatment train of SCPs.

v) Principal temporary and permanent storage facilities that capture sediment-laden runoff and allow sedimentation should be planned and implemented prior to the commencement of soil disturbing activities.

vi) All accumulated sediment and debris should be removed as required. Once construction activities are complete, all related materials and temporary structures should be removed and properly disposed of, and any remaining disturbed areas permanently stabilized.

vii) Construction roads and parking areas will require temporary stabilization to reduce erosion and sedimentation potential. Where possible, temporary roads should follow the contour of the natural terrain. Temporary parking areas should be located on flat areas, but should be graded to provide drainage. A layer of aggregate should be applied to provide stabilization. Periodic maintenance will be required.

Devices such as the one shown in ***Figure 9-5*** will fail if SCPs (erosion, run-on, and runoff controls) are not properly planned or implemented. There are no SCPs implemented on the construction site shown in ***Figure 9-5***.

Figure 9-5: Failed Storm Inlet Protection

9.4.3 Stripping, Grading and Site Preparation Controls

Careful scheduling and phasing of construction and operation activities considers season and weather, preserves vegetation, and reduces the length of time soil is exposed. Exposed soils should be graded and roughened/textured to promote infiltration of water and reduce the magnitude and velocity of runoff.

Proper salvage, placement and protection of topsoil will maintain a viable and valuable resource when revegetating and landscaping the disturbed area. For more information on stripping, grading and site preparation controls, refer to The City of Calgary's *Guidelines for Erosion and Sediment Control*.

Providing vegetative cover on the soil stockpile shown in ***Figure 9-6*** controls erosion and helps preserve the biological, chemical, and physical integrity of the soil. A perimeter control (silt fence) was installed around the stockpile to control migration of sediment during stabilization.

Figure 9-6: Providing Vegetation Cover

9.4.4 Runoff Controls

During construction, it is not always possible or practical to provide surface cover for disturbed areas. Modifying the slope surface, reducing slope gradients, controlling runoff velocities, diverting flows around the affected area, and providing upstream storage can significantly reduce erosion of exposed soils.

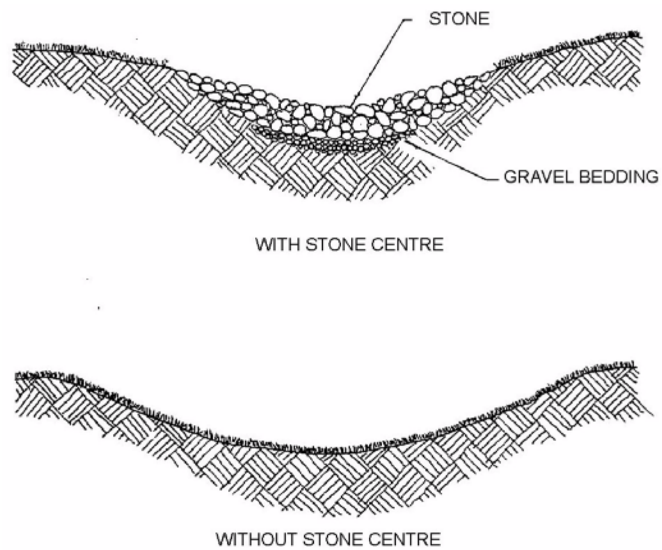
9.4.4.1 Grassed Waterways

Grassed waterways are broad, shallow channels that are designed and constructed to carry concentrated surface runoff to a drainage outlet. The channels are stabilized with herbaceous vegetation such as grass. Although waterways can be designed to accommodate various grades, the channel bottom should be constructed with relatively shallow grades of about 1% so runoff is conveyed slowly. The vegetation in the channel reduces runoff velocity and promotes infiltration, thereby reducing soil erosion.

Prior to construction of any runoff conveyance, it is important that a stabilized outlet be constructed to prevent scour erosion. It might be necessary to provide temporary erosion control using mulch and/or erosion control blankets prior to permanent vegetation establishment in the channel. Vegetation can also be used in combination with permanent turf reinforcement mats for channels where vegetation alone would provide insufficient erosion control.

Regular maintenance is important to keep the waterway in good working condition. Bare and eroded spots should be quickly seeded or re-sodded. Mowing and spraying for weed control should be done on a regular basis.

Figure 9-7: Grassed Waterways



9.4.4.2 Stormwater Channels and Ditches

Stormwater channels are designed to safely convey excess stormwater runoff from a developing area. The channels are lined with vegetation or structural material (such as turf reinforcement mats or riprap) to prevent erosion. Capacity of the channel should be carefully considered in the design.

Open ditches are usually less expensive to install than other types of drains and inspection is easy. However, the maintenance costs can exceed the cost of other types of installations.

9.4.5 Erosion Controls

Erosion controls are surface treatments that stabilize soil exposed by grading or excavation. Erosion control practices, also commonly referred to as BMPs, typically include SCPs, vegetative controls, and non-structural controls. For more information and specific details, refer to The City of Calgary's *Guidelines for Erosion & Sediment Control*.

Choosing the right erosion control practices can be confusing and difficult given the wide range of techniques available. Too often, cost is used to solely determine the erosion control practice used. While cost is an important consideration, other factors related to the site should be considered, including soil type, climate, flow velocities, and construction activity. In many circumstances, covering the ground as quickly as possible provides the best means of erosion control. Options are available to provide cover during critical periods, including mulch, erosion control blankets, and plastic sheeting.

The erosive energy of raindrop splash and overland flows needs to be considered when selecting appropriate erosion control practices. The use of temporary or permanent vegetative and non-vegetative cover (such as mulch) will significantly reduce erosion of exposed soils.

9.4.5.1 Vegetative Cover

Vegetative cover can include seeding, mulching, hydro-mulching, hydro-seeding or sodding, or a combination of these.

i) **Seeding:**
Seeding is typically done with annual or perennial grasses and legumes. Often fertilizer and mulch/tackifier are applied during or immediately after to aid in establishing cover. Seeding can provide long-term stabilization of disturbed areas and has a relatively low cost. Seeding will not provide immediate cover, and bare soil will persist until the plants have taken hold (mulch application can provide temporary erosion control until seedlings are established). When loam piles are left for long periods of time, seeding can also help control weeds and protect the biological, physical, and chemical integrity of the loam.

ii) **Mulching:**
Mulching refers to the application of organic material or other suitable substances to the soil surface to conserve soil moisture and to help establish plant cover. Mulching could also reduce surface compaction, reduce runoff and surface erosion, and control weeds. Long-term and short-term erosion control can be accomplished with mulching. Organic mulches include straw, shredded woody material from site clearing, wood fibre, and recycled paper fibre. Several wood and paper fibre products can be applied using conventional hydroseeding equipment. Straw mulch can be applied by hand or using a straw blower and, due to long fibres, can provide excellent short to medium-term erosion control (straw might need to be crimped into the soil in windy areas).

iii) **Hydro-Seeding:**
Hydro-seeding involves the spray application of a slurry containing annual or perennial seeds, fertilizer, mulch, soil adhesive (tackifier), and water to areas that will be revegetated. Steep rocky or gravely slopes can be revegetated with hydro-seeding; it can also be used in areas where seeding or sodding is applied. Care should be taken when considering the materials to be used in the hydro-seeding mixture, since success of the application will depend on adequate knowledge of site conditions such as soil drainage, texture, and pH.

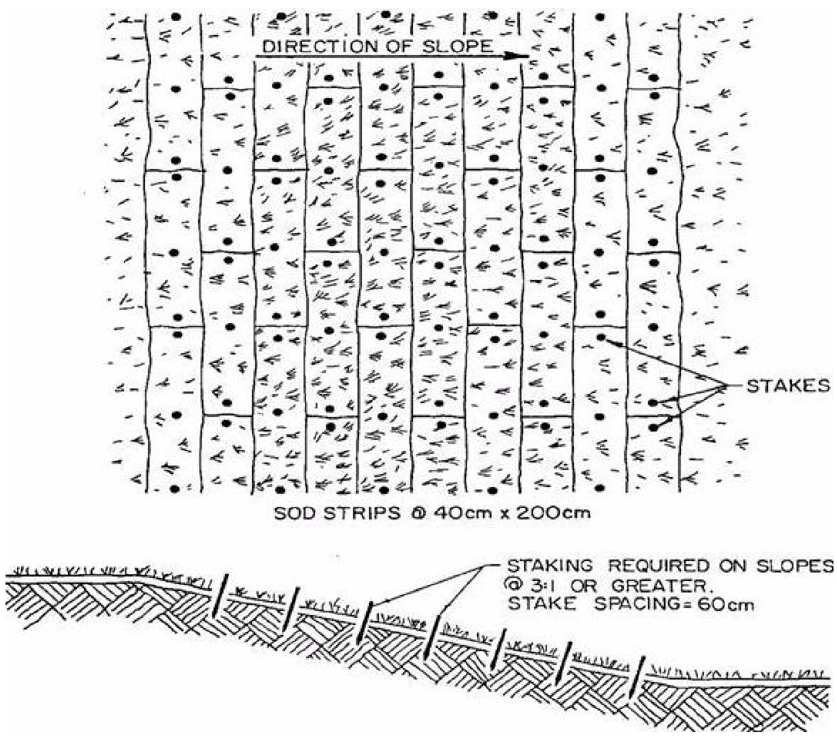
iv) **Sodding:**
Permanent grass sod can be used to cover and stabilize disturbed areas, particularly in areas where complete cover is immediately required or where seeding is not practical (i.e., drainage ways). Sod is best used where adequate topsoil or fertilizer and water can be provided for establishment. The surface must be graded relatively smooth and free of debris, large stones, trash and other large objects; otherwise the sod roots will not take hold. Freshly laid sod will require irrigation to moisten the soil for rooting.

v) **Trees and Shrubs:**
Trees and shrubs can be used to cover and stabilize disturbed areas, as well as to prevent the initiation of erosion. Trees and shrubs provide a canopy above the ground that protects the soil surface from the full impact of rainfall

and winds. If the stands are well established, there could be a layer of organic material on the ground that increases the absorption capacity of the soil. However, the roots of trees and shrubs are not as effective as grass roots are at holding topsoil in place.

Unfortunately, time is needed to establish good cover, and planting is usually expensive. Trees and shrubs can be used to provide permanent protection of graded or cleared areas. They are best used on steep or rocky slopes where moving is not feasible, in shady areas where other types of vegetation species experience difficulty, and where forestry, landscaping, and wildlife features are desired.

Figure 9-8: Typical Installation Detail for Grass Sod



9.4.5.2 Non-Vegetative Cover

Non-vegetative cover can include rip-rap, gabions, aggregate cover, paving, rolled erosion control products, and soil stabilizers.

i) **Rip-Rap:**
Rip-rap provides a durable erosion-resistant ground cover that protects the soil surface from erosive forces, slows runoff velocity, and stabilizes slopes. Rock rip-rap is the most popular material used, since it is durable, heavy, and flexible (rip-rap adjusts to changes resulting from erosion beneath the stones). The most common locations for rip-rap are stream channel banks, slopes of dikes, inlet and outlet structures, and bridge abutments. Rip-rap should be placed before runoff has an opportunity to create erosion. A geotextile fabric

or gravel underlay should be applied prior to placement of rip-rap to separate the soil from the rip-rap, redistribute forces acting on the soil, and provide drainage facilities.

ii) **Gabions:**

A gabion wall is a retaining wall made of rectangular containers (baskets) fabricated of thick galvanized wire that are filled with stone and stacked on one another, usually in tiers that step back with the slope rather than vertically. These structures are typically used to stabilize shorelines or slopes against erosion, including improving slope stability as a retaining wall.

Gabion baskets have some advantages over loose riprap because of their modularity and the ability to stack them in various shapes; they are also resistant to being washed away by moving water. Gabions also have advantages over more rigid structures because they can conform to ground movement, dissipate energy from flowing water, and drain freely. Their strength and effectiveness can increase with time in some cases, as silt and vegetation fill the interstitial voids and reinforce the structure. They are sometimes used to keep stones that fall from cliffs or highway cut slopes from endangering users of public right-of-ways (RoWs).

iii) **Aggregate Cover:**

Aggregate cover includes the use of crushed stone or gravel applied directly to the soil surface. The aggregate stabilizes the soil, and therefore reduces erosion potential. Aggregate cover can be used to stabilize soils impacted by construction traffic, in wet areas or on slopes. It is also suitable for areas where ground water emerges through the surface of the soil.

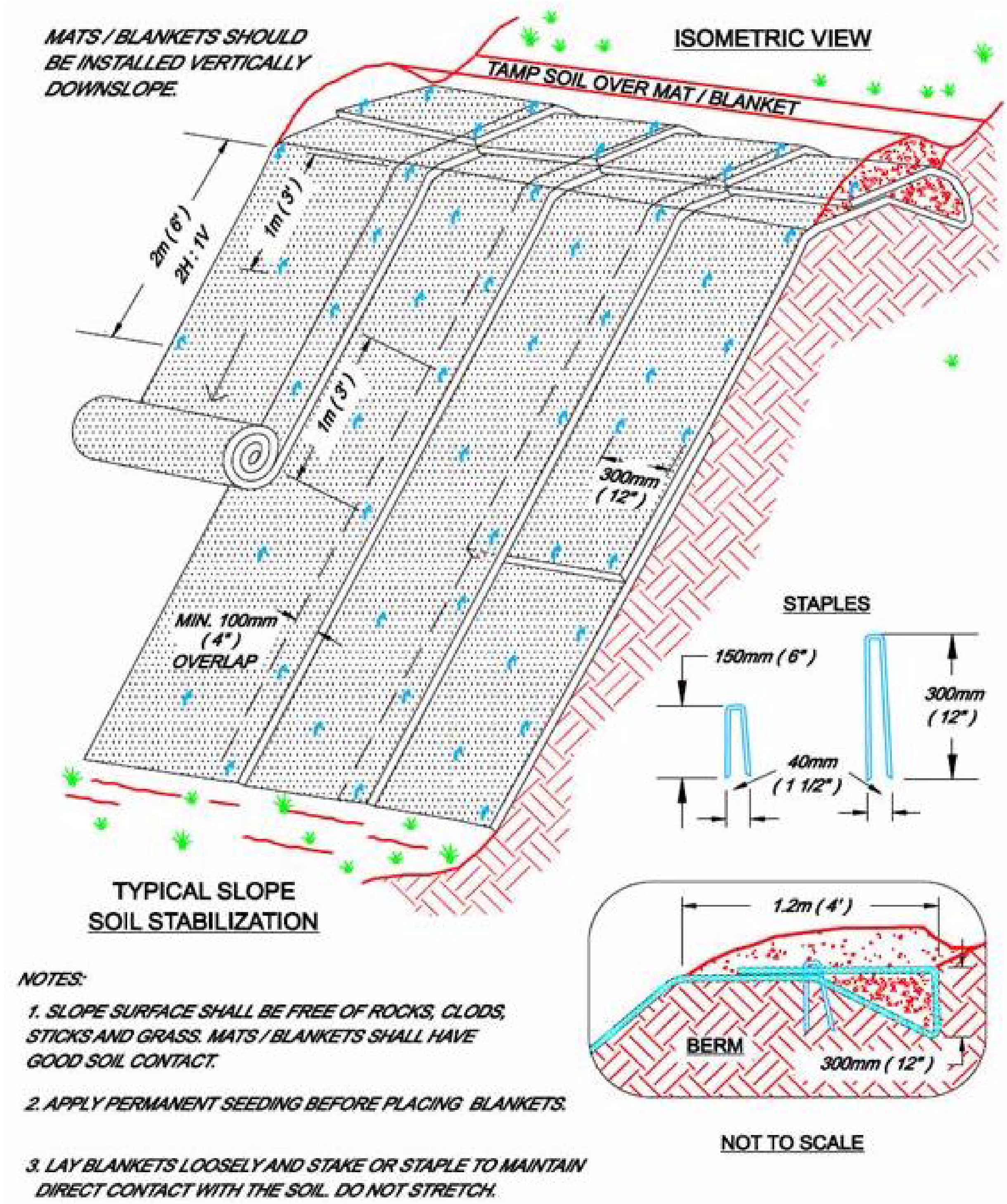
iv) **Rolled Erosion Control Products:**

Rolled Erosion Control Products (RECPs) include Erosion Control Blankets (ECBs) applied to slopes to provide immediate erosion control, as well as Turf Reinforcement Mats (TRMs) applied in channels to provide (long-term to permanent) control of erosion caused by the velocity and shear of flowing water during permanent vegetation establishment (refer to ***Figure 9-9***). RECPs typically consist of a synthetic or organic mulch material held together with synthetic or organic netting, examples of which include straw, coconut fibre, jute, and polypropylene. Several products now include biodegradable and open-weave netting designed to reduce wildlife entrapment in sensitive areas. A range of software is available to consultants and installers to help with proper RECP selection and installation.

v) **Chemical Stabilization:**

Chemical substances, or stabilizers, could be used to change the properties of the soil surface, generally by aggregating the finer soil particles. The stabilizers can be used in place of (or in combination with) mulch materials. Chemical soil stabilizers can be used to protect exposed soil slopes, or used in areas where the use of vegetation as a soil stabilizer is not possible. The stabilizers work best on dry, highly permeable soils, and on soils subject to sheet flow rather than concentrated flow. Long-term protection might be difficult to achieve; therefore, this method should be considered to be only temporary. Anionic polyacrylamides (PAMs) are a common, effective and non-toxic class of stabilizers applied to exposed soils to provide temporary erosion control for soils disturbed by agricultural and construction activities.

Figure 9-9: Typical Installation Detail for RECPs on Slopes[68]



68. Adapted under license from Salix Applied Earthcare.

9.4.6 Sediment Controls

Sediment controls capture soil particles that have eroded. While the prevention of initial erosion should be the primary goal, sediment generation on construction sites cannot be entirely eliminated. To complement runoff and erosion control practices, it is necessary to plan and implement sediment control practices. Depending on soil types and the quantity of sediment-laden runoff to be treated, sediment control can generally be achieved through filtration of the sediment laden flows, or by detention or retention of sediment-laden flows to allow settling. Sediment control practices are also commonly referred to as BMPs, and include several structural and non-structural controls. For more information and specific details, refer to The City of Calgary's *Guidelines for Erosion & Sediment Control*.

Effective sediment control is achievable through several methods, some of which are outlined in ***Table 9-6***.

9.4.6.1 Filtering

Soil particles suspended in runoff can be filtered through porous media consisting of natural and artificial materials (i.e., vegetative strips, rock filters, compost, or synthetic fibres). Filtering is most effective when applied to sheet flow from a wide area; a line perpendicular to the flow at the top or toe of an embankment slope, or mid-section of a slope, can reduce slope length exposed to erosion and can provide sufficient filtering action.

9.4.6.1.1 Vegetative Filters/Buffer Strips

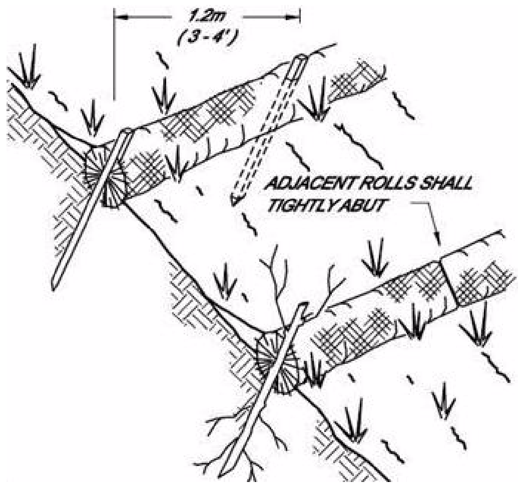
Vegetated filter/buffer strips are densely vegetated bands consisting of grasses, forbs, shrubs, and/or trees. They are usually oriented perpendicular to the direction of sediment-laden flow. The strips can be used to protect property boundaries, steep slopes, surface water such as receiving streams, and other areas sensitive to sedimentation.

Strips of dense vegetation can be used to prevent erosion and sedimentation between disturbed areas and sensitive areas. Sediment, organic matter, and other pollutants are removed from runoff through filtration and adsorption. A strip of trees or shrubs can also provide a windbreak to reduce wind erosion.

9.4.6.1.2 Compost Filters, Straw/Fibre Wattles, Rock Filters, and Brush Barriers

In general, filters remove sediment and reduce runoff velocity. Filters can also be effective at reducing erosion by reducing continuous slope lengths. They can be constructed from any stabilized porous media, such as coarse compost material, other organic and synthetic fibres (refer to ***Figure 9-10***), shredded woody material and rock. There is no predetermined shape for filters. However, it is important that runoff flow through the filter, rather than around or under it.

Figure 9-10: Use of Straw/Fibre and Compost Socks on a Slope

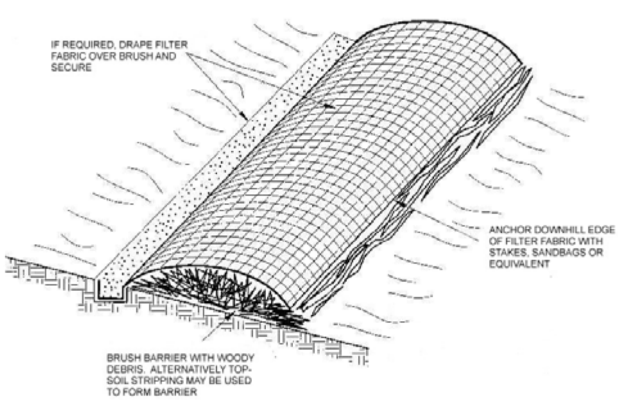


Filters can be used around drain inlets, along the toes or mid-sections of slopes, on small slopes, on sediment basin dams, between water bodies, and next to adjacent downhill properties and resources. Filters should be used where there is an existing drainage system, and are most effective for relatively small drainage areas.

Rock filter media should be composed of clean, hard, durable particles free of organic matter, clay, or other material that would interfere with filtering capacity. Rock filters can be constructed in a form similar to check dams.

Brush barriers (refer to ***Figure 9-11***) are used as temporary filters. The barrier is constructed by piling brush, rock and root mats into a mounded row. During clearing operations, a mixture of tree limbs, small vegetation, roots and small amounts of soil and rock can be made into windrows along the toe of a slope.

Figure 9-11: Brush Barrier



Water body protection can be enhanced with a seeded compost berm and compost blanket (as shown in ***Figure 9-12***) to promote filtering of sediment-laden runoff and provide erosion-resistant buffer.

Figure 9-12: Protection of Water Body Adjacent to Stripped Area of Land

9.4.6.1.3 Check Dams

Check dams are used to prevent channel erosion by reducing runoff velocity, lengthening detention time, and increasing the cross-sectional area of the channel. They are used when vegetative measures are not sufficient to handle runoff velocities, in areas of excessive slope conditions, or where runoff must travel from a higher elevation to a lower elevation.

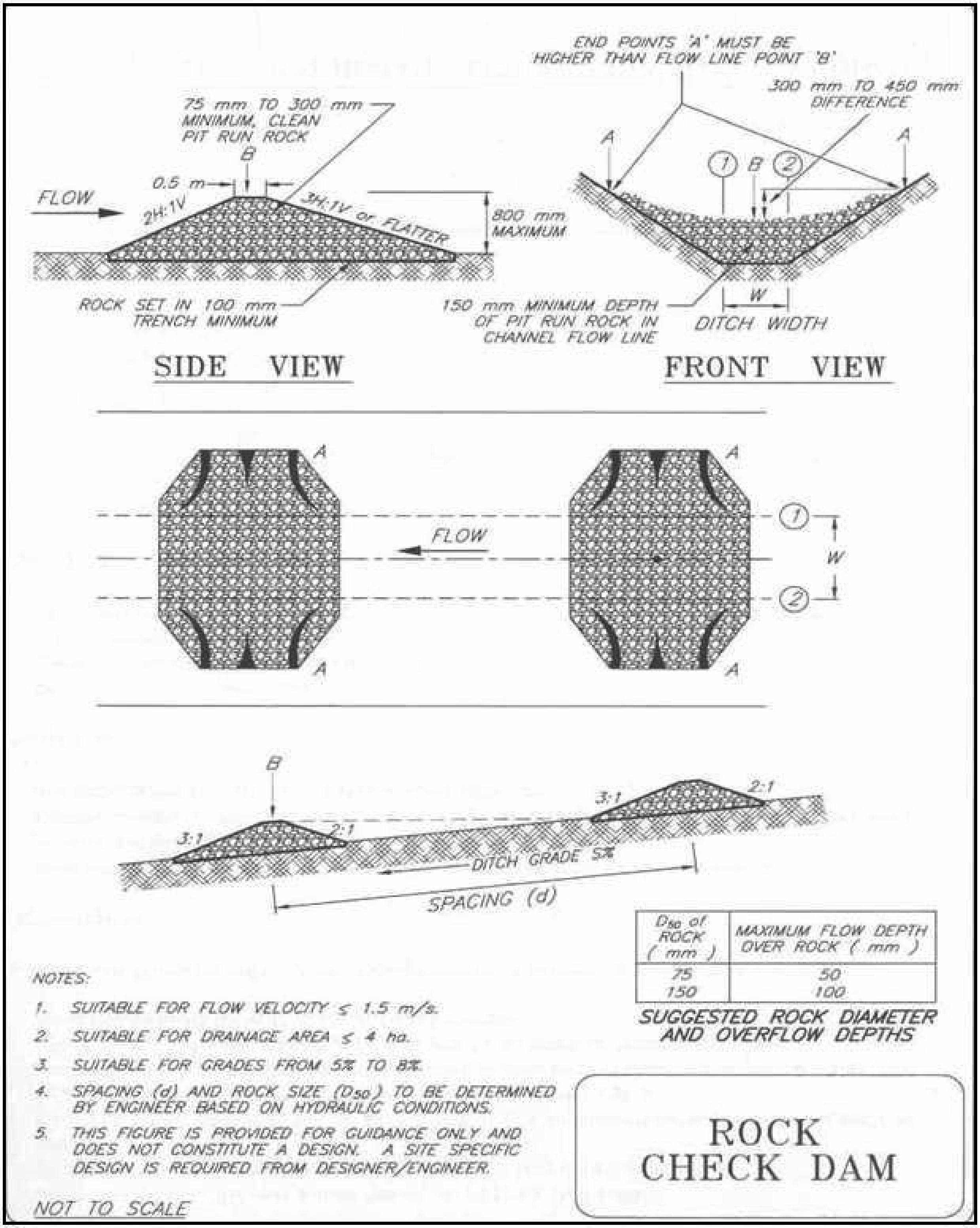
Check dams can be constructed of rock (refer to ***Figure 9-13*** and ***Figure 9-14***), concrete, metal, gabions, wood (logs) or other materials (refer to ***Figure 9-15***). A number of effective commercial synthetic products are also available.

Note: Strawbales are susceptible to scour, undermining, and washouts, and are not recommended.

Check dams are constructed across the channel, perpendicular to the direction of flow. **It is important that check dams are properly keyed into to channel and side slopes to prevent undermining of the structure or scouring caused by water flowing around the structure.** Maximum spacing for check dams in a channel must be designed such that the base of a check dam is at the same elevation as the top of an adjacent downstream check dam, otherwise channel scour could occur. It is also advisable to install a section of erosion control blanket or turf reinforcement mat immediately downstream of all check dams to prevent scour when dams are overtopped by runoff during higher flows.

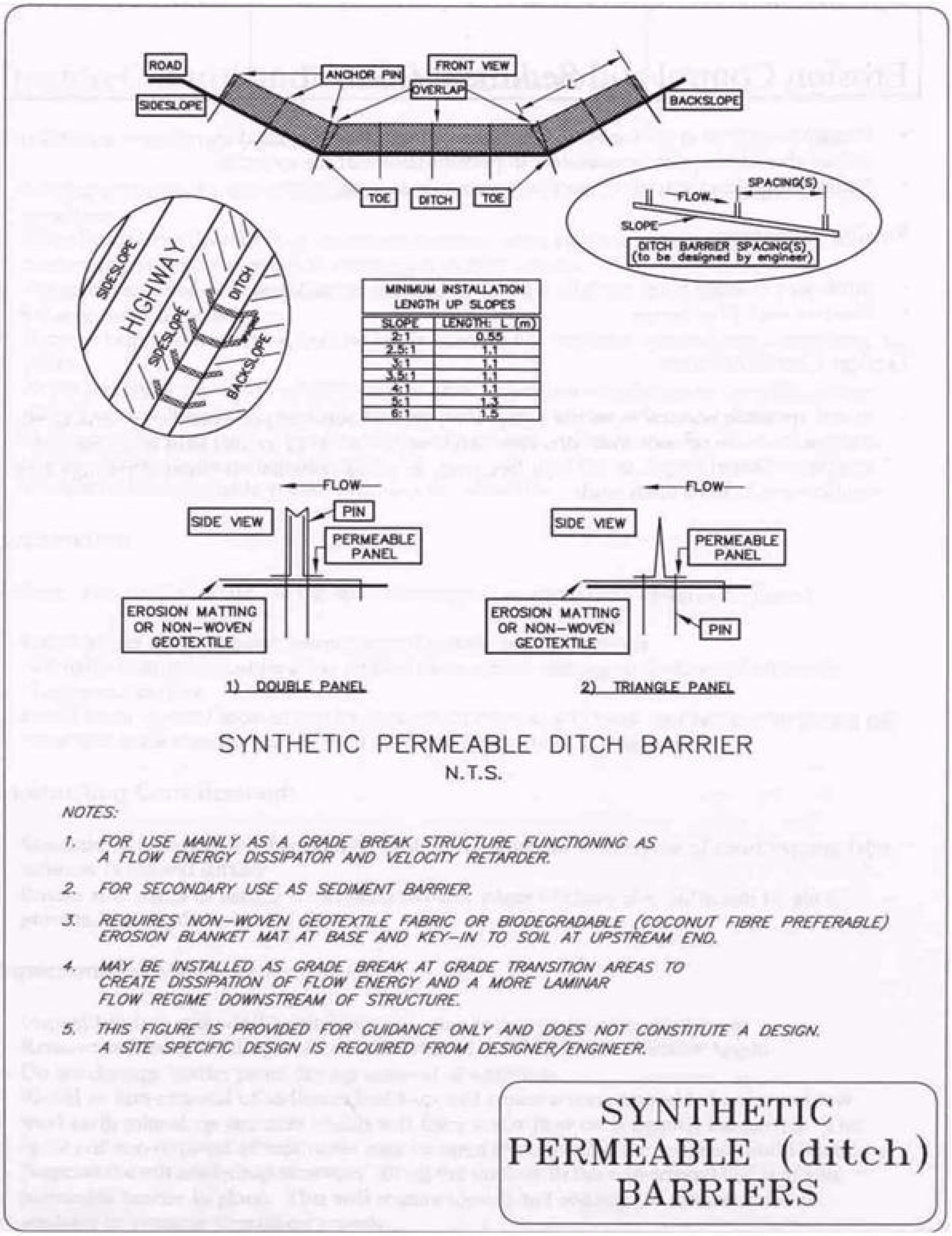
Figure 9-13: Rock Check Dam

Figure 9-14: Rock Check Dam Detail[69]



69. Source: Alberta Transportation 2003 (page 7-3).

Figure 9-15: Synthetic Permeable Barriers Detail[70]



70. Source: Alberta Transportation 2003 (page 10-4).

9.4.6.2 Impoundment

Impoundment of sediment-laden runoff permits the settling of suspended sediments. Runoff can either be temporarily detained behind structures that provide a combination of filtering and settling of suspended solids or, where there is sufficient storage, be retained in impervious traps, basins, or other structures. For more information on sediment control practices, including siting and sizing requirements for sediment traps and basins, refer to applicable sediment control BMP details in Appendix A of The City of Calgary's *Guidelines for Erosion & Sediment Control.*

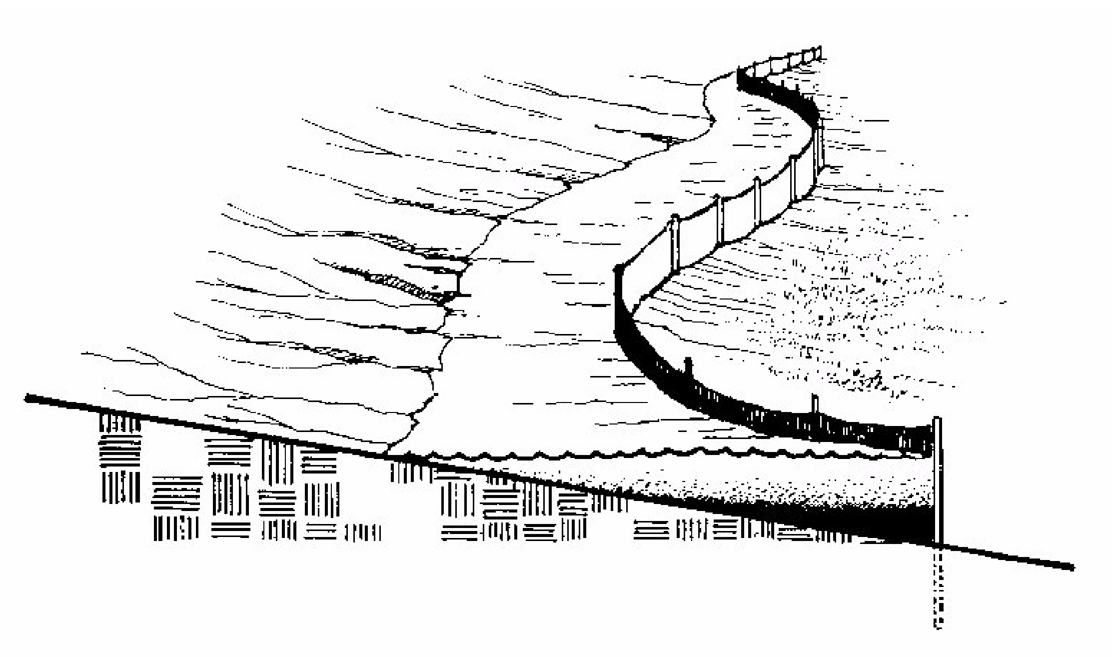
9.4.6.2.1 Silt Fences

A silt fence is a sediment barrier that uses standard or extra strength filter fabric attached to a support fence. A properly installed and configured silt fence detains sheet flow, allowing settling of sediment behind the fence. Silt fences are most effective when used to control sediment below disturbed areas, where sheet or rill erosion occurs. Silt fence should not be used in areas prone to concentrated flow (such as across drainage channels).

Silt fence fabric is composed of both natural and synthetic materials. Woven and non-woven fabrics are available commercially, with the woven fabrics generally having higher strength. Due to the variability in permeability of the material, there can be considerable differences in filtering capacities for finer silt and clay particles.

The height of a silt fence should not exceed 1.0 m, so as not to impound dangerously large quantities of water. The bottom of the silt fence must be firmly anchored in the soil for best filtering results. A silt fence should be considered to be a temporary barrier, with a useable life span of about six months.

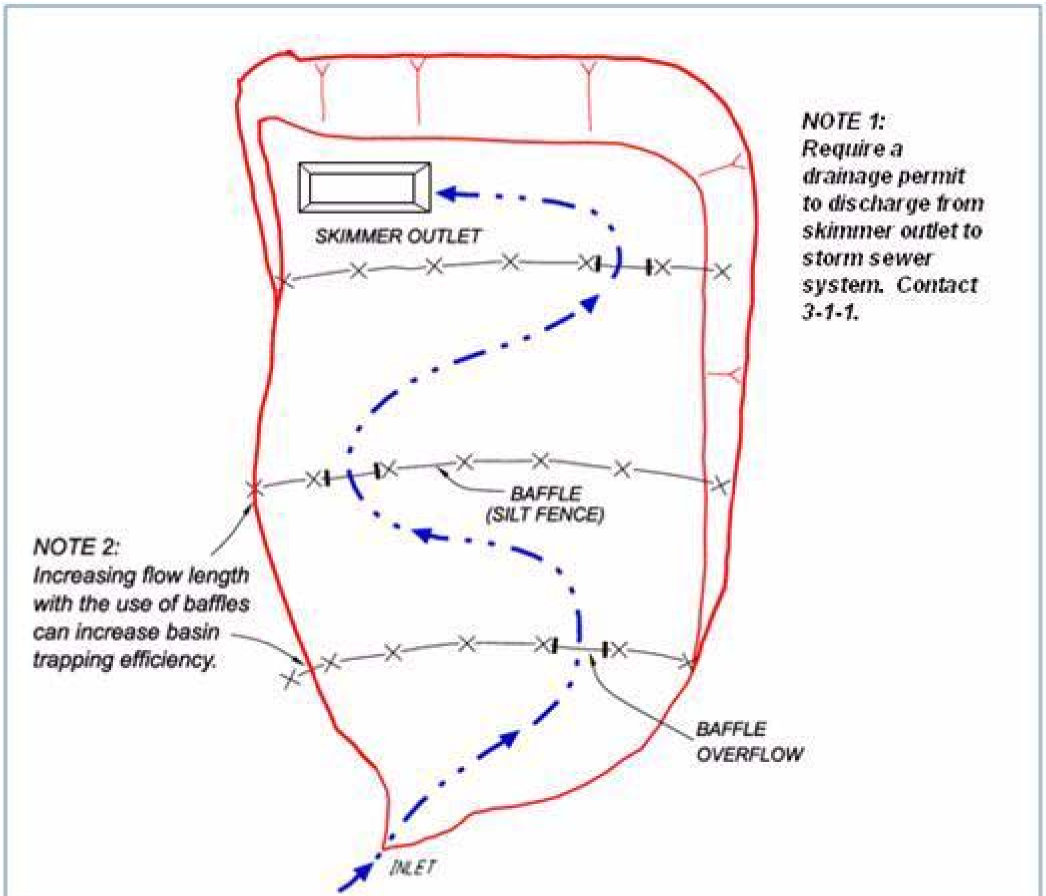
Figure 9-16: Silt Fence Installation at the Toe of a Slope



9.4.6.2.2 Sediment Traps and Basins

Sediment traps or basins can be formed through excavation or above ground berming, or a combination of both. Soil, rock, and silt fencing can be used to construct the traps (an example detail for a sediment basin with baffles and a skimmer outlet is provided in ***Figure 9-17***). If properly constructed and well maintained, sediment traps are an effective method to minimizing the transport of sediment off-site. Care should be taken when designing large embankments, since these might have to be designed to small dam standards. Sediment traps and basins require frequent inspection and maintenance, especially during and after rainfall or snowmelt, and it is often necessary to remove excess ponded water and accumulated sediment.

Figure 9-17: Typical Sediment Basin with Baffles and a Skimmer Outlet[71]



Sediment traps and basins should be located in areas where sediment-laden runoff can be slowed in velocity prior to entering a drainage inlet, allowing sediment to settle out. Release rates from the basins are controlled. Sediment traps are smaller settling ponds that sometimes use a spillway with a simple outlet control structure. Overall, traps are simple and relatively inexpensive to install. They are most effectively used where drainage swales enter the sewer system or receiving water.

71. Adapted under license from Salix Applied Earthcare.

Figure 9-18: Simple Sediment Trap with Stabilized Inlet and Outlet

Note: The sediment trap in ***Figure 9-18*** includes application of an erosion control blanket to protect side slopes.

9.5 Temporary Practices vs. Permanent Practices

ESC Practices can typically be divided into two groups:

- **Temporary** practices which are used only during the construction phase, and
- **Permanent** practices which are intended for permanent use and should be incorporated into the overall design of the development

9.5.1 Temporary Practices

Temporary ESC Practices are typically used only during the construction phase. The purpose of these temporary practices is to prevent the transport of sediment to streams, wetlands, lakes, drainage systems, and adjacent properties. These measures can include, but are not limited to: buffer strips, filters (strawbale, rock or brush), sediment traps, and ponds.

9.5.2 Permanent Practices

There are a number of permanent structures that can be incorporated for the long-term control of runoff. These structures would not be removed after construction completion, but would become part of the overall site stormwater plan through integration into the urban design. These permanent structures include wet ponds and extended detention ponds, grassed swales, filter strips, and constructed wetlands.

9.5.2.1 Wet Ponds and Extended Detention Ponds

After construction and site stabilization, wet ponds provide a measure of water quality improvement through detention. Regular maintenance of the forebay to remove accumulated sediment is required to ensure that adequate capacity and drainage is maintained.

Extended detention ponds allow runoff to be detained through slow release rates and allow a small measure of sediment to settle out. Due to the slow release, these ponds are generally designed to be dry between runoff events, but clogging of the outlet is a significant concern due to the slow release rate. Therefore, the outlet should be protected, or designed accordingly.

During construction of the upstream drainage areas, the use of wet ponds and extended detention ponds for sediment control is not recommended. In limited situations, it is acceptable to use future wet ponds and extended detention ponds as sediment basins prior to connection of underground upstream and downstream storm infrastructure. Once connections are installed, these facilities must not be used as the primary means of sediment control downgradient of areas under construction.

9.5.2.2 Grassed Swales

Grassed swales act as conveyance channels which enhance sediment removal and increase infiltration. By increasing detention time over the length of the swale (through check dams), sediment removal can be enhanced.

9.5.2.3 Filter Strips

Filter strips are usually vegetated strips that buffer the development site and the waterway. The strips are generally flat, and provide sediment reduction by overland runoff flowing over the strips. Proper maintenance is required to ensure effective treatment.

9.5.2.4 Constructed Wetlands

The shallow pools in constructed wetlands provide a suitable growing condition for marsh plants, which in turn provides sediment and pollutant removal through uptake, retention, and settling. Periodic maintenance is required to remove accumulated sediments in the forebay and cells of the wetland. Natural wetlands should not be used to provide stormwater treatment, and the use of wetlands (constructed and natural) for sediment control is not recommended.

9.6 Low Impact Development (LID)

Erosion and sediment control and stormwater management are closely related. Application of Low Impact Development (LID) concepts emphasize phasing and minimizing disturbed areas and delineate drainage areas into small manageable sub-catchment areas - the same basic principles of ESC.

However, it is important to consider that LID practices intended to reduce stormwater runoff and treat stormwater (i.e., bioretention or absorbent landscaping) can become plugged with sediment due to lack of planning, implementation, and maintenance of ESC Practices during construction of adjacent, contributing areas. Also, excessive compaction of soils within areas intended for LID practices can reduce effectiveness. Where possible, delay installing these practices until near the end of construction, once contributing areas are stabilized.

Sites that incorporate LID practices to improve stormwater quality require close attention to detail, since small amounts of sediment can cause plugging of the LID and render it unoperational. To counteract this, ESC Practices are required to minimize erosion control at the source (i.e., control run-on and runoff, and stabilize soils). As a result, grading and ESC Practices need to be applied on a smaller scale (i.e., a sub-catchment or lot-by-lot scale).

The following principles must be followed:

i) **Planning:**
During site design and construction, plan and implement ESC Practices at the sub-catchment and individual lot level. When laying out the lots, the designer must analyze the topography, existing tree cover to be preserved, building locations and associated set-backs, slope steepness and length, drainage ways, and soil types.

ii) **Control Erosion:**
Erosion control is the first line of defense to prevent plugging-up or damage to existing LID practices (and those under construction). Control run-on and runoff from upstream areas, and ensure timely, temporary or permanent stabilization of disturbed soils. Ensure that permanent erosion control practices are implemented as soon as practical.

iii) **Control Sediment:**
Even with the best erosion control efforts, sediment transport will occur. For this reason, on-lot sediment traps, perimeter fibre rolls, and/or silt fences are necessary.

iv) **Implementation:**
Expose the smallest practical area of land for the shortest time possible. Ensure that primary ESC Practices are in place and functional prior to construction, and continue to implement successive ESC Practices as construction proceeds. Provide temporary stabilization for disturbed areas as quickly as possible. Areas that have been disturbed and are not actively being worked, as well as areas that are being final graded, must be stabilized within 14 days.

v) **Inspect and Maintain ESC Practices:**
Inspect practices at least every 7 days, and within 24 hours of significant rainfall and snowmelt. Accumulated sediment must be removed on a periodic basis and inspected for excessive accumulation after every major storm. Particular attention should be paid to the stabilization of disturbed areas and the integrity of sediment control devices.

vi) **Address Soil Compaction:**
Minimize soil compaction by keeping heavy equipment out of locations for LID facilities. Where compaction occurs or is unavoidable, it will be necessary to scarify or deep-rip soils, as well as conduct percolation tests to ensure that infiltration rates are adequate.

9.7 Inspection, Monitoring, and Maintenance

All temporary and permanent ESC Practices must be inspected, maintained and repaired by the developer/owner, or their appointed designate, during the construction phase as needed to ensure continued performance. Refer to The City of Calgary's *Guidelines for Erosion and Sediment Control* for more information on inspection and maintenance requirements. **As a minimum, all construction sites should employ Good Housekeeping Practices (refer to *9.4.2 Good Housekeeping Practices*).**

9.7.1 Inspections

All erosion and sediment controls must be inspected every 7 days and following significant rainfall (typically 12 mm or greater in a 24 hour period), prolonged wet weather, or snowmelt events. All disturbed areas of the site, material storage areas, entrance and exit roads, and **all** erosion and sediment controls must be inspected. The controls must be in good operating condition until the area they protect has been completely stabilized and the construction activity complete. Inspection is the responsibility of the developer/owner or their designate, which could be the contractor and/or consultant. Inspection procedures can vary, depending on the season (i.e., spring/summer compared to fall/winter). The developer/owner, or designate, must ensure compliance to regulatory requirements.

The federal *Fisheries Act (F-14)* and the Alberta *Environmental Protection and Enhancement Act* require that releases of substances that cause or could cause a deleterious or adverse affect on the environment must be immediately reported. Release of substances includes sediment-laden runoff from construction sites. Spills and releases can be reported by calling the Provincial Spill Reporting Line at 1-800-222-6514, allowing for a coordinated response between federal and provincial authorities. City staff that observe, or are informed of a spill or release should utilize the Corporate X-217 Substance Release reporting form and fax the form to HazMat (in emergency situations or where the spill cannot be contained, contact the Calgary Fire Department through 9-1-1.

9.7.2 Winter Shutdowns and Inactive Sites

Construction projects can be shut down during winter. Frozen soils are not prone to erosion. However, surface soils can be detached by ice lens formation and thawing surface soils that quickly become saturated in spring. As a result, erosion potential on many construction sites can be very high during spring thaws or prolonged chinook conditions. Therefore, it is essential to ensure effective ESC Practices are installed prior to freeze-up and inspected during snowmelt.

Prior to winter freeze-up, all exposed areas and stockpiles must be stabilized and inspected before a site is left in an inactive or winter shutdown state. **Any site that is inactive for greater than seven days must be inspected every two weeks during prolonged winter freeze-up conditions.** This includes inspection during/after winter snowmelt conditions.

9.7.3 Maintenance and Repairs

Maintenance and repair of control practices are the responsibility of the developer/owner, or the appointed designate. A schedule of planned maintenance activities is required with the submission of the ESC report and drawings and must be followed. **When implemented controls are insufficient or not working properly, changes to the ESC report and/or drawings (typically documented as an addendum) must be made to ensure continued compliance.**

Some practices, such as silt fences and inlet protection devices, will require periodic replacement and removal of accumulated sediment. Sediment basins (traps and ponds) will require periodic sediment removal when the design storage level is one third full. **Damage or deficiencies to control measures must be corrected promptly after an inspection.**

9.7.4 Documenting Inspection, Maintenance, and Repair Changes

Documentation of inspection, maintenance, field and repair changes applies to all construction projects, including City capital construction projects. Until final site stabilization, the developer/owner, or their designate, must maintain an up to date record of inspections, maintenance, damages and deficiencies for all temporary and permanent ESC Practices on site. An on-site inspection and report must be undertaken every 7 days, as well as following rainstorms or snowmelt events. The same document should be used to record maintenance and repairs undertaken after the inspection. It is the responsibility of the developer/owner, or their designate, to design and implement the inspection and maintenance record. The record must be signed by the developer's/owner's inspector, and must be available for on-site review by City inspectors, and/or provincial and federal inspectors/regulators, at any time. Where ESC Practices detailed in the ESC report and drawings need to be modified in the field, an addendum update must be made to the report and/or drawings and be submitted to The City of Calgary for review and approval.

If it is found that there has been a failure to complete inspection/maintenance/repair record(s), follow ESC Practices, or adequately maintain erosion and sediment controls, The City of Calgary will require bi-weekly submission of the inspection and maintenance record to the Erosion Control Technician or Development Inspector for review.

9.8 Technical Requirements for ESC Reports and Drawings

9.8.1 Submission Requirements

Water Resources' Water Quality Services division reviews ESC reports and drawings for stripping and grading applications, subdivisions, and projects falling under standard development permit and development liaison applications. This group is also responsible for the review of ESC reports and drawings for City capital construction projects, as well as for reviewing requests and issuing drainage and dewatering permits (authorizing the discharge of impounded surface runoff and/or groundwater) from construction sites to storm sewers. Refer to ***Table 9-7*** and ***9.8.2 Report Requirements*** for more information about Water Quality Services reviews, approvals, and inspections.

Table 9-7: Summary of Erosion and Sediment Control Reviews, Approvals, and Inspections Undertaken by Water Quality Services

The City of Calgary Water Resources Water Quality Services: Erosion and Sediment Control
1. **City of Calgary Capital Construction Projects:** Review/approval and compliance inspection of erosion and sediment controls for projects owned or operated by: • Transportation Infrastructure. • Parks - unless in a subdivision under Development Permit. • Roads - unless in a subdivision under Development Permit. • Calgary Transit. • Water Resources. • Water Services. • Waste & Recycling. • Corporate Properties. 2. **Stripping & Grading under a Development Permit, Development Agreement, or Development Liaison** Review/approval and compliance inspection of erosion and sediment controls. 3. **Construction Drawings (ESC) Review for Residential, Commercial, and Industrial Development** Review/approval and compliance inspection of erosion and sediment controls. 4. **Cash Pre-payment Sites** 5. **Indemnification Agreements** Underground utilities and surface construction. 6. **Standard Development Permits, Development Liaisons, and Airport Development** 7. **Drainage & Dewatering Permits** Review of applications and issuance of drainage/dewatering permits to allow temporary discharge of impounded water from construction sites and facilities to the storm sewer system. Additional application and processing information can be found on the *Erosion and Sediment Control* page on The City of Calgary's website. 8. **Complaints** Complaints associated with any of the above.
Contact the Water Resources Erosion Control Coordinator: **Phone: 403-268-2655 Fax: 403-268-4557** Website: *http://www.calgary.ca/UEP/Water/Pages/Water-Services.aspx* Corporate Call Centre: 3-1-1

ESC reports and drawings are required for sites greater than or equal to 2 ha in **overall site size**. At the sole discretion of The City of Calgary, an ESC report and/or drawings might also be required for sites smaller than 2 ha in overall size where risk factors such as soil erodibility, adjacent water bodies, environmental reserves, residential areas, or slopes are significant.

ESC reports and drawings consist of a written portion (report) and an illustrative portion, which includes maps and construction details (drawings). The written portion should explain and justify the control measures chosen, and include information concerning site conditions, construction schedules, inspection and monitoring schedules, and other pertinent items not contained in the drawings. The drawings should describe where and when the various measures will be installed, the expected performance, and actions to be taken if performance goals are not achieved. The report and drawings should be stand-alone documents that must be easily located on the construction site for use by construction and inspection personnel. As site work progresses, the report and drawings should be modified by the consultant and/or contractor to reflect changing conditions, with updates submitted to The City of Calgary and maintained on site. Further information on ESC report and drawings development, including a standardized application template, can be found on the *Erosion and Sediment Control* page on The City of Calgary's website.

A copy of the ESC drawings and pertinent details must be included in the Construction Drawing set (preliminary and final) for all subdivisions, Development Site Servicing Plans (DSSPs), Development Permits (DPs), and City capital construction projects. This is to ensure that the ESC information is readily and easily accessible to all personnel, including inspectors and contractors. Erosion and sediment control is everyone's responsibility.

9.8.2 Report Requirements

The intent of an ESC report is to provide useful background and supporting information regarding the level of ESC planning, implementation, inspection, and maintenance for the project. A standardized report template is available on the *Erosion and Sediment Control* page on The City of Calgary's website.

ESC reports should include the following:

- The completed template, providing general information on the location of the project, contact information, a project overview, details on existing site conditions, and limitations of the field investigations at the time of the report preparation.
- Site specific details regarding soil types, soil loss calculations (complete the template section when soil loss calculations are required, using RUSLEFAC for the calculations), and information on any critical areas that will require additional protection.
- Descriptions and construction details for all temporary and permanent ESC Practices, including practices to control run-on and run-off, stabilize soils, and contain sediment.

- Details on additional practices required during winter operations, periods of site shutdown, and for any inactive, disturbed areas on the site.
- A construction schedule for each stage of the proposed development. If this is not available at the time of the report preparation, it will need to be submitted as a report amendment prior to project start-up.
- Details on inspection and maintenance of all ESC Practices, including removal of temporary practices when they are no longer required. Include an inspection and maintenance log specific to the practices to be implemented on site.

Refer to Section 3.0 of The City of Calgary's *Guidelines for Erosion & Sediment Control* for detailed information on report submission requirements

9.8.3 Drawing Requirements

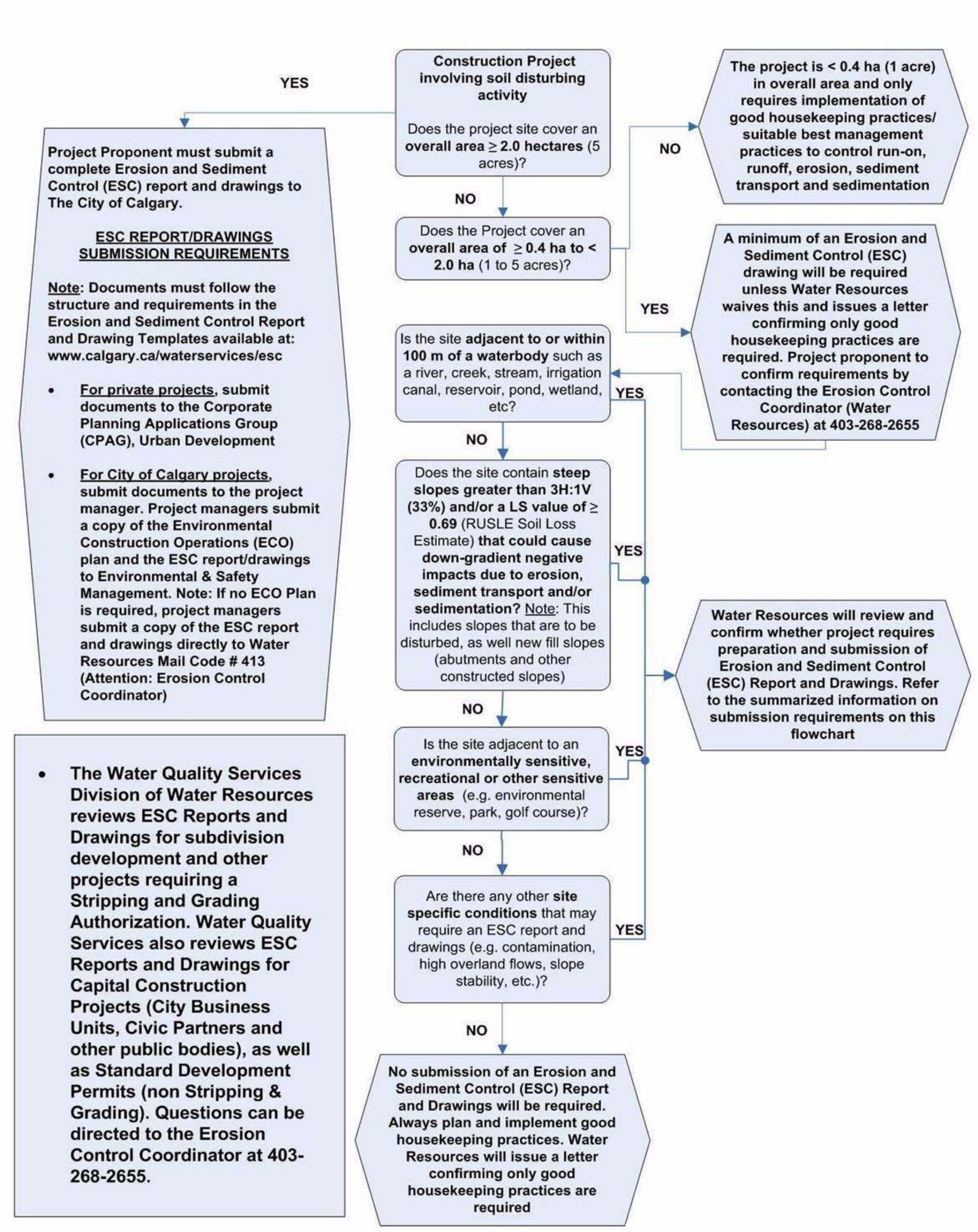
The intent of the ESC drawings is to provide the contractor and other field personnel information on the type and location of controls and the timing of installation, inspection, maintenance and, in the case of temporary controls, removal. More information on drawings submission requirements can be found on the *Erosion and Sediment Control* page on The City of Calgary's website.

ESC drawings should include the following:

- Construction details for each ESC Practice, along with a log for capturing details on installation, inspection, and maintenance.
- A Present Conditions drawing (refer to the template guide for what needs to be included).
- An Intermediate/Final Conditions Drawing (refer to the template guide for what needs to be included).
- A Cut & Fill Drawing (where there are any cuts or fills over 2.0 m in depth).
- A Landscaping/Permanent Stabilization Drawing.
- A Phasing Drawing (if the construction/development project is being divided into phases).

Refer to ***Figure 9-19*** for an overview of the report and drawing requirements for private and City construction projects.

Figure 9-19: Erosion and Sediment Control Report and Drawing(s) Requirements for All Construction/Development Projects Involving Soil Disturbance



CHAPTER 10: OPERATING, MAINTENANCE, AND MONITORING REQUIREMENTS

10.1 General

10.1.1 History

In the past, stormwater management consisted of the construction of stormwater systems that were designed to emphasize conveyance and flood control. Stormwater ponds would typically be designed to shave off the “peak” of the rainstorm, while sediment removal was a secondary consideration, if it was considered at all. Stormwater in the ponds was usually detained for a relatively short period of time, thereby limiting the degree of water quality enhancement provided.

The introduction of water quality into stormwater management changed the focus of design, operation, and maintenance. Sediment removal maintenance is now an important consideration, since sedimentation is a primary design criteria for water quality. Nutrient loading will continue to play an increasingly major role. Source and site control Best Management Practices (BMPs) are designed to promote water quality enhancement and, in some cases, reduce runoff volume. Both ponds and BMPs must be properly operated and maintained to ensure their continued performance.

10.1.2 Need for Maintenance

There are a number of operation and maintenance activities that must be carried out if a stormwater management system is to function properly. **Generally, it is the lack of proper maintenance that causes a system to fail; in some cases, this failure results in great expense and inconvenience to the public.** Inspection, operation, and maintenance go hand-in-hand in ensuring that stormwater systems function properly. Under *Drainage Bylaw 37M2005*, the owner of a BMP (i.e., oil/grit separator, bioretention area, rain water harvesting system, etc.) must properly operate, maintain, and repair (if needed) that BMP.

Maintenance can generally be divided into preventive and corrective activities.

10.1.2.1 Preventive Maintenance

Preventive maintenance is scheduled maintenance that includes the inspection of the system, record keeping, regular maintenance, and the analysis of data related to past complaints and problems. Video inspection (typically for the underground pipe system) should be carried out as required; the frequency and extent should reflect historical maintenance problems, the age of the system, and/or operational parameters, such as discharge rates or water quality. Preventative maintenance might also include sediment removal, maintenance of control gates and structures, algae removal, proper vegetation maintenance, and maintaining side slopes (ponds). Preventive maintenance is also required to ensure the continued performance of BMPs (i.e., removing sediment to ensure an adequate percolation rate for a bioretention area or repairing/replacing vegetation). Record keeping is essential to maintaining a useful database.

10.1.2.2 Corrective Maintenance

Corrective maintenance is unscheduled, and typically relates to emergency situations. Corrective maintenance includes the immediate repair of pipe breaks, collapses, or washouts, as well as removing blockages or restoring infiltration capacity. Corrective actions can reduce flood potential, limit liability, prevent personal injury, or protect the environment.

10.1.3 Responsibilities

During the required maintenance period (i.e., prior to the issuance of a Final Acceptance Certificate (FAC)), the developer is responsible for operation and maintenance of the stormwater/drainage system; this typically includes all associated costs. However, The City of Calgary's Water Services business unit will respond to monitoring system alarms and spills (including hazardous spills) during the maintenance period. For vegetation below the HWL (for storm ponds), maintenance is the responsibility of the developer during the maintenance period, and then the responsibility of Water Services once the FAC has been issued. The developer will be advised of any corrective maintenance or repair work that is required before the FAC can be issued.

After the maintenance period (i.e., after the FAC has been issued) Water Services is responsible for operation and maintenance of the stormwater/drainage system. Parks typically provides cleanup and maintenance for the areas above the HWL immediately adjacent to the ponds. Prior to FAC acceptance of the stormwater system, the developer is responsible for any maintenance or cleaning required, including sediment removal from stormwater ponds and BMPs. The maintenance of BMPs is similar to that for ponds: replacement of a BMP (including vegetation) is the responsibility of Water Resources if the BMP is located on public land (i.e., following issuance of FAC), and the responsibility of the owner if it is located on private land.

A limited number of private maintenance agreements have been set up in the past. In these circumstances, the owner is responsible for ongoing maintenance required for a public facility after FAC issuance. Where the owner is negligent in maintaining a minimum standard of care for the system's upkeep, Water Services will charge the owner for maintenance services required. As well, optional amenities might be removed and/or repaired if maintenance is inadequate. If the situation cannot be adequately resolved, Water Services has the right to revoke the maintenance agreement and seize any holdback funds used to set up the agreement.

10.1.4 Inspections

Regularly scheduled inspections and activities are required for each stormwater system to ensure proper operation. The frequency of maintenance will vary with the activity, and will be conducted on an "as required" basis. The frequency for the expected activities should be included in the Operating and Maintenance (O&M) Manual for each BMP. Otherwise, inspections should be conducted on a monthly basis, and after significant rainstorms.

Standard Operating Procedures (SOPs) are being developed to provide additional inspection and maintenance activity information. Other factors that affect these activities, such as land use and upstream development, should be taken into consideration. Refer to ***Table 10-1*** for more information.

10.1.5 Contacts

During the maintenance period, the public should contact the developer or the developer's consultant regarding inspection, maintenance, and operational issues, unless there is a safety issue or a spill. **All hazardous spills must be reported immediately to the Fire Department (9-1-1) and Alberta Environment (1-800-222-6514).**

If the developer is negligent in carrying out required work, then Water Services (Field Services - Business Performance team) and/or Water Resources, Development Approvals should be contacted to resolve the issue(s).

After the maintenance period, all calls pertaining to public systems should be directed to Water Services through the 3-1-1 system.

For private maintenance agreements, the owner should be contacted directly. Water Services should be contacted only when the owner is negligent in carrying out the required work.

10.1.6 Equipment Access

It is imperative that access for (mechanized) maintenance equipment be included in the design of the stormwater system and ponds. Access to wet ponds and wetlands must be provided for scrapers, tractors, and trucks to facilitate sediment removal, maintain vegetation, and respond to emergency situations (i.e., spills, rescues, etc.). Fences, landscaping, or other features should not obstruct these access points. Additionally, adequate space must be available to allow the equipment to move and turn around. Refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for more information.

10.2 Operation and Maintenance Activities

10.2.1 Minor System

The minor system and associated components are typically subject to problems such as clogging and collapse. Maintenance is required to preserve the capacity of the system, otherwise the potential for surcharging and flooding increases. Regular maintenance ensures that the stormwater pipe system functions properly.

Water Services maintains a database of all pipes, manholes (MHs), catchbasins (CBs), service connections, and interceptors (e.g., oil/grit separators). This database keeps up-to-date records of complaints, inspections and repairs, ensuring that valuable information is preserved.

Preventive maintenance includes:

- Cleaning of streets (serviced by Calgary Roads).
- Removing sediment from CBs.
- Steaming of frozen CBs, outfalls, and culverts.
- Regular maintenance and cleaning of weirs, skimming MHs, oil/grit separators, Source Control Practices (SCPs), and other similar appurtenances.
- Repairing or replacing of damaged pipe, MHs, CBs, and other appurtenances.
- Inspecting pipe condition by visual or video. as required.
- Reviewing and updating records for the asset management database.

Corrective maintenance includes the immediate repair or replacement of pipe breaks and collapses, as well as looking after hazardous, chemical spills that enter the pipe system; in these situations, it is imperative that efforts are made to prevent the spill from entering and contaminating the river system. **All hazardous spills must be reported immediately to the Fire Department (9-1-1) and Alberta Environment (1-800-222-6514).**

10.2.2 Stormwater Ponds

10.2.2.1 General Activities

Regular maintenance activities are required at all stormwater ponds (the actual water body and its adjacent lands) to maintain safety, operational integrity, aesthetic appearances, and recreational utility. These activities include, but are not limited to maintenance of water quality, maintenance of inlet, outlet and control structures, sediment removal, weed control, etc. The *Principles for Stormwater Wetlands Management in the City of Calgary* should also be consulted for wetland maintenance protocol (available from Water Resources upon request).

All ponds have a regular maintenance program that includes inspection and maintenance on an ongoing rotational basis, starting in the spring. During and immediately after significant rainstorms, all ponds are checked; repair and maintenance is conducted as required. Refer to ***APPENDIX H: Maintenance And Response Procedures For Stormwater Ponds (Water Resources And Water Services)***. **In all circumstances, ponds on school sites have high priority.**

During a rainstorm event, Water Services is responsible for securing stormwater ponds as required; as well, they will conduct general cleanup of the ponds afterwards. Parks provides cleanup and maintenance of the areas immediately adjacent to the pond, typically above the pond's HWL. During the maintenance period, the developer will be contacted regarding any further maintenance or repair required as a result of the rainstorm. If public safety issues arise or unauthorized discharges occur to the environment during this time, The City of Calgary may exercise discretion and take the necessary action to remedy the problem(s). The developer will be charged for all expenses incurred by The City of Calgary.

Design of stormwater ponds should facilitate maintenance activities. Key areas should focus on access, emergency escape routes, forebays, maintenance/ drawdown pipes, and bypasses. Refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for more information.

10.2.2.2 Control of Hazardous Spills and Chemical Treatments

One of the main purposes of wet ponds and wetlands is to provide water quality enhancement. Although aquatic vegetation further enhances pollutant removal, hazardous spills can have detrimental effects on vegetation. It is imperative that efforts are made to prevent hazardous, chemical spills from getting into the stormwater pond where it could ultimately discharge to the river system. In many of the ponds, special structures on the inlets have been constructed for containment purposes. **All hazardous spills must be reported immediately to the Fire Department (9-1-1) and Alberta Environment (1-800-222-6514).**

Chemical treatment of wet ponds and wetlands to correct special problems (i.e., turbidity, algal blooms, etc.) is generally discouraged. Where special treatment procedures are required, Water Services should be contacted for review and approval. The application rate and frequency will be determined based on the specific nature of the treatment procedure. After the pond has received FAC approval, Water Services would be responsible for any chemical treatments required for the pond, and will obtain the services of a qualified company/consultant to undertake the work.

10.2.2.3 Turf and Landscaping

Turf and landscape maintenance can be a significant and costly activity. It is often a regular activity during spring, summer, and early fall. The frequency of turf and landscaping activities should conform to The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction*.

Grass cutting is typically undertaken to enhance the aesthetics (or "perceived" aesthetics) of a stormwater pond; it is usually dependent on the surrounding land uses and the adjacent homeowners' expectation of manicured appearances.

However, manicured turf around wet stormwater facilities attracts geese, and fecal bacteria problems can occur as a result. Therefore, grass cutting should be eliminated, or at least limited, around ponds where possible. Use of indigenous grass mixtures and vegetation is also encouraged.

Dry ponds will usually have more manicured turf than wet stormwater facilities. Where grass cutting is required, care should be taken to ensure that grass clippings are not discarded into the pond, since this increases organic loading to the pond (and ultimately the river system) and creates potential plugging problems.

Tree pruning might also be required to the same extent as any other park area. Parks should be consulted in these circumstances. Where possible, and depending on the function of the pond, the number of trees in the grassed area should be limited to provide ease of mowing and visibility for safety purposes.

10.2.2.4 Debris Removal and Vandalism

Debris and litter can be significant issues that require frequent visits to empty litter containers, remove floating and wind blown debris, and check for vandalism. In particular, inlet and outlet structures should be checked for blockages due to debris. Even grass clippings can contribute to blockage of gratings and trash racks. Debris removal and inspection of structures should be carried out in the spring; sufficient monitoring should be implemented throughout the remainder of the summer to ensure proper operation. Inspection for debris should occur after any significant rainstorm (refer to ***APPENDIX H: Maintenance And Response Procedures For Stormwater Ponds (Water Resources And Water Services)***). Debris removal activities should be documented in a pond operation and maintenance log.

Vandalism can involve signage, landscaping, structures, and graffiti. Vandalized property and graffiti should be repaired as soon as possible, particularly if it affects operation of the facility or public safety.

10.2.2.5 Control of Weeds, Aquatic Weeds, and Algae

The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction* and The City of Calgary's *Integrated Pest Management Plan* should be followed for control of weeds.

10.2.2.5.1 Weeds

Weeds around the perimeter of stormwater ponds are described as unwanted vegetation. Weeding should be done by hand to prevent destruction of surrounding vegetation. Refer to The City of Calgary Parks' *Development Guidelines and Standard Specifications-Landscape Construction* for more information.

Herbicide and pesticide use near wet stormwater facilities is discouraged, since this can impact water quality. Alberta's *Code of Practice for Pesticides* should be followed. Contact Parks for more information regarding pesticide use. Use of fertilizers should also be limited to minimize nutrient loading to the ponds.

10.2.2.5.2 Aquatic Weeds

The growth of aquatic weeds in stormwater ponds is affected by water depth, turbidity, and the availability of nutrients. When the water depth exceeds 1.20 m, emergent vegetation is rarely a problem[72], but weed growth around the inside perimeter could still create a problem. Weed control options in this zone include the following:

- Accepting the perimeter weed growth. Many people do not consider emergent vegetation, such as cattails, unsightly.
- Sterilizing the soil along the perimeter with a chemical to restrict weed growth for two years or more.
- Cutting and removing the weed growth from either the land or water. This is generally a short-term solution that will likely require repeated action on an annual basis.
- Draining the pond, removing weed growth, and re-sterilizing the perimeter soil.
- Lowering the water surface for a period of time (i.e., over the winter) to kill the weed growth, then re-establish the water level.

The selected method for weed control is a matter of choice; the last two methods should only be considered if no other methods are viable. However, tolerating the growth is the most economical option, and it protects water quality. Alternatives other than the ones listed above should be investigated and approved by Water Services.

10.2.2.5.3 Algae

Algal growth can occur in any stormwater pond that has an excessive supply of nutrients. Prolonged warm weather also encourages growth. Algal blooms are most likely to occur in areas of the pond adjacent to the inlets. Effective treatment might be possible with the application of chemicals such as alum or lime, but it is not desirable. Bacteria, such as live liquid microorganisms (LLOs), may also be considered for use where possible. The use of pesticides approved by Alberta Environment and Parks may be used, but only as a last resort. Consideration should be given to the timing of chemical applications, as this can impact their effectiveness.

Frequency of weed control is based solely on an “as required” basis. Where possible, the use of chemical treatment is discouraged. Alternate methods are subject to review by, and the approval of, Water Services.

10.2.2.6 Vegetation and Harvesting

It is important that aquatic vegetation in wet stormwater facilities be monitored to ensure that it remains healthy and performs the functions it was designed to carry out. When these objectives cannot be met, vegetation must be re-established or altered to suit the conditions. Determining plant species suitable to Calgary's

72. Source: Alberta Environment 1999 (page 7-5).

climate, and the required objectives, can be difficult, and is often subject to "trial and error" (refer to ***APPENDIX E: Recommended Plant Species***). Where the original plant palette has not necessarily survived intact, but has evolved, this could still be acceptable, as long as the overall objective of the facility is still being met.

When necessary, mechanical harvesting can be used to harvest aquatic plants. Harvesting should only be considered when there is a significant amount of dead vegetation or when the abundance of vegetation growth negatively impacts flood control volumes. Although water quality is promoted in the design of wet stormwater ponds, it must be balanced with flood control (water quantity) objectives. Harvesting of vegetation should be done on an "as required" basis, with input from Water Resources and Parks. Alternative methods to harvesting should also be considered.

10.2.2.7 Pest Management

The City of Calgary has an Integrated Pest Management Program (IPM) that provides detailed information on how to prevent and manage pests, including:

- Weeds.
- Insects and invertebrates (includes mosquitoes).
- Vertebrates (includes wildlife).

For mosquitoes, control efforts are typically concentrated on larger water bodies where stagnation is evident and locations where there are large breeding counts. Spraying is confined to these areas to obtain the best benefit.

In general, wet stormwater facilities are not sprayed unless there is a major problem. Alternate methods of mosquito control are advocated and preferred (i.e., increase circulation, control water level fluctuations, ensure quick drying of pond bottom for dry ponds, manage vegetation, etc.). Natural predators such as dragonflies and minnows also help control mosquito populations. Where spraying is still necessary, approval from Parks is required.

10.2.2.8 Odour Control

In Calgary, odour has generally not been a significant problem at stormwater ponds. Sometimes complaints can arise due to decaying algae or anaerobic conditions. Design of the ponds can take into consideration methods of controlling odours, such as ensuring adequate water circulation (no deadbay areas), applying SCPs to minimize organic loadings, or removing sediment on a more frequent basis. Although aeration generally aids in the control of odour, it is considered a cure rather than a preventive measure. Organic loadings can be minimized by the harvesting of dead vegetation in and around the pond, and by locating deciduous trees away from the water body. Odour control is carried out on an "as needed" basis.

10.2.2.9 Aeration and Circulation

In general, aeration and circulation equipment is not supported by Water Services due to its limited value, as well as the fact that it tends to be used mostly for aesthetic purposes. Although aeration and circulation equipment can make the pond environment less conducive to algae and mosquito production, some researchers have found that algae production can be enhanced when oxygen, rather than sunlight or nutrients, is the limiting factor. Therefore, it is better to ensure that wet stormwater ponds are designed for adequate circulation, by avoiding deadbay areas and controlling the growth of weeds and algae, than to aerate and circulate.

Where developers or owners have entered into a private maintenance agreement, and included aeration or circulation equipment in the pond design, the developers/ owners are responsible for maintenance and servicing on a regular basis. It might be necessary to remove the equipment in the fall and re-install it during the spring, so that it is not affected by winter conditions.

10.2.2.10 Makeup Water

Makeup water can be used to assist in:

- The control of mosquitoes and algae (if it is introduced in a turbulent manner at the right locations).
- Water quality control through dilution.
- Water level control when circumstances dictate the need.

The most appropriate source for makeup water is the municipal system. Due to the high costs associated with makeup water, it should only be used for water quality control, and even then, only after careful consideration of alternative measures.

10.2.2.11 Sediment Removal and Disposal

Sediment control is one of the most important activities for stormwater ponds, since the accumulation of sediments will eventually reduce the permanent storage volume. As well, continued discharge of sediment to a wet facility will ultimately degrade the pond's water quality to a point where the quality of water exiting the pond is no longer acceptable.

Monitoring of sediment buildup is perhaps one of the best means to prevent deterioration of water quality. It is the most easily observed; and, since many other contaminants are affected by sediment, control of this parameter will lead to control of many other substances.

10.2.2.11.1 Removal

The frequency of sediment removal is subjective and varies with the facility and upstream land use;. There are several ways to determine when sediment removal is required, but at this point in time, there is no method that is more reliable than the others.

- An approximate removal interval can be estimated through computer modelling based on an average Total Suspended Solids (TSS) removal efficiency. Refer to ***6.3.2.8 Sediment Forebay*** and ***7.5.3.2 Particle Sizes and Settling Velocities*** for more information on sediment storage capacities.
- The depth of sediment buildup can be monitored. Depth markers could be installed in locations indicative of where sediment buildup will likely occur.
- A bathymetry survey of the pond and/or forebay can be undertaken on a regular basis to determine the rate of buildup.
- Removal is required when the sediment storage volume of the forebay is reduced by a certain percentage or when the dead pool volume of the pond or wetland is reduced by a certain percentage. Work is still being done to determine what this target percentage should be.

Design and operation of the facility will dictate the frequency of sediment removal required. Forebays and sediment traps will require more frequent cleaning due to their smaller size. Use of forebays and main cells of ponds for temporary erosion control in lieu of distributed on-site detention is strongly discouraged, as this is a contravention of the *Drainage Bylaw;* it also leads to problems with siltation of infrastructure. If required, the pond should be cleaned out prior to FAC application. When full development of the catchment has been reached, sediment removal from the entire pond would only be expected every 50 to 100 years, while other BMPs could require cleaning on a more frequent basis. However, with water quality control requirements, deterioration of water quality will likely be the governing factor.

There are no set or preferred methods for sediment removal. Although dredging (mechanical excavation) has been the predominant method used, Water Services is interested in alternate methods. Hydraulic (suction) dredging has also been used. No matter which method is used, it is important to mitigate sediment re-suspension. This can be accomplished with silt curtains, or by scheduling removal maintenance during the driest month(s) of the year, or during winter. Prior to FAC issuance, the developer might be required to remove any accumulated sediment from the pond.

10.2.2.11.2 Disposal

Generally, sediment removed from stormwater ponds is not contaminated to the point where it would be classified as hazardous waste. However, all sediment removed from these stormwater facilities should be tested to determine the appropriate disposal method. Private laboratories should be used to test sediment samples and recommend disposal methods based on acceptable parameter levels. In the majority of situations, disposal at a sanitary landfill will be the likely option; a paint filter test might also be required. Depending on the quality of the sediment, the material could be used as fill material in other areas.

10.2.2.12 Signage

It is important that warning signs be posted at all public entrances and critical access points to the ponds to inform the public of the function of the ponds and the inherent danger (refer to ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** and ***APPENDIX D: Signage for Ponds***). Depending on the size of the pond, additional signs (such as educational ones) might be required around the pond. All signs should be properly maintained for public information and safety. Signs should be inspected throughout the year and repaired as required. Installation of signs should occur prior to the CCC inspection.

10.2.2.13 Structures

10.2.2.13.1 General

Pond structures such as inlets, outlets, outlet control structures, and dry pond CBs (drain inlets) require regular inspection and maintenance to ensure proper operation and public safety. This could include removing gravel, debris, grass clippings, and trash. All gratings must be properly bolted and secured. When necessary, the internal pipe system(s), adjacent pipe systems, and structures should be flushed and the accumulated sediments removed. Inspection should be conducted every spring and after significant rainstorms. Refer to ***APPENDIX H: Maintenance And Response Procedures For Stormwater Ponds (Water Resources And Water Services)***.

10.2.2.13.2 Outlet Valve Adjustments/Water Level Controls

Some ponds, particularly wetlands, might incorporate stop logs to control water levels and discharges to mimic natural pre-existing conditions. Adjustment of these water levels and outlet discharges must still meet water quality, water quantity, and set discharge rate criteria (as set out in the Staged Master Drainage Plan (SMDP) report and/or Pond Report). Where available, Operation and Maintenance (O&M) manuals should be used as a guideline. Contact Water Services and/or Parks s for more information.

10.2.2.13.3 Gate Valves/Automatic Control Gates/Controllers

Gate valves (or bypass valves), automatic control gates, and process logic controllers (PLCs) should be inspected, tested, and serviced on a regular basis. Maintenance should follow the manufacturer's recommended instructions. Maintenance manuals are required from the developer for the installation and use of automatic control gates and controllers.

10.2.2.13.4 Trash Racks and Grates

Trash racks (located in the outlet control structure) and gratings (typically on pond CBs, inlets, and inlet/outlet structures) should be inspected and cleaned on a regular basis, particularly during the rain season. The frequency of cleaning will be a function of the pond design and its operation. For example, gratings with smaller openings will require more frequent cleanings. If trash racks and gratings are not cleaned on a regular basis, the buildup of debris could plug the openings. This will result in grates blowing off and, in the case of trash racks, prevent the pond from draining.

All grates must be bolted. Bolting should also be checked on a regular basis to ensure that it is properly secured and there is no damage from water pressures trying to blow off grates. Any repair work that is required for gratings and bolting should be completed immediately.

10.2.2.14 Winter Activities

Ice skating is a typical winter activity. However, it is only allowed at certain dry ponds where Parks maintains the skating facility. Water Services does not support winter activities such as ice skating on wet ponds and wetlands, mainly due to the fact that Water Services is unable to monitor ice surface thickness for safety or to supervise activities.

Tobogganing activities at dry ponds are supported, provided that the facility has been designed to incorporate toboggan hills. These activities are not supported at wet ponds and wetlands due to ice thickness and monitoring issues.

10.2.2.15 Winter Operation

There are a small number of ponds that have winter bypasses. At the end of the rain season (October), the bypass should be prepared and activated. Prior to the rain season (April), the bypass should be closed. These bypasses and special features should be highlighted in the O&M manual prepared for the pond.

10.2.3 Other Best Management Practices (BMPs)

With the increased emphasis on water quality requirements, there will be increasing use of other BMPs. These technologies are generally still new to Calgary, so must be carefully monitored and maintained. Generally, these technologies are implemented for small urban stormwater runoff areas, and they require frequent inspection and cleaning. Refer to ***CHAPTER 8: BEST MANAGEMENT PRACTICES*** for BMP descriptions.

Some of these technologies are based on percolation principles, and their implementation can increase the recharge potential in a catchment area, decrease overland runoff during storm events, and maintain baseflows in adjacent streams during dry weather periods. Potential groundwater contamination must be a consideration, along with the predominant soil type. Calgary has a large amount of clay based soils that might preclude implementation of such technologies unless appropriate provisions are implemented.

Regular inspections should be conducted. Water Services has adopted the following inspection table based on information compiled by the Ontario Ministry of Environment and The City of Calgary's *Stormwater Source Control Practices Handbook*. Also refer to ***APPENDIX J: Operation And Maintenance Activities for Stormwater Source Control Practices*** for a summary of inspection and maintenance requirements of the SCPs summarized in ***8.3 Source Control Practices (SCPs)***.

Table 10-1: Inspection Routines for Stormwater Facilities[73]

Type of Facility	Inspection Routine
Vegetated Swale - Dry Swale	(1) Is there standing water in an enhanced grass swale? This indicates a blocked upstream check dam or decrease the permeability of the swale. The check dam should be inspected for blockage by trash/debris or sediment. (2) Is the grass/vegetation dead? This indicates a need to re-vegetate the swale. The use of inappropriate grass/vegetation species, exposure to toxins, etc. can cause dead grass/vegetation. (3) Is there erosion downstream of the swale? This might indicate frequent overtopping of the swale, and as such, blockage of the dam or decreased swale permeability. The dam should be inspected for blockage and the erosion corrected by sodding. There might be a need to provide further erosion control (rip rap or plant stakings) to prevent the reoccurrence of erosion).
Vegetated Swale - Bioswale	(1) Is there standing water in the bioswale more than 24 hours after a moderate summer storm (with depth less than 20 mm)? This could indicate clogging of the filter media by sediment or a blockage in the subdrain, and does indicate the need for sediment removal and aeration of the media. If this does not improve the percolation capability of the media, the media might need to be replaced. (2) Is the bioswale always dry, or relatively dry shortly after a storm event? This could indicate blockage (requiring removal of debris) or indicate improper dimensions and/or grading of the inlet. (3) Is there a visible accumulation of sediment in the bottom of the bioswale? This indicates the need for sediment removal. (4) Are there signs of erosion in the bioswale? This indicates the need for better dispersion of the flow over the filter bed, or the provision of mulches not prone to erosion. (5) Is the vegetation in poor condition or dead? This might be caused by vegetation that cannot withstand fluctuations in soil moisture or accumulation of contaminants, or routing of runoff from stormwater hotspots into the bioswale. (6) Is the vegetation overgrown or is there a weed infestation? This might indicate the need for additional mulches. Vegetation should be pruned or removed, as necessary, and weeds pulled and removed.
Absorbent Landscaping	(1) Is there standing water in the landscaped area shortly after a moderate summer storm (with depth less than 20mm)? This could indicate inadequate grading of the landscaped area, improper dispersion of the inflows, improper soils or compaction of the soils. (2) Is the landscaped area always dry, or relatively dry shortly after a storm event. This could indicate that the inflow from downspouts or hard surfaces is not evenly distributed over the landscaped area. (3) Are there signs of erosion in the landscaped area? This indicates the need for better dispersion of the flow over the soils or the provision of mulches not prone to erosion. (4) Is the vegetation in poor condition or dead? This might indicate the need for additional mulches. Vegetation shall be pruned or removed, as necessary, and weeds pulled and removed.

73. Source: Ontario Ministry of Environment 2003 (pages 6-5 through 6-7).

Type of Facility	Inspection Routine
Bioretention Area	(1) Is there standing water in the bioretention area more than 24 hours after a moderate summer storm (with depth less than 20 mm)? This could indicate clogging of the filter media by sediment or a blockage in the subdrain, and does indicate the need for sediment removal and aeration of the media and/or cleaning of the sub-drain. If sediment removal and aeration do not improve the percolation capability of the media, the media might need to be replaced. (2) Is the bioretention area always dry, or relatively dry shortly after a storm event? This could indicate blockage requiring removal of debris, or indicate improper dimensions and grading of the inlet (3) Is there a visible accumulation of sediment in the bottom of the bioretention area? This indicates the need for sediment removal. (4) Are there signs of erosion in the bioretention area? This indicates the need for better dispersion of the flow over the filter bed, or the provision of mulches not prone to erosion. (5) Is the vegetation in poor condition or dead? This could be caused by vegetation that cannot withstand fluctuations in soil moisture or accumulation of contaminants, or routing of runoff from stormwater hotspots into the bioretention area. (6) Is the vegetation overgrown or is there a weed infestation? This might indicate the need for additional mulches. Vegetation shall be pruned o removed, as necessary, and weeds pulled and removed.
Permeable Pavement	(1) Is there standing water on the porous pavement shortly after a moderate summer storm (with depth less than 20 mm)? This could indicate clogging of the pavement structure by sediment or a blockage in the subdrain, and does indicate the need for sediment removal and /or cleaning of the sub-drain. If sediment removal does not improve the percolation capability of the pavement structure, the pavement structure might need to be replaced. (2) Does the pavement experience frost heave? This could indicate clogging of the pavement structure by sediment, and does indicate the need for sediment removal in spring. If sediment removal does not improve frost heave in the following winter, the pavement structure may need to be replaced. (3) Is the vegetation in a turf paving system in poor condition or dead? This may be caused by vegetation that cannot withstand fluctuations in soil moisture, accumulation of contaminants, heat stress, or routing of runoff from stormwater hotspots onto the porous pavement.
Rainwater Harvesting	(1) Does the tank spill for most storm events? This could indicate an undersized tank or lack of demand. The water balance analysis should be revisited to establish the course of action required. (2) Are there signs of (wind) erosion in the landscaped area? This might indicate the need for mulches not prone to erosion. (3) Is the vegetation in poor condition or dead? This may be caused by vegetation that cannot withstand fluctuations in soil moisture and micro-climate. (4) Is the vegetation overgrown or is there a weed infestation? This might indicate the need for pruning or removing of vegetation, as necessary, and pulling and removing of weeds. (5) Does the green roof leak? This indicates a penetration of the underlying waterproof membrane, improper flashing, or blockage of inlets and overflows. The presence of a leak detection system would assist with pinpointing the exact location of the leak.
Stormwater Capture and Re-use	(1) Are the nozzles in an irrigation system subject to unacceptably high maintenance? This could indicate the need to change the location of the inlet in the stormwater pond or the need for a pre-treatment system.

Type of Facility	Inspection Routine
Filter Strips	(1) Are there areas of dead or no vegetation downstream of the level spreader? This indicates the need to re-vegetate the filter strip. (2) Are there indications or rill erosion downstream of the level spreader? This indicates the need to re-vegetate the filter strip. The rill erosion may be caused by non-uniform spreader height. The spreader should be checked near the erosion areas to determine if it is in need of repair. (3) Is there erosion of the level spreader? This indicates that the spreader should be re-constructed in areas where the spreader height is non-uniform. (4) Is there standing water upstream of the level spreader? This indicates that the level spreader is blocked. The level spreader should be checked for trash, debris, or sedimentation. The blockage should be removed and the spreader re-constructed if necessary.
Buffer Strips	(1) Are there areas of dead vegetation along the buffer strip? This indicates the need to re-vegetate the buffer strip.
Oil/Grit Separators	(1) Is there sediment in the separator? The level of sediment should be measured using a gradated pole with a float plate attached to the bottom. The pole should be gradated such that the true bottom of the separator compared to the cover/grate is marked for comparison. (2) Is there oil in the separator? A visual inspection of the contents should be made from the surface for trash/debris and/or the presence of an oil/industrial spill. An oily sheen, frothing or unusual colouring to the water will indicate the occurrence of an oil or industrial spill. The separator should be cleaned in the event of spill contamination.
Filters - Sand Filters	(1) Is there standing water in the sand filter more than 24 hours after a moderate summer storm (with depth less than 20 mm)? This could indicate clogging of the sand by sediment or a blockage in the subdrain, and does indicate the need for sediment removal and aeration of the sand and/or cleaning of the sub-drain. If sediment removal and aeration do not improve the percolation capability of the sand, the sand may need to be replaced. (2) Is the sand filter always dry or relatively dry shortly after a storm event? This could indicate blockage requiring removal of debris, or indicate improper dimensions and grading of the inlet. (3) Is there a visible accumulation of sediment in the bottom of the sand filter? This indicates the need for sediment removal. (4) Are there signs of erosion in the sand filter? This indicates the need for better dispersion of the flow over the filter bed, or the provision of mulches not prone to erosion.
Filters - Cartridge Type Filters	(1) Is there standing water in the cartridge filter more than 24 hours after a moderate summer storm (with depth less than 20 mm)? This could indicate clogging of the cartridges by sediment or a blockage in the subdrain, and does indicate the need for sediment removal, cleaning and replacement of the cartridge filters, and cleaning of the sub-drain. If the cleaning and replacement frequency of the cartridges is unacceptably high, better pre-treatment may be required. (2) Is the cartridge filter always dry, or relatively dry shortly after a storm event? This could indicate blockage requiring removal of debris, or indicate improper dimensions and grading of the inlet. (3) Is there a visible accumulation of sediment in the bottom of the vault containing the cartridge filters? This indicates the need for sediment removal.
Soakaway Pit	(1) Does the soakaway pit spill for most events or have standing at the surface? This indicates that the soakaway is likely clogged and needs to be cleaned out.

Type of Facility	Inspection Routine
Wet Ponds Wetlands	(1) Is the pond level higher than the normal permanent pool elevation more than 24 hours after a storm? This might indicate blockage of the outlet by trash or sediment. Visually inspect the outlet control structure for debris or blockage. (2) Is the pond level lower than the normal permanent pool elevation? This could indicate a blockage of the inlet. Visually inspect the inlet structure for debris or blockage. (3) Is the vegetation around the pond dead? Is the pond all open water (i.e., no bulrushes or vegetation in the water)? Are there areas around the pond with easy access to open water? This indicates a need to re-vegetate the pond. (4) Is there an oily sheen on the water near the inlet or outlet? Is the water frothy? Is there an unusual colouring to the water? This indicates the occurrence of an oil or industrial spill and the need for cleanup. (5) Is sediment visible in the effluent or throughout the pond? This indicates the need for sediment removal. The sediment depth can be checked using a gradated pole with a flat plate attached to the bottom. A marker (pole, buoy) should be placed in the pond to indicate the spot(s) where the measurement should be made. A visual inspection on the pond depth can also be made if the pond is shallow and a gradated marker is located in the pond.
Dry Ponds	(1) Is there standing water in the pond more than 24 hours after a storm? This could indicate blockage of the outlet by trash or sediment. Visually inspect the outlet control structure for debris or blockage. (2) Is the pond always dry, or relatively dry within 24 hours of a storm? This could indicate a blockage of the inlet or too large of a water quality/erosion control outlet. Visually inspect the inlet structure for debris or blockage. (3) If applicable, is the vegetation around the pond dead? Are there areas around the pond with easy access to open water? This indicates a need to re-vegetate the pond. (4) Is there a visible accumulation of sediment in the bottom of the pond or around the high water line of the pond? This indicates the need for sediment removal.

10.2.3.1 Vegetated Swales

10.2.3.1.1 Dry Swales

Dry swales convey stormwater runoff to other BMPs, stormwater management facilities, or receiving water bodies. The vegetation in the dry swales filters sediments in the runoff while reducing flow velocity, soil compaction, and erosion. They are often equipped with check dams, allowing for temporary storage and sedimentation in a series of pools. Maintenance involves:

- Removing debris and litter at inlets, culverts, and throughout the dry swales.
- Removing of sediment.
- Spiking and scarifying the bottom and removing of the thatch layer.
- Mowing grass.
- Weeding and removing invasive species.
- Repairing check dams.

10.2.3.1.2 Bioswales

Bioswales combine aspects of dry, grassed swales and infiltration trenches. They are designed to allow the runoff volume from the water quality design event to slowly infiltrate into the pore space of an underlying fine media layer. During and between runoff events, the media layer gradually dewaters into the subsoils or an underlying gravel or drain rock reservoir system, often equipped with a subdrain system. A surface swale provides conveyance for larger storm events. Maintenance involves:

- Removing debris and litter at inlets, culverts, and throughout the bioswale.
- Removing sediment.
- Spiking and scarifying the bottom and removing the thatch layer.
- Mowing grass.
- Pruning and removing trees and shrubs,
- Weeding and removing invasive species.
- Removing and replacing mulches and filter media.
- Cleaning the subdrain.

10.2.3.2 Absorbent Landscaping

Absorbent landscaping, acting like a sponge, soaking up, storing and slowly releasing stormwater runoff, provides the functionality of the native soils prior to development. By preserving and/or restoring soil moisture, storage and infiltration capability of soils, it can significantly reduce runoff volume. Maintenance of the landscaped area includes:

- Watering as needed, especially during the vegetation establishment period.
- Mowing grass.
- Pruning and trimming trees and shrubs.
- Dividing and replanting perennial plants.
- Weeding and removing invasive species,
- Replenishing mulch and compost.
- Removing the thatch layer.
- Spiking and scarifying soil.
- Removing debris and litter.

10.2.3.3 Filter Strips

Filter strips are vegetated strips that diffuse stormwater runoff directed by a level spreader upstream. The runoff is distributed as sheet flow. Filter strips are similar in many respects to grassed swales. Filter strips slow down surface flow, thereby allowing infiltration and sedimentation. Typically, filter strips are designed for small runoff areas. Maintenance activities involve maintaining the vegetated cover and removing sediment upstream of the filter strip. Removal of the upstream sediment can be accomplished using a vacuum truck or conventional small grading equipment, such as a bobcat. Refer to ***8.4.1 Filter Strips*** for design.

10.2.3.4 Buffer Strips

Buffer strips are vegetated areas placed adjacent to water bodies. Buffer strips are not generally engineered and do not provide a location for collection of concentrated runoff flows. Sediment removal is not advocated, since sedimentation will be dispersed and cleanout would likely destroy the vegetation. However, where vegetation fails to establish itself, re-vegetation will be required. Refer to ***8.4.2 Buffer Strips*** for design.

10.2.3.5 Oil/Grit Separators

Oil/grit separators are structures or appurtenances that separate sediment and oil from stormwater runoff. Due to the size of the structure, only a small area of runoff can be treated, otherwise efficiency removal is lost. There are primarily two types of oil/grit separators: 3-chamber separators and bypass separators. Maintenance on 3-chamber separators involves the removal of sediment and oil from the chambers as required. Bypass separators, such as Stormceptors and Vortechnics, are more easily maintained by vacuum trucks. Entry into the structure is not required. Cleaning for all oil/grit separators should be carried out annually and after any known spills have occurred. Refer to ***8.4.3 Oil/Grit Separators (OGSs)*** for design.

10.2.3.6 Filters

Filters are treatment BMPs that promote pollutant removal. They can be constructed as either surface systems (i.e., sand or organic filters) or sub-surface devices (i.e., cartridge type filter systems).

Maintenance for sand filters involves:

- Removing debris and litter at the inlet and throughout the sand filter.
- Removing of sediments.
- Spiking and scarifying the bottom and removing the schmutzdecke.
- Removing and replacing mulches and sand.
- Cleaning the subdrain.

Maintenance of cartridge type filters consists of removal of debris and litter at the inlet, removal of sediments, and cleaning and replacement of cartridge filters. Refer to ***8.4.4 Filters*** for design.

10.2.3.7 Soakaway Pits

Soakaway pits or dry wells are typically only considered as temporary systems where storm sewers are not available and the gravelly subsurface soil conditions allow for adequate drainage. They are normally used to infiltrate relatively clean water from areas such as rooftops, which reduces the potential for clogging and maintenance. The filter should be cleaned on an annual basis during the fall (i.e., after the leaves have fallen off the trees). Frequent overflows during small summer rainstorms indicate that maintenance of the filter is required.

10.2.4 Pumping Facilities

Pumping facilities are infrequently used in stormwater management systems. Implementation of pumping facilities is strongly discouraged where gravity drained systems can be implemented. Pumping stations are a major concern in stormwater systems because they are infrequently utilized, and the consequences of failure can be severe if they are not designed properly. When a pump system/storm lift station is approved, a backup system (i.e., both power supply and pumps) is required. Storage facilities may also be required to be oversized to accommodate a pump failure. Refer to ***3.3.9 Pumping and Lift Stations*** for more information.

10.2.5 Monitoring Requirements

10.2.5.1 Water Level and Water Quality

Monitoring is important to ensure proper facility design and operation. Water Services typically requires two types of monitoring: water level monitoring and water quality monitoring.

All stormwater ponds are required to have remote water level monitoring (refer to ***6.1.9 Operating and Maintenance (O&M) Manuals***). This allows monitoring by Water Resources' staff when the pond is being used for storage purposes. The water level monitoring equipment activates the alarm system, based on various conditions.

Water quality monitoring may be required at wet ponds, wetlands and other BMPs during the maintenance period. The program must be approved by Water Resources. Refer to ***7.5 Water Quality Modelling*** and ***7.8 Water Quality Monitoring Programs***. The purpose of water quality monitoring is to ensure ponds and BMPs are meeting established water quality and other relevant performance criteria.

10.2.5.2 Annual Maintenance and Checks

It is important that the water level monitoring equipment be checked on an annual basis prior to the start of the rain season (spring) and on an "as needed" basis during the rain season. Refer to ***APPENDIX H: Maintenance And Response Procedures For Stormwater Ponds (Water Resources And Water Services)***. All equipment and alarm settings must work properly. A log book of maintenance and repairs should be kept. Water Resources/Services conducts all monitoring checks. The developer is responsible for the cost of any repairs required during the maintenance period.

10.2.6 Operating and Maintenance (O&M) Manual

An O&M manual must be prepared by the owner/developer, or his designated consultant, for all stormwater ponds (refer to ***6.1.8 Signage***) and other BMP technologies (as required). The manual is required to ensure all facilities are operated and maintained properly, particularly when there may be special features incorporated (i.e., automatic control gates, water level control logs, vegetation requirements, etc.). The manual should be submitted as part of the CCC application. Information in the manual should include, but is not limited to the following:

- Schematic or plan of facility showing pertinent structures
- Detailed schematics of components and control logic for the pond
- List of additional mechanical and electrical equipment used in the design of the facility. This should include manufacturer's and monitoring manuals, equipment/ part lists, manufacturer's operation requirements, maintenance, service and repair instructions, and warranties.
- Proposed operating instructions for normal and emergency conditions.
- Itemized maintenance list and proposed checking and cleaning schedules, including maintenance requirements for special features, such as underdrains.
- Long term and short term maintenance requirements for vegetation.
- Maintenance record and costs for the pond or BMP during the maintenance period.

Water Resources will forward a copy of the manual to the Field Services (Asset Maintenance/Business Performance) group who is responsible for maintenance after FAC.

10.2.7 Capital and Operating Costs

Capital and operating costs of stormwater facilities (BMPs) can be difficult to estimate for construction and maintenance activities. However, the life-cycle cost of stormwater systems is important to overall development, and should not be overlooked when assessing alternative stormwater management systems. Maintenance and operation costs are, arguably, the most important, since these facilities and systems must be maintained and operated in perpetuity.

Most BMPs are very site specific, and design may vary due to local conditions, design objectives, land uses, and public preferences. Therefore, there might be a great deal of variability in capital and operating costs.

Although Water Services has limited information regarding construction and maintenance of stormwater BMPs, the experience of other municipalities can be useful to designers in their efforts to select appropriate BMPs. It is necessary for designers to examine the costs on a site-by-site basis for each BMP selected. Water Services is trying to track construction and maintenance costs, but most of the current information is for stormwater pond BMPs.

The total cost of implementing stormwater BMPs includes a number of components that relate to administration, planning and design, land acquisition, site preparation and development, and operation and maintenance.

- Capital Costs: This represents the total cost, including labour and materials, associated with the actual construction of the BMP facility.
- Engineering Costs: This includes the planning, design. and construction management costs of the BMP facility. Engineering costs are often estimated at 10% to 15% of the total capital cost.

- Contingency Costs: This includes unforeseen costs that occur over the construction period. Contingency costs are often estimated at 15% of total capital cost.
- Operation and Maintenance Costs: This represents the costs required to ensure the proper operation, longevity, and aesthetic functioning of the BMP at acceptable levels. This should also include any source control costs required.
- Decommissioning and Replacement Costs: Although the stormwater systems are assumed to exist in perpetuity, each component has a finite life span. Therefore, decommissioning and replacement costs represent the costs to replace a defective BMP and/or decommission a BMP when it is no longer needed.

CHAPTER 11: TECHNICAL REQUIREMENTS

Note: This chapter details the requirements for stormwater-related reports and Engineering (construction) drawings. Additional information might be requested from time to time by Water Resources for complex sites. While Water Resources allows for a degree of flexibility in the presentation and formatting of the reports, the actual content, as a function of the type of proposed project and works, should closely reflect the submission requirements identified in this Chapter. It is noted that, while the Technical Requirements summarized in this section are believed to be comprehensive, other relevant issues might need to be addressed by the designer as a function of the uniqueness of each site. It should also be noted that the requested information is subject to change.

11.1 Reports

Stormwater reports are typically required to establish technical backup demonstrating the viability of proposals and ultimately the basis for detailed design. Specific drainage concerns must be addressed at an appropriate and increasing level of detail as planning and development proceeds. The reports provide continuity to the progressing development and design of Calgary's communities. ***Figure 1-4*** illustrates the planning process, as well as when the different types of reports are required. Listed in the following sections are the report requirements for the different stages of stormwater management planning and design. Report definitions can be found in ***CHAPTER 1: STORMWATER MANAGEMENT AND PLANNING***.

11.1.1 River Basin Plans (RBPs)

River Basin Plans (RBPs) are typically a provincial responsibility. At this level, issues will focus on the supply and demand for water as a resource. Water quantity, quality, and habitat protection are significant factors at this level. The River Basin Plan relevant to the City of Calgary is the *South Saskatchewan River Basin Water Management Plan* developed by Alberta Environment.

11.1.2 Watershed Plans (WPs) and Water Management Plans (WMPs)

Watershed Plans (WPs) and Water Management Plans (WMPs) are generally carried out as a joint responsibility between the City of Calgary, the Province, and adjacent municipalities, and often involve multiple stakeholders as well. WMPs provide a conceptual framework for stormwater and drainage servicing at a watershed or sub-watershed level. At this level, structural components can include servicing options, drainage and environmental constraints, Best Management Practices (BMPs), stormwater ponds, and alternatives. Non-structural components might include economic issues, staging, utility corridors, Biophysical Impact Assessments (BIAs), and performance criteria. Report requirements are jointly established by Water Resources, the Province, and any other stakeholders at the time the WMP is commissioned. Reports are typically prepared by qualified consultants, academics, and stakeholder groups. Examples of relevant WMPs include the *Bow Basin Watershed Management Plan* (in progress), the *Nose Creek Watershed Water Management Plan* and the *Pine Creek Watershed Study*.

11.1.3 Master Drainage Plans (MDPs)

A Master Drainage Plan (MDP) report should be prepared in support of Area Structure Plans (ASPs) or Community Plans (CPs). As such, it encompasses one or multiple development cells or subdivisions, and in some cases additional external areas, and generally covers a portion of the area served by a WMP. Although the MDP area is often serviced by one outfall, it can include several outfalls. Typically, an MDP interprets the recommendations established in a WMP, providing more detailed guidance for the area covered by the MDP.

11.1.3.1 Submission Requirements

i) Submission. of an MDP report is required prior to approval of Outline Plans (OPs) or Staged Master Drainage Plans (SMDPs). **If an MDP is prepared in support of an OP that contains a pond or wetland subject to compensation, the contents must reflect the requirements of both an MDP submission (as per this section) and an SMDP submission (as per *11.1.4 Staged Master Drainage Plans (SMDPs)*).**

   Specific attention must be paid to the interface with the river valleys or streams, and whether compensation is required, to address impacts on existing wetlands. A BIA must therefore be conducted prior to or in conjunction with the MDP report. The scope of the study must be verified with, and any additional issues to be addressed identified by, Water Resources' Planning and Analysis team for the MDP and Parks for the BIA.

ii) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer's stamp and company permit stamp and/or permit number.

iii) *Checklist #9: Master Drainage Plan (MDP)* must be completed and submitted to Water Resources, Planning & Analysis as part of the MDP report. If the MDP is combined with a SMDP, *Checklist #10, Staged Master Drainage Plan (SMDP)* must be submitted as well. Both checklists are available on the *Development Approvals Submissions* page on The City of Calgary's website.

iv) A total of five (5) hard copies of the report are required for review purposes. All reports must be forwarded to: Leader, Planning & Analysis, Water Resources. Copies of the report will be then be forwarded to the appropriate reviewing personnel or agencies, including Alberta Environment and Calgary Parks.

   If an MDP also covers the contents of an SMDP, it must be identified as such in the cover letter; it will then be reviewed jointly by Water Resources Planning & Analysis and Development Approvals teams. Prior to final acceptance of the report, five (5) updated hard copies of the report must be submitted, along with one (1) copy in PDF format. This (revised) document must include all updated written content, tables, figures, and drawings reflecting the comments received during the review period.

11.1.3.2 Technical Requirements

The technical requirements for an MDP report are typically similar to those required for an SMDP report (refer to ***11.1.4 Staged Master Drainage Plans (SMDPs)***). If stand-alone SMDP reports are anticipated at a later stage, the MDP report can be more general in nature. In that case, all dimensions presented in the MDP must be identified as "preliminary and subject to confirmation and change during the preparation of the SMDP", and the MDP would be considered insufficient to support an OP submission.

The MDP should be developed through the evaluation of multiple servicing strategies that provide an acceptable level of service while meeting the objectives of the WMP, as well as satisfying constraints imposed by topography, natural features, land uses, and land ownership. The options should be evaluated, and the option selected that best provides an acceptable level of service. More specifically, the MDP should:

i) Document the findings of site inspections of existing drainage features, such as wetlands, perennial and intermittent streams including ravines, as well as man-made drainage infrastructure such as impoundments, ponds, and culverts.

ii) Evaluate the stability thresholds and conveyance characteristics of existing streams and ravines, with specific attention to those streams and ravines that convey the (concentrated) runoff from outfalls, gutters, or overflows.

iii) Identify the extent of ravines to be maintained in a natural-like state.

iv) Identify those wetlands owned (or potentially subject to be claimed by) the Province, and/or those that are subject to compensation. Also identify those wetlands deemed important for preservation by Parks.

v) Confirm pre-development and post-development drainage boundaries.

vi) Based on existing WMPs and/or the analysis of pre-development conditions, confirm post-development runoff rate and volume targets.

vii) Establish water quality and habitat protection requirements.

viii) Identify the capacity of existing drainage infrastructure.

ix) Identify and locate the following:

- Overland drainage routes.
- Approximate storm trunk alignment, dimensions and elevations.
- Stormwater management ponds.

x) Describe other types of BMPs, including the Source Control Practices (SCPs) envisioned.

xi) Present the results of a post-development rainfall-runoff analysis, including the envisioned SCPs, to determine preliminary pond surface area, storage capacity requirements, and runoff volumes.

xii) Conduct a planning-level hydrogeological assessment addressing the following:

- Groundwater impacts relevant to the preservation of existing streams or ravines in a natural-like state.
- Hydrogeological aspects related to the implementation of SCPs (including soil texture, permeability, groundwater levels, etc.).

xiii) Prepare estimates of probable costs for City of Calgary funded infrastructure.

xiv) Present recommendations for future analysis and/or design during the preparation of the SMDPs.

Refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for analysis and modelling requirements.

Servicing options should be investigated where required, with recommendations for the most practical alternative. Typically, the minimum area serviced by a pond is about ¼ Section.

If stormwater discharges into existing streams or ravines are proposed, post-development flow-duration curves should mimic pre-development flow-duration curves, to ensure long term morphologic stability, aesthetic and habitat function comparable to pre-development conditions. In addition, Parks approval will be required.

11.1.4 Staged Master Drainage Plans (SMDPs)

An SMDP typically includes a large area that may or may not be serviced by an outfall. The SMDP generally covers a portion of the areas served by an MDP, and is not necessarily required in all circumstances. Typically, an SMDP interprets the recommendations established in an MDP, providing more detailed guidance for the area covered by the SMDP, specifically any stormwater management facilities.

An MDP might be sufficient provided there is enough detail, the catchment boundaries have not significantly changed, and there is no significant deviation from the stormwater management system proposed. **However, the level of detail found in a full-fledged SMDP is required when the footprint of a dry pond, wet pond, or stormwater wetland (i.e., either constructed stormwater wetland or engineered natural stormwater wetland) needs to be established in support of an OP submission (**refer to ***6.4.1 Wetland Categories*** for stormwater wetland definitions). Specifically, any time the footprint of a stormwater management facility might be impacted by wetland compensation or similar issues, sufficient detail needs to be provided to demonstrate that the footprint of the pond is adequate to provide sufficient flexibility for the actual design of the pond.

As per ***CHAPTER 1: STORMWATER MANAGEMENT AND PLANNING***, an SMDP is often followed by a stand-alone Pond Report. However, the Pond Report can be incorporated into an SMDP report. In that case, the contents of the SMDP report **must reflect the requirements of both an SMDP submission (as per this section) and a Pond Report submission (as per *11.1.6 Stormwater Ponds***). If details of the pond are likely to change significantly, a separate Pond Report is recommended; then the SMDP can provide more generalized information on the ponds. However, resolution of wetland or compensatory issues with Parks that might affect the footprint of the facility cannot be left until the Pond Report stage.

A minimum time period of **20 business days** is required for SMDP review and comments by Water Resources. Comments by Parks will be incorporated in Water Resources' response.

For the latest version of SMDP submission and technical requirements, refer to the *Development Approvals Submissions* page on The City of Calgary's website, where relevant checklists and templates are provided (or will be provided in the near future).

11.1.4.1 Submission Requirements

i) Submission of an SMDP report is required prior to approval of the OP that covers the area in question. As per ***11.1.3.1 Submission Requirements*** an MDP report can include the contents of an SMDP; however, in that case, the MDP report must address the requirements of both an MDP submission as per ***11.1.3 Master Drainage Plans (MDPs)*** and an SMDP submission as per ***11.1.4 Staged Master Drainage Plans (SMDPs)***. Similarly, if an MDP does not exist, the contents of the SMDP must address the requirements of both an MDP submission and an SMDP submission.

Specific attention must be paid to the interface with the river valleys or streams and whether compensation is required to address impacts on existing wetlands. A BIA must therefore be conducted prior to or in conjunction with the SMDP report. Any additional issues to be addressed will be established by Water Resources, Development Approvals for the SMDP and Parks for the BIA.

ii) If the SMDP is intended to include the contents of a detailed Pond Report, the SMDP report must address the requirements of both an SMDP submission as per ***11.1.4 Staged Master Drainage Plans (SMDPs)*** and a Pond Report submission as per ***11.1.6 Stormwater Ponds***. Approvals as per the *Environmental Protection and Enhancement Act (EPEA)* and the *Water Act* (outlined in ***11.1.7.1 Submission Requirements*** (Item ii)) will need to be secured as well. Allow sufficient time for review and processing of the registration. In addition, approval of the joint SMDP/Pond Report is required **prior** to review and approval of the Final Construction Drawings.

iii) When the study area of the SMDP includes natural wetlands subject to compensation or engineered natural stormwater wetlands (refer to ***6.4.1 Wetland Categories***), any issues that might affect the footprint of proposed stormwater management facilities need to be resolved with Parks prior to acceptance of the SMDP report. These issues could include:

- Level of pre-treatment required for the stormwater allowed to enter an engineered natural stormwater wetland, with specific attention to Total Suspended Solids (TSS) size removed, and removal of nutrients and heavy metals.
- Number and location of inlets to an engineered natural stormwater wetland.
- Type and location of forebays or equivalents.
- Winter bypasses minimizing the impact of chloride-laden winter runoff on sensitive areas.
- Magnitude and volume of runoff allowed to enter an engineered natural stormwater wetland, minimizing scour and erosion potential at the inlets, and acceptable water level fluctuations.
- Measures proposed to prevent use of substrates that are “contaminated” or contain invasive or non-desirable species.
- Erosion and sediment control provisions to minimize possibility of sediment-laden runoff from upstream catchment area entering an engineered natural stormwater wetland. As well, identify those wetlands deemed important for preservation by Parks.
- Sediment deposition occurring prior to a Final Acceptance Certificate (FAC) inspection.

iv) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer’s stamp and company permit stamp (or company permit number), and be signed and dated by the Engineer.

v) A total of **four (4)** copies of the report are required for review purposes. All reports must be forwarded to the Leader, Development Approvals in Water Resources. Copies of the report will be then be forwarded to the appropriate internal reviewing personnel or external agencies, including Alberta Environment.

11.1.4.2 Technical Requirements

SMDP reports should include all of the elements outlined in sections ***11.1.4.2.1*** through ***11.1.4.2.12***.

11.1.4.2.1 Cover Letter

The cover letter should

- Identify whether any ponds are public or private.
- Highlight areas where there are any unresolved issues or areas where guidelines and/or checklist items cannot be met.
- If applicable, identify whether the report covers both an MDP and an SMDP, or both an SMDP and a Pond Report.
- identify compensatory requirements that might impact the drainage design for the study area.

11.1.4.2.2 Checklists

Checklist #10: Staged Master Drainage Plan (SMDP) must be completed and submitted to Water Resources, Development Approvals as part of the SMDP report. It is available on the *Development Approvals Submissions* page on The City of Calgary's website.

All stormwater management ponds should be located within the developer's property limits. If the proposed pond and/or associated downstream tie-ins or outfalls are off-site, a **Statement of Agreement** with affected stakeholders should be enclosed. This statement **must** be co-signed by all the affected stakeholders.

If there is no preceding MDP, the SMDP might have to address all items from the MDP checklist! Contact Water Resources, Development Approvals to verify specific requirements. Similarly, if the SMDP is combined with a Pond Report, the checklists outlined under *11.1.7.2.2 Checklists* must be completed and submitted.

11.1.4.2.3 Study Area and Location

Include and/or identify the following:

- OP #.
- Name of the project and phase.
- Name of developer and/or landowner.
- Land location (legal description).
- Overall study area description and catchment area size.

It is best to include **both** of the following figures:

- **Location Area**, showing the location of the area with respect to the city (showing major roadways).
- **Study Area**, showing legal land location and section number(s), development and overall catchment area boundaries, catchment area size, and contours. Also clearly identify existing wetlands owned by the Province and subject to compensation.

The drainage boundaries for an SMDP report should not be based on jurisdictional boundaries, as this may not provide the best servicing concept for the area.

11.1.4.2.4 Site Description

The description of the study area should include:

- Type and size of individual development cells (i.e., residential, industrial, commercial, etc.).
- Interim undeveloped or future external development areas included in the study area, if applicable.
- Total site area, including external areas.
- Overland drainage direction, downstream storm ponds, receiving ponds and outfalls.
- All stormwater quality treatment facilities or SCPs existing or envisioned in the catchment.

11.1.4.2.5 Design Objectives

With reference to the relevant WMP and MDP reports, state:

- Allowable unit area and total discharge rates (in L/s/ha and L/s respectively), as well as and runoff volume target (in mm) if applicable, to downstream areas or into ravines. Changes from existing or pre-development conditions need to be rationalized.
- Storm discharge and runoff (expressed in L/s/ha and L/s, and mm, respectively) allowed from upstream catchment areas, including temporary undeveloped catchments.
- Design basis for storm sewer system (expressed in L/s/ha).
- Design basis for required storage capacity.
- Water quality performance targets.
- Water re-use strategies. including seasonal usage patterns if applicable. In case of water re-use strategies, the report must also address a fall-back scenario in which the re-use strategies are not operational.

The designer must confirm that the catchment boundaries for the SMDP report match those of existing reports. Alternatively, supplemental information must be provided to rationalize any changes.

Information about stormwater quality treatment facilities or SCPs upstream of any ponds, or water re-use strategies, is of particular importance where the design of these facilities is directly affected.

In the case of engineered natural stormwater wetlands and constructed stormwater wetlands that provide compensatory value, identify the design objectives for the operation of the “habitat” components of the wetlands, as agreed with Water Resources and Parks during the establishment of the MDP or preparation of the SMDP.

11.1.4.2.6 Biophysical Impact Assessment (BIA) and Inventory

Identify BIA and Biophysical Inventory reports for the study area, and identify habitat targets. Summarize the conclusions from these reports and demonstrate how the recommendations have been incorporated into the drainage concept for the study area.

11.1.4.2.7 Subcatchments

Include a figure:

- Delineating subcatchments and sizes of the subcatchments in the catchment area of the pond (including upstream external areas, if applicable).
- Showing how overland drainage from upstream areas, if any, is routed into the stormwater management facilities. Identify what level of pre-treatment is provided.

Other details such as initial abstraction losses, imperviousness and infiltration characteristics such as curve numbers or infiltration rates are to be included with the computer model and/or in the appendices.

It is best to include a **Storm Area Design** figure showing:

- Pre-development boundaries (i.e., for existing wetlands).
- Existing drainage features that are retained as part of the drainage concept, such as wetlands, perennial and intermittent streams including ravines, and man-made drainage infrastructure (i.e., impoundments, ponds, and culverts).
- Proposed catchment area boundaries.
- On-site unit permissible area discharge rates, storage requirements, and runoff volume targets.
- Legal boundaries (as appropriate).
- Overland drainage routes.
- Location and type of stormwater management facilities.
- All overland emergency escape routes.
- Contours of adjacent properties.
- Receiving water bodies and outfalls.
- Trunk alignment.

11.1.4.2.8 Pond Characteristics

Identify type of stormwater management facilities (i.e., dry pond, wet pond, constructed stormwater wetland or engineered natural stormwater wetland) and preliminary bottom, Normal Water Level (NWL) (or Lower Normal Water Level ((L)NWL) and Upper Normal Water Level ((U)NWL) if subject to water re-use), High Water Level (HWL), and Freeboard (FB) elevations. Tabulate the Stage-Storage-Discharge relationship for the pond, as per ***Table 11-1***.

Table 11-1: Stage-Storage-Discharge Table for Pond

Elevation (m)	Depth Above NWL (m)	Area (m^2)	Total Storage Volume (m^3)	Active Storage Volume (m^3)	Discharge (L/s)	
65.75	N/A	1,949.0	0.0	0.0	0.00	
66.00	N/A	2,447.0	548.0	0.0	0.00	
66.25	N/A	4,049.0	1,352.0	0.0	0.00	
66.50	0.00	5,650.0	2,559.0	0.0	0.00	NWL
66.75	0.25	7,122.0	4,152.0	1,593.0	25.80	
67.00	0.50	8,178.0	6,063.0	3,504.0	41.10	
67.25	0.75	8,999.0	8,209.0	5,650.0	52.00	
67.50	1.00	9,204.0	10,484.0	7,926.0	61.10	
67.25	1.25	10,044.0	12,890.0	10,331.0	68.90	
68.00	1.50	10,848.0	15,501.0	12,942.0	76.00	HWL
68.25	1.75	11,578.0	18,303.0	15,744.0		Freeboard

If the discharge is composed of multiple components (i.e., orifice and overflow weir or multiple outlets), the discharge relationship for the individual components must be presented. Also, ensure that ***Table 11-1*** reflects the presence of forebays and maintenance access roads to the inlet and outlet structures and/or main cell(s), as well as pathways to the extent that the footprint of the pond might be affected.

11.1.4.2.9 Storm Sewers (On-Site/Off-Site)

Identify preliminary design flow rates and approximate trunk sizes, alignment, elevations, and HGL(s) to the extreme extent of the storm sewer system to ensure that the upstream drainage system can operate properly, without undue surcharge conditions, with the proposed elevations of the pond.

Identify what typical amount of trap low storage can be expected within the development on a per unit area basis. Based on this, outline the achievable UARR for the study area.

11.1.4.2.10 Hydrogeological

Conduct a planning-level hydrogeological assessment addressing groundwater impacts relevant to the preservation of existing streams or ravines in a natural-like state and hydrogeological aspects related to the implementation of SCPs (including soil texture, permeability, groundwater levels, etc.).

Where infiltration/percolation into the subsoils is proposed to meet runoff volume targets, the proponent must:

- Assess the impact on the groundwater table.
- Demonstrate that the assumed percolation rates are sustainable in the long run on a local and a regional level.
- Demonstrate that the percolating runoff will have no detrimental impact on adjacent roadways or any downstream structures.
- Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

Infiltration and/or percolation into the subsoils are not permitted if the runoff is contaminated with highly mobile constituents as assessed by an environmental specialist with The City of Calgary's Environmental & Safety Management business unit.

11.1.4.2.11 Methodology

Provide a brief description of:

- Single-event and/or continuous simulation computer models.
- Design storm parameters (design storm and duration) and/or climate database employed.
- Data used for modelling of the major and minor system (as applicable).
- Modelling of contributions from external areas including interim undeveloped or existing development conditions (as applicable).
- Boundary conditions and starting water levels (as applicable).
- Basis for inlet capture at catchbasins (CBs) including hydraulic capacity, presence of inlet control devices (ICDs), etc. (as applicable).
- Data used for storage units including trap lows, underground storage, and/or storm ponds (as applicable).
- Representation of emergency spill routes (as applicable).
- Runoff and pollutant simulation and sedimentation process (as applicable).
- Statistical analysis performed on results of continuous simulation.
- Basis for representation and modelling of BMPs and SCPs distributed across the catchment.
- Model input parameters.
- Model schematic.

Refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for requirements.

11.1.4.2.12 Results and Summary

Include the following:

i) **Model Input and Output**:

- Summarize model input and output data, and provide hard copy of computer simulation data files and modelling schematic in an appendix.
- Include the results of analyses of external upstream catchment for pre-development and/or post-development conditions, if applicable.
- For SCPs in the upstream catchment that affect sizing of storm ponds, provide all relevant output data.

ii) **Off-Site Discharge**:

- Summarize permissible and actual 1:100 year discharge to receiving water bodies or downstream drainage system(s), expressed in L/s/ha and L/s.
- Provide derivation of emergency escape design flow rate and demonstrate that the configuration and capacity of the emergency escape route is adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route.
- Summarize annual runoff volume discharged (in mm) from the ponds or wetlands, if applicable. For wet ponds subject to water re-use, summarize quantify volumes of water available for re-use.

iii) **Stormwater Storage Requirements**:

- Summarize 1:100 year storage requirements based on single-event and/or continuous simulation.
- Provide results of statistical analysis of annual maxima for each frequency distribution analyzed. Identify preliminary NWL (or (L)NWL and (U)NWL for water re-use strategies) and HWL elevations.

iv) **Overland Drainage**: Outline the overland drainage paths and demonstrate adequate performance of the overland drainage system during a 1:100 year event, demonstrating that the depth / velocity requirements are within Alberta Environment's guidelines and the trap low depths meets inundation depths and extents, as per ***3.4.3 Roads*** and ***3.4.4 Trap Lows (Surface Ponding)***.

Specific attention shall paid to emergency escape routes and the anticipated performance of concrete drainage gutters, as per ***3.4.7 Swales***, especially for those gutters that operate under back-to-front grading conditions for the adjacent lots.

It is highly recommended that the operation of concrete drainage gutters be evaluated as early as possible during the layout phase of a subdivision (i.e., at the time of the preparation of the Outline Plan and SMDP), if even only in a preliminary fashion. This ensures that the gutters fully contain the peak

1:100 year flow rate without the flow jumping out of the gutters when on a supercritical slope, and with minimal need for high back gutters.

v) **Habitat**: In the case of engineered natural stormwater wetlands and constructed stormwater wetlands that provide compensatory value, demonstrate how the design objectives for the operation of the "habitat" components of the wetlands, as agreed with Water Resources and Parks, have been met.

vi) **On-Site Servicing**: Tabulate the preliminary on-site permissible unit area discharge rates, storage requirements, and runoff volume targets for each of the individual development cells within the study area. This information must be displayed on the Storm Area Drainage figure as well.

vii) **SCPs:** Outline in detail which types of SCPs will be implemented, and the corresponding performance requirements for each land use area (i.e., single-family residential lots, park space, roadways, multi-family residential and commercial/industrial properties, etc.). Demonstrate collectively how each land use contributes to meeting the overall runoff rate and volume and water quality criteria set out for the development.

viii) **Recommendations**: Present recommendations for future analysis and/or design during the preparation of the Pond Report, Subdivision Stormwater Management Report (SWMR), and/or Development Site Servicing Plan (DSSP) Reports.

Typically, no construction drawings are required at the time of SMDP submission; however, the servicing must be shown to be achievable.

If the SMDP report is to include detailed information regarding stormwater ponds, the submission should follow the technical requirements corresponding to a Pond Report submission (refer to ***11.1.7.2 Technical Requirements*** for more information).

11.1.5 Community Drainage Studies

These studies are typically initiated by Water Resources, Planning & Analysis to address drainage problems in existing communities. As part of these studies, the current level of service and options to improve the level of service are identified. Water Resources subsequently identifies which improvements are to be implemented; the preliminary and detailed design of these improvements is supervised by Water Resources, Infrastructure Delivery.

Although the scope of Community Drainage Studies is usually tailored to the project at hand, the contents are anticipated to include the components outlined in ***11.1.5.2***. All work is to follow the requirements of the Stormwater Management & Design Manual, where applicable.

11.1.5.1 Submission Requirements

Submission requirements for Community Drainage Studies are established on a case-by-case basis. The consultant must confirm the relevant submission requirements with Water Resources, Planning & Analysis.

11.1.5.2 Technical Requirements

All Community Drainage Study reports should include the elements outlined in sections ***11.1.5.2.1*** through ***11.1.5.2.6***.

11.1.5.2.1 Cover Letter

The cover letter should highlight areas where guidelines and/or checklists cannot be met.

11.1.5.2.2 Checklists

Relevant checklists might need to be completed and included as part of the Community Drainage Study reports. Examples of these checklists are:

- *Checklist #3: Stormwater Management Report*
- *Checklist #4: XP SWMM Models*
- *Checklist #5: Water Quality BMP (Oil-Grit Separator)*
- *Checklist #6: Pond Report*
- SCP Checklists (as outlined in ***8.3 Source Control Practices (SCPs)***).

Refer to the *Development Approvals Submissions* page on The City of Calgary's website for copies of the latest version of these checklists.

11.1.5.2.3 Study Area Location and Description

The description of the study area must include:

- Type of development (residential, industrial, commercial, etc.).
- Total site area, including external areas.
- Overland drainage direction, downstream storm ponds and outfalls.

• Findings of review of all relevant background reports and data including complaints and flooding records.
• All stormwater quality treatment facilities or SCPs in the study area.

It is best to include two figures:

• One showing the location of the study area with respect to the city (showing major roadways).
• One showing sub-catchment boundaries in relationship to the study area boundary. Contours of adjacent lands should be displayed as well. The direction of minor and major drainage should be shown along with any overland flows that enter the study area.

11.1.5.2.4 Subcatchments

Include a Storm Area drawing showing

• Legal boundaries (as appropriate).
• Contours.
• Overland drainage routes.
• Storm sewer alignment.
• Location and type of stormwater management facilities, including BMPs and SCPs.
• Delineation and sizes of subcatchments.
• CB locations, type, special CB interconnections, and inlet restrictions.
• On-site unit permissible area discharge rates, storage requirements, and runoff volume targets.
• Receiving water bodies and outfalls.

Other details such as initial abstraction losses, imperviousness, and infiltration characteristics (i.e., curve numbers or infiltration rates) are to be included with the computer model and/or in the appendices.

11.1.5.2.5 Methodology

Provide a brief description of

• Single-event and/or continuous simulation computer models.
• Design storm parameters (design storm and duration) and/or climate database employed.
• Data used for modelling of the major and minor system (as applicable).
• modelling of contributions from external areas including interim undeveloped or existing development conditions (as applicable).
• Boundary conditions and starting water levels (as applicable),
• Basis for inlet capture at CBs including hydraulic capacity, presence of ICDs, etc. (as applicable).
• Data used for storage units including trap lows, underground storage and/or storm ponds (as applicable).

• Representation of emergency spill routes (as applicable).
• Runoff and pollutant simulation and sedimentation process (as applicable).
• Statistical analysis performed on results of continuous simulation.
• Basis for representation and modelling of BMPs and SCPs distributed across the catchment.
• Model input parameters.
• Model schematic.

Where the Community Drainage Study involves the establishment of a detailed dual drainage model, the preferred model is usually XP-SWMM. Multiple levels of service are typically examined, ranging from a 1:2 year condition to a 1:100 year condition.

Data for ponds must be included when a pond is modelled in the report. Typically, an elevation vs. depth vs. surface area vs. total storage volume vs. active storage volume vs. discharge rate (i.e., orifice and/or weir) curve should be provided. Refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for requirements.

11.1.5.2.6 Results and Summary

Include the following:

i) **Model Input and Output**: Summarize model input and output data, and provide electronic and hard copies of all computer simulation data files in an appendix. To facilitate the review and communications with the consultant, the digital files should be formatted as follows:

- Use header with the following info: project name, page x of y.
- Use footer with following info: filename/date-time.
- Use a coloured sheet to separate data files.
- Text in data files should not wrap at the end of the line - consider using “Courier New” font in WORD.

A computer model schematic with size commensurate with the number of model elements must be included. The model identification numbering system should match the Overland Drainage and Storm Drainage Drawings to the greatest extent possible.

ii) **Existing Level of Service**: Based on the computer model, establish the level service corresponding to the existing drainage conditions. Also, for the storm trunk system, graphically display the capacity of the system on a unit area basis. Quantify the performance of the existing drainage system for design storm events ranging from a 4 hour, 1:2 year design storm event to a 4 hour, 1:50 year design storm event. As part of the study, the hydraulic grade line (HGL) should be estimated for the various level of service examined. Typically, a 2.40 m freeboard relative to existing ground is deemed required for a satisfactory level of service.

iii) **Potential Drainage System Upgrades**: Identify potential options to improve the existing level of service. The investigation of options must include:

- Minor system upgrades including twinning or upsizing existing storm lines, benching of manholes (MHs), etc.
- Underground storage units or storm ponds.
- Stormwater quality upgrades such as wet ponds, Constructed stormwater wetlands or other BMPs.
- SCPs, where applicable.

iv) **Analysis of Potential Upgrades**: Examine the level of service resulting from the implementation of the potential upgrades. Also identify planning-level life-cycle cost estimates.

v) **Evaluation Objectives**: Establish criteria for the selection and priority ranking of proposed upgrades. Apply criteria to potential upgrades.

vi) **Conceptual Design and Cost Estimates**: Prepare conceptual design and cost estimates for the preferred upgrades. Cost estimates are to be life-cycle costs, including all initial capital costs associated with the proposed upgrades and operation and maintenance costs.

vii) **Evaluation of Proposed System during Extreme Event:** Evaluate the performance of the drainage system, including the proposed upgrades during a 1:100 year event. If a 1:50 year level of service is deemed not achievable, repeat this step for a 1:50 year event. Display graphically the resulting capacity of the storm trunk system on a unit area basis.

viii) **Recommendations**: Present recommendations for future analysis and/or design during the detailed design of the recommended drainage improvements.

Tabulate the assumed on-site discharge rates, storage requirements, and runoff volume (where applicable) for each of the individual subcatchments within the study area. This information, which will be used to guide future re-development within the study area, should be displayed on the Storm Area Drainage figure as well.

Typically, no construction drawings are required at the time of Community Drainage Study report submission; however, the concepts must be shown to be achievable. Feedback from public consultation, where applicable, should be incorporated into the final report and modelling.

If the Community Drainage Study report is to include detailed information regarding stormwater ponds, the submission should follow the technical requirements corresponding to a Pond Report submission (refer to ***11.1.7.2 Technical Requirements***).

11.1.6 Stormwater Ponds

Reports must be submitted for all dry ponds, wet ponds, and stormwater wetlands (i.e., both constructed stormwater wetlands and engineered natural stormwater wetlands). Refer to ***6.4 Wetlands*** for wetland definitions). Zero-discharge facilities, such as temporary evaporation ponds, also require report submission (refer to ***11.1.8 Development Site Servicing Plans (DSSPs)*** for more information); contact Water Resources, Development Approvals for more information.

A Pond Report could be either a stand-alone report or be included in the SMDP report. If details of the pond are likely to change significantly, a separate report is recommended; then the SMDP can provide more generalized information on the ponds.

A minimum time period of **20 business days** is required for Pond Report review and comments by Water Resources. Comments by Parks will be incorporated in Water Resources' response.

A Pond Report Template to guide consultants in the preparation of Pond Reports is available from Water Resources. For the latest version of Pond submission and technical requirements, including report templates and checklists, refer to the *Development Approvals Submissions* page on The City of Calgary's website. Also refer to the Pond Section in the *Guide to Development Approvals* that can be downloaded from the same site.

11.1.6.1 Submission Requirements

i) It is recommended that the Pond Report is submitted concurrent with, or shortly following, the Preliminary Construction Drawings. Approval of the Pond Report is required **prior** to approval of the Final Construction Drawings. Water Resources will not review final construction drawings for which a Pond Report has not been approved. **Stormwater ponds must be in place, or approved for construction, prior to the first phase(s) of development being approved for construction.**

ii) Following approval of the Pond Report, including resolution of any outstanding issues with Parks that might impact the contents of the Pond Report, the consultant will be requested to supply the filled-in Alberta Environment *Application Form and Guide for Registration to Construct and Operate a Municipal Storm Drainage System*. A copy of the Pond Report and the EPEA form will be submitted by Water Resources to Alberta Environment. Alberta Environment will review the Pond Report and submit comments, if necessary. Sufficient review time must be allowed for provincial review. Approval under the *Water Act* will be required in case natural wetlands or engineered natural stormwater wetlands are involved.

Once Alberta Environment approves the application, a Letter of Authorization is issued by Alberta Environment (refer to ***CHAPTER 2: AUTHORIZATIONS AND PROCESSES***). In addition, Alberta Environment requires registration under the *Environmental Protection and Enhancement Act (EPEA)* for new outfalls, which is typically done with the off-site storm sewers from new stormwater ponds.

It is imperative that all authorizations are in place prior to construction. This applies to both public ponds (that will become the responsibility of The City of Calgary) and private ponds. Whereas the City of Calgary will coordinate the registration of public ponds under the *EPEA* with Alberta Environment, private ponds need to be registered by the proponent after the Pond Report and DSSP drawings have been approved by Water Resources.

iii) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer, and company permit stamps (or company permit number) and be signed and dated by the Engineer.

iv) A total of **four (4)** copies of the report are required for review purposes. All reports must be forwarded to the Leader Development Approvals in Water Resources. Copies of the report will be then be forwarded to the appropriate internal reviewing personnel.

11.1.6.2 Technical Requirements

All pond reports should include the elements outlined in sections ***11.1.6.2.1*** through ***11.1.6.2.12***.

11.1.6.2.1 Cover Letter

The cover letter should identify whether the pond is public or private, and highlight any unresolved issues or areas where guidelines and/or checklist items cannot be met.

11.1.6.2.2 Checklists

The following checklists must be completed and submitted as part of the Pond Report. Refer to the *Development Approvals Submissions* page on The City of Calgary's website for the latest version of these checklists.

- *Checklist #4: XP-SWMM Models (if applicable).*
- *Checklist #5: Water Quality BMP (Oil-Grit Separator (if applicable).*
- *Checklist #6: Pond Report.*

All stormwater management ponds should be located within the developer's property limits. If the proposed pond and/or associated downstream tie-ins or outfalls are off-site, a **Statement of Agreement** with affected stakeholders should be enclosed. This statement must be co-signed by all the affected stakeholders.

If there is no preceding SMDP, the Pond Report must address all items from the *Checklist #10: Staged Master Drainage Plan (SMDP)*, as well. Refer to ***11.1.4.2.2*** for more information.

11.1.6.2.3 Study Area and Location

Include and/or identify:

- OP # and/or DP #.
- Name of the project and phase.
- Name of developer and/or landowner.
- Land location (legal description).
- Overall study area description and catchment area size.

It is best to include two figures:

- **Location Area**, showing the location of the area with respect to the city (showing major roadways).
- **Study Area**, showing legal land location and section number(s), development and overall catchment area boundaries, catchment area size, contours of land adjacent to the pond, and adjacent LOC numbers.

11.1.6.2.4 Site Description

The description of the study area must include

- Type of development (residential, industrial, commercial, etc.).
- Interim undeveloped or future external development areas included in the study area, if applicable.
- Total site area, including external areas.
- Overland drainage direction, downstream storm ponds, receiving ponds and outfalls.
- All stormwater quality treatment facilities or SCPs existing or envisioned in the catchment.

11.1.6.2.5 Design Objectives

With reference to the relevant Water Management, MDP and SMDP reports, state:

- Allowable unit area and total discharge rates (in L/s/ha and L/s, respectively), and runoff volume target (in mm) if applicable, to downstream areas.
- Storm discharge and runoff (expressed in L/s/ha, L/s and mm, respectively) allowed from upstream catchment areas, including temporary undeveloped catchments.
- Design basis for storm sewer system discharging into the storm pond (expressed in L/s/ha).
- Design basis for required storage capacity.
- Water quality performance targets for the forebay (or equivalent) and main cell(s) of the pond.
- Water re-use strategies including seasonal usage patterns, if applicable. In case of water re-use strategies, the report must also address a fall-back scenario in which the re-use strategies are not operational.

The designer must confirm that the catchment boundaries for the pond match those of existing reports. Alternatively, supplemental information must be provided to rationalize any changes.

Information about stormwater quality treatment facilities or SCPs upstream of the pond, or water re-use strategies, is of particular importance where the design of the pond is directly affected.

In the case of engineered natural stormwater wetlands and constructed stormwater wetlands that provide compensatory value, identify the design objectives for the operation of the "habitat" components of the wetlands, as agreed with Water Resources and Parks during the establishment of the SMDP.

11.1.6.2.6 Biophysical Impact Assessment (BIA) and Inventory

Identify BIA and Biophysical Inventory reports for the development area, and identify habitat targets. Summarize the conclusions from these reports and demonstrate how the recommendations have been incorporated into the pond design.

For ponds in the vicinity of the Calgary International Airport, describe the wildlife mitigation measures that are being implemented.

11.1.6.2.7 Subcatchments

Include a figure:

- Delineating subcatchments and sizes of the subcatchments in the catchment area of the pond (including upstream external areas, if applicable).
- Showing all stormwater quality treatment facilities or SCPs upstream of the pond.
- Showing how overland drainage from upstream areas, if any, is routed into the pond. Identify what level of pre-treatment is provided.

Other details such as initial abstraction losses, imperviousness, and infiltration characteristics (i.e., curve numbers or infiltration rates) are to be included with the computer model and/or in the appendices.

It is best to include a **Storm Area Design** figure showing:

- Pre-development boundaries (i.e., for existing wetlands).
- Existing drainage features that are retained as part of the drainage concept such as wetlands, perennial and intermittent streams including ravines, and man-made drainage infrastructure (i.e., impoundments, pond, and culverts).
- Proposed catchment area boundaries.
- Unit-area discharge.
- Legal boundaries (as appropriate).
- Overland drainage routes entering the pond.
- All overland emergency escape routes.
- Contours of adjacent properties.
- Receiving water bodies and outfalls.
- Trunk alignment.

11.1.6.2.8 Pond Characteristics

i) Tabulate the Stage-Storage-Discharge relationship for the forebay(s) **and** the main cell(s) of the pond as per ***Table 11-2***. The information in ***Table 11-2*** must match the data presented in the preceding SMDP report; changes, if any, must be rationalized.

Table 11-2: Stage-Storage-Discharge Table for Main Cell of Pond

Elevation (m)	Depth Above NWL (m)	Area (m^2)	Total Storage Volume (m^3)	Active Storage Volume (m^3)	Discharge (L/s)	
65.75	N/A	1,949.0	0.0	0.0	0.00	
66.00	N/A	2,447.0	548.0	0.0	0.00	
66.25	N/A	4,049.0	1,352.0	0.0	0.00	
66.50	0.00	5,650.0	2,559.0	0.0	0.00	NWL
66.75	0.25	7,122.0	4,152.0	1,593.0	25.80	
67.00	0.50	8,178.0	6,063.0	3,504.0	41.10	
67.25	0.75	8,999.0	8,209.0	5,650.0	52.00	
67.50	1.00	9,204.0	10,484.0	7,926.0	61.10	
67.25	1.25	10,044.0	12,890.0	10,331.0	68.90	
68.00	1.50	10,848.0	15,501.0	12,942.0	76.00	HWL
68.25	1.75	11,578.0	18,303.0	15,744.0		Freeboard

Ensure that ***Table 11-2*** reflects the presence of maintenance access roads to the inlet and outlet structures and/or main cell(s) as well as pathways. If the discharge in ***Table 11-2*** is composed of multiple components (i.e., orifice and overflow weir and/or constant water re-use withdrawals), the discharge relationship for the individual components must be presented and the "Discharge" column expanded to show the contribution from the individual components.

ii) Describe sediment forebay(s), or equivalent, and tabulate key forebay characteristics as per ***Table 11-3***.

Table 11-3: Common Characteristics for Forebay

Parameter	Unit	Value
Bottom Elevation	m	
Normal Water Level (NWL)	m	
High Water Level (HWL)	m	
Invert Elevation of incoming pipe	m	
Pond Depth below NWL	m	
Forebay Length	m	
Forebay Width	m	
25-Year Sediment Storage Capacity	m^3	

iii) Summarize length to width ratios of the forebay(s) and the main cell(s) of the pond. Describe how short-circuiting is avoided.

iv) Express wet pool storage volume of wet ponds on a unit area basis.

v) An adequate number of (11 x 17" format minimum size) drawings need to be included with the Pond Report to explain the operation of the pond and facilitate review. At a minimum, the following information must be included:

- Maintenance vehicle access.
- Pathways.
- Monitoring equipment (location and type).
- Pond volume.
- Pond contours and grading showing bottom, NWL (or (L)NWL and (U)NWL), HWL and FB elevations, where applicable.
- Pond depth.
- Side slopes.
- Sediment forebay.
- Storm sewer inlet and overland flow inlet details.
- Rim, gratings, orifice, trash rack, and gate valve.
- Outlet control structure details.
- Piping information (inverts, size, type, length, and slope) and block profiles where applicable.
- Pond discharge rates (provide Stage-Storage-Discharge Table).
- Overland Escape Route (location and spill elevation).

Refer to ***11.2.2.2 Drawing Requirements*** for the drawing requirements of the subsequent construction drawings.

11.1.6.2.9 Storm Sewers (On-Site/Off-Site)

Identify approximate trunk sizes, alignment, elevations, and HGL(s) at the pond interface. Also, identify any flow off site.

If this information is not available from previous reports, such as the SMDP, it must be detailed in the Pond Report submission. In this case, the HGL(s) must be estimated, tabulated, and graphically displayed to the extreme extent of the storm sewer system to ensure that the upstream drainage system can operate properly, without undue surcharge conditions, with the proposed elevations of the pond.

11.1.6.2.10 Geotechnical

Identify the Geotechnical Report and summarize relevant information pertaining to:

- Pond lining.
- Toe drains.
- French drains.
- Forebay berm including core.
- Stable slopes.
- Any other pertinent elements.

Identify whether any embankments need to be classified as a **dam** under the *Water Act*. Also identify whether any infiltration or percolation into the subsoils is proposed to meet runoff volume targets.

Where infiltration/percolation into the subsoils is proposed to meet runoff volume targets, the proponent must:

- Assess the impact on the groundwater table.
- Demonstrate that the assumed percolation rates are sustainable in the long run on a local and a regional level.
- Demonstrate that the percolating runoff will have no detrimental impact on adjacent roadways or any downstream structures.
- Demonstrate that the percolating runoff will not contribute to an increase in inflow and infiltration into the sanitary system.

Infiltration and/or percolation into the subsoils are not permitted if the runoff is contaminated with highly mobile constituents as assessed by an environmental specialist with Environmental Safety Management (The City of Calgary).

11.1.6.2.11 Methodology

Provide a brief description of the following:

- Single-event and/or continuous simulation computer models.
- design storm parameters (design storm and duration) and/or climate database employed.
- data used for modelling of the major and minor system (as applicable).
- modelling of contributions from external areas including interim undeveloped or existing development conditions (as applicable).
- boundary conditions and starting water levels (as applicable).
- basis for inlet capture at CBs including hydraulic capacity, presence of ICDs, etc., (as applicable).
- data used for storage units including trap lows, underground storage and/or storm ponds (as applicable).
- representation of emergency spill routes (as applicable).
- runoff and pollutant simulation and sedimentation process.
- statistical analysis performed on results of continuous simulation.
- model input parameters.
- model schematic.

For zero-discharge facilities that do not empty from year to year, the starting water level or pond volume for the simulation must be established iteratively, and correspond to the average water level or pond volumes over the period of record.

When CFD analysis techniques are used as part of the analysis, the proponent must meet with Water Services to discuss submission requirements prior to submitting the report.

Refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for requirements.

11.1.6.2.12 Results and Summary

Include the following:

i) **Model Input and Output**:

- Summarize model input and output data, and provide hard copy of computer simulation data files and modelling schematic in an appendix.
- Include the results of analyses of external upstream catchment for pre-development and/or post-development conditions, if applicable.
- For SCPs in the upstream catchment that affect sizing of storm pond, provide all relevant output data.

ii) **Discharge**:

- Summarize permissible and actual 1:100 year discharge to receiving water bodies or downstream drainage system(s), expressed in L/s/ha and L/s.
- Provide derivation of emergency escape design flow rate and demonstrate that the configuration and capacity of the emergency escape route is adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route.
- Summarize annual runoff volume discharged (in mm) from the pond or wetland, if applicable.
- For wet ponds subject to water re-use, quantify volumes of water available for re-use.

iii) **Stormwater Storage Requirements**: Summarize storage requirements based on single-event and/or continuous simulation. Provide results of statistical analysis of annual maxima for each frequency distribution analyzed.

iv) **For zero-discharge facilities:**

- Describe area subject to inundation for the 1:100 year event.
- Demonstrate balance between runoff and evaporation losses and/or water re-use for average annual year.
- Identify area subject to inundation and water level for 1:100 year event in case water re-use system is not operational (if applicable).

v) **Pond Characteristics**:

Tabulate key characteristics of the pond as per ***Table 11-4*** and ***Table 11-5***, as applicable.

Table 11-4: Common Characteristics for Main Cell(s) of Pond (Conventional)

Parameter	Value
Bottom Elevation	m
Normal Water Level (MNWL)	m
High Water Level (HWL)	m
Invert Elevation of outlet control structure	m
Pond Depth below NWL	m
Active Pond Depth (NWL to HWL)	m
Area at NWL	ha
Area at HWL	ha
Discharge at HWL	m^3/s
Emergency overflow design rate	m^3/s
Emergency overflow design rate elevation	m
Freeboard Elevation	m
Storage Volume at NWL	m^3
Storage Volume at HWL	m^3
Live Storage Volume at HWL	m^3
1:100 Live Storage Volume	m^3
1:100 Water Level	m
1:100 Discharge	m^3/s

Table 11-5: Common Characteristics for Main Cell(s) of Pond (Subject to Stormwater Reuse)

Parameter	Value
Bottom Elevation	m
Lower Normal Water Level (LNWL)	m
Upper Normal Water Level (UNWL)	m
High Water Level (HWL)	m
Invert Elevation of outlet control structure	m
Pond Depth below LNWL	m
Water Re-Use Depth (LNWL to UNWL)	m
Active Pond Depth (UNWL to HWL)	m
Area at LNWL	ha
Area at UNWL	ha
Emergency overflow design rate	m^3/s
Emergency overflow design rate elevation	m
Freeboard Elevation	m
Discharge at HWL	m^3/s
Storage Volume at LNWL	m^3
Storage Volume at UNWL	m^3
Storage Volume at HWL	m^3
Live Storage Volume at HWL	m^3
1:100 Live Storage Volume	m^3
1:100 Water Level	m
1:100 Discharge	m^3/s

vi) **Forebay**: Summarize the following:
- Forebay settling length.
- Dispersion length.
- Minimum forebay bottom width.
- 25-year sediment accumulation in forebay.

vii) **Water Quality Enhancement**: Summarize the following:
- TSS removal in the pond in tabular format.
- Detention time.
- Length to width ratios in the pond.

viii) **Frequency of inundation analysis**: Provide elevation exceedance curves for the following:
- For wetlands; compare to pre-development conditions, if applicable.
- For wet ponds subject to water re-use.

ix) **Habitat**: In the case of engineered natural stormwater wetlands and constructed stormwater wetlands that provide compensatory value, demonstrate how the design objectives for the operation of the “habitat” components of the wetlands, as agreed with Water Resources and Parks during the establishment of the SMDP, have been met.

x) **Weeping Tile Drains/Subdrainage System**: Provide design of weeping tile drains and subdrainage system for dry ponds.

xi) **Tolerances**: Construction tolerances for engineered natural stormwater wetlands must be identified, and agreed to by Water Resources and Parks, as part of the Pond Report.

xii) **Operation and Maintenance Considerations**: Describe the following:
- Sediment removal.
- Weed and vegetation removal.
- Algae treatment.
- Mosquito control.
- Outlet control structures.
- Monitoring system.
- Maintenance access.

11.1.7 Subdivision Stormwater Management Reports (SWMRs)

Detailed SWMRs must be prepared for areas covering subdivision plans and OPs. A report is required for **all** subdivision development phases, and will correspond to an applicable set of construction drawings. At this level, details pertaining to the storm sewer and related structures, HGL analysis, 1:100 year storage requirements, trap lows, escape routes, BMPs, and water quality requirements are required.

A minimum time period of **twenty business days** is required for SWMR review and comments by Water Resources.

A template to guide consultants in the preparation of SWMRs is available from Water Resources. For the latest version of SWMR submission and technical requirements, including report templates and checklists, refer to the *Development Approvals Submissions* page on The City of Calgary's website.

11.1.7.1 Submission Requirements

i) Submission of an SWMR is required prior to review and approval of the Final Construction Drawings. Water Resources will return, without review, all Final Construction Drawings for which a SWMR has not been submitted. As well, no surface approvals will be given without an approved SWMR; underground approval **may** be provided, at the discretion of Water Resources. If a developer proceeds with construction following issuance of underground approval, but prior to the approval of the SWMR report, the construction is fully at the risk of the developer. The costs associated with any changes to the underground infrastructure based on Water Resources' review of the SWMR report are the responsibility of the developer.

   Culverts are **not** part of the underground approval; they are covered under the surface approval!

ii) **All reports must be prepared by qualified consultants**. Reports must include the Professional Engineer and company permit stamps.

iii) **Two (2)** copies of the report are required for review purposes. All reports must be forwarded to the Leader, Development Approvals in Water Resources. Copies of the report will be then be forwarded to the appropriate internal reviewing personnel.

11.1.7.2 Technical Requirements

All SWMR should include the elements outlined in sections ***11.1.7.2.1*** through ***11.1.7.2.8***.

11.1.7.2.1 Cover Letter

The cover letter should highlight any unresolved issues or areas where guidelines and/or checklists cannot be met (in particular, Alberta Environment velocity-depth guidelines).

11.1.7.2.2 Checklists

The following checklists must be completed and submitted as part of the SWMR. Refer to the *Development Approvals Submissions* page on The City of Calgary's website for the latest version of these checklists.

- *Checklist #3: Stormwater Management Report.*
- *Checklist #4: XP-SWMM Models (if applicable).*
- *Checklist #5: Water Quality BMP (Oil-Grit Separator) (if applicable).*

11.1.7.2.3 Study Area and Location

Include and/or identify:

- OP # and/or SB #.
- Name of the project and phase.
- Name of developer and/or landowner.
- Land location (legal description).
- Overall site description and land use types.
- Downstream storm ponds and outfalls.
- Figure(s) showing location and section number.

It is best to include two figures;

- One showing the location of the area with respect to the city (showing major roadways).
- One showing the overall study area boundary, site phase boundary, and surrounding phases or (external) areas (showing section numbers and major roadways). An example is shown in ***Figure 11-1***.

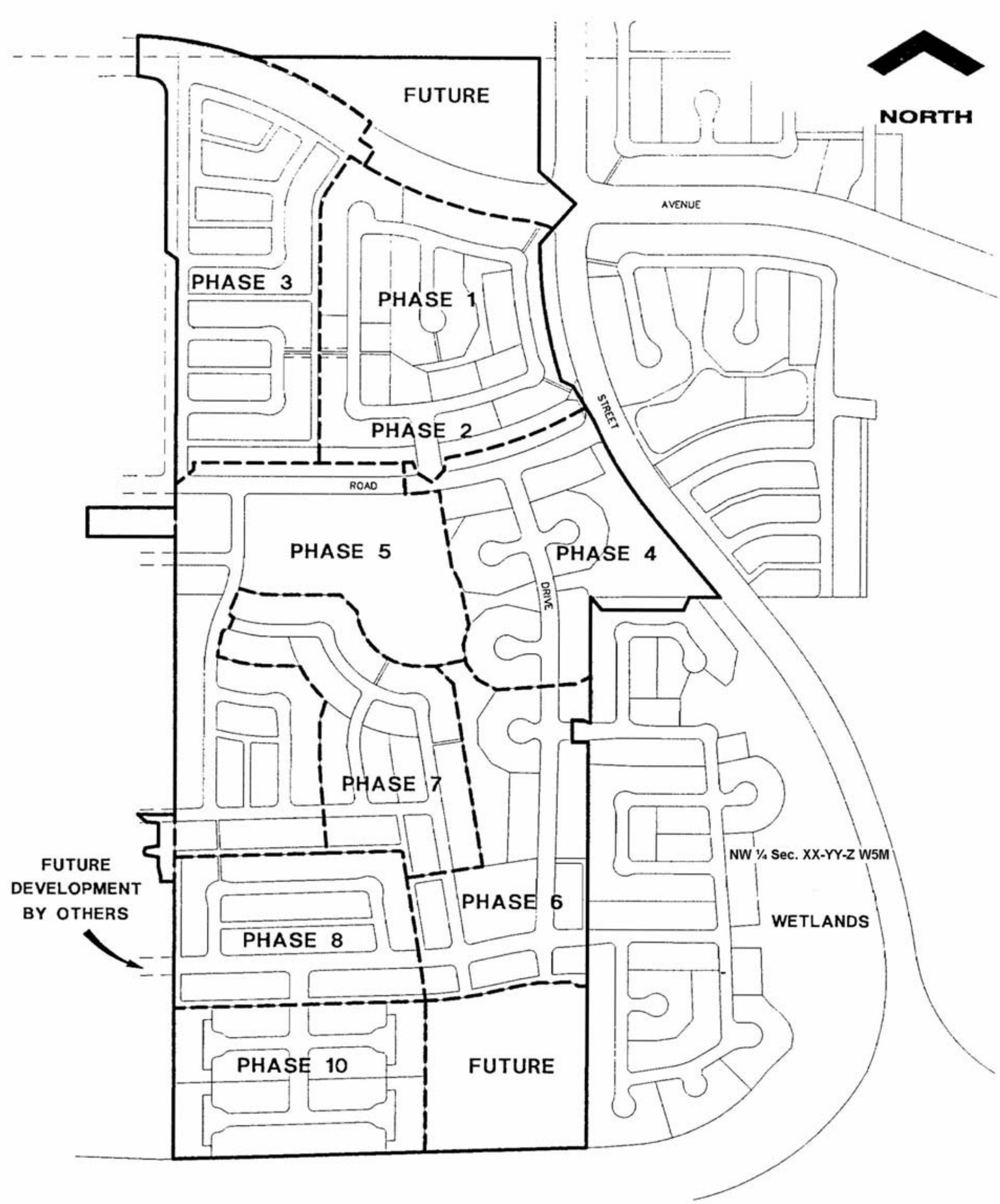
11.1.7.2.4 Site Description

The description of the study area must include

- The type of development (residential, industrial, commercial, etc.).
- Interim undeveloped or future external development areas included in the study area, if applicable.
- Total site area, including external areas.
- Overland drainage direction, downstream storm ponds and outfalls.
- All stormwater quality treatment facilities or SCPs in this phase or development.

It is best to include a figure showing catchment boundaries in relationship to site phase boundaries. Contours of adjacent properties should be displayed as well. The direction of minor and major drainage should be shown along with any overland flows that enter the subdivision phase.

Figure 11-1:Study Area Boundary Example



11.1.7.2.5 Design Objectives

With reference to the relevant MDP/SMDP reports or previous SWMRs for adjacent phases, state:

- Criterion used for sizing the minor system (i.e., Unit Area Release Rate method or Rational Method).
- Allowable minor system discharges from upstream areas into previous, now downstream phases (***Table 11-6***).
- Allowable overland spill from upstream areas into previous, now downstream phases (***Table 11-7***).
- State if non-surcharge conditions are used or if surcharge is allowed with justification.
- Overland flow depths and velocities to meet depth-velocity criterion (***Table 11-8***).
- Water quality objectives.

Table 11-6: Minor System Boundary Conditions - Permissible Inflows from Upstream Areas into Previous Phases

Location	Manhole Number	Area Size (ha)	Flow Rate		Runoff Volume		HGL	Design Storm	Source of Information
			(L/a)	(L/s/ha)	(m^3)	(mm)	(m)		

Table 11-7: Major System Boundary Conditions - Permissible Overland Inflows from Upstream Areas into Previous Phases

Location	Area Size (ha)	Flow Rate		Runoff Volume		Design Storm (type and duration)	Source of Information
		(L/a)	(L/s/ha)	(m^3)	(mm)		

Table 11-8: Permissible Depth and Velocities of Overland Flow

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

11.1.7.2.6 Subcatchments

Include a figure:

- Delineating subcatchments and sizes of the subcatchments in the subdivision phase.
- Showing ICDs and special CB interconnections.

Other details such as initial abstraction losses, imperviousness and infiltration characteristics such as curve numbers or infiltration rates are to be included with the computer model and/or in the appendices.

11.1.7.2.7 Methodology

Provide a brief description of:

- Computer model.
- Design storm parameters (design storm and duration).
- Data used for modelling of the major and minor system (as applicable).
- Basis for inlet capture at CBs including hydraulic capacity, presence of ICDs, etc.
- Data used for storage units including trap lows, underground storage and/or storm ponds (as applicable).
- Representation of emergency spill routes (as applicable).
- Model input parameters.
- Model schematic (refer to ***Figure 11-2*** for a sample schematic.

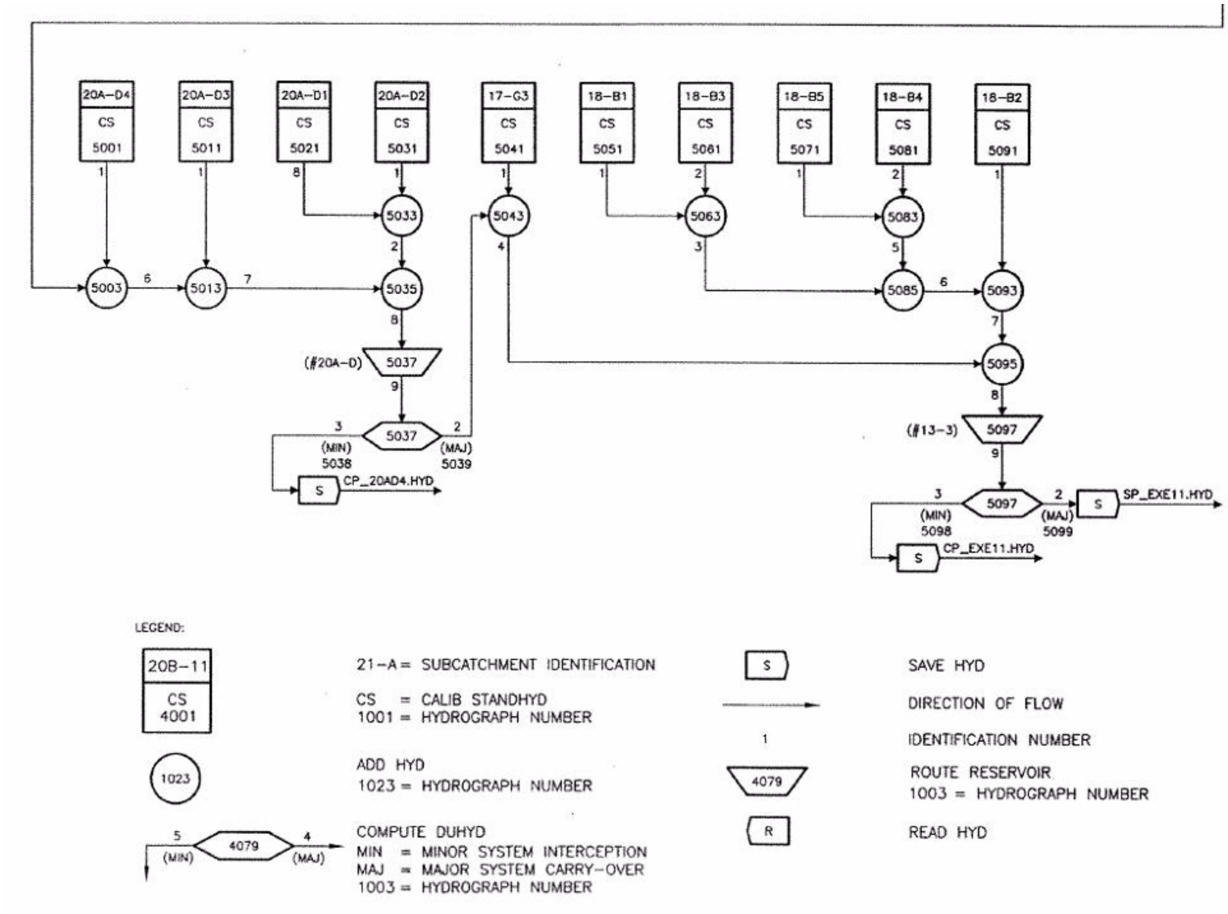
Refer to ***CHAPTER 3: STORMWATER DESIGN*** and ***CHAPTER 6: STORMWATER PONDS AND WETLANDS*** for requirements.

The numbering system must be logical. Preferably, catchment, street segment, and storm sewer identification numbers should relate to the phase and MH number. For instance, MH 5-8D, located in Phase 5, receives runoff from Catchments 5-8A through 5-8E, Street segments 5-8-1 and 5-8-2, and Trap low 5-8.

If a spreadsheet analysis is used for the minor system analysis, describe approach and assumptions.

Data for ponds must be included when the pond is modelled in the report. This information must match the data presented in the preceding SMDP or Pond Report. Typically, an elevation vs. depth vs. surface area vs. total storage volume vs. active storage volume vs. discharge rate (i.e., orifice and/or weir) table should be provided.

Figure 11-2: Model Schematic Example



11.1.7.2.8 Results and Summary

Include the following:

i) **Summary of Minor Flows**

Include summary of minor flows for the 1:100 year event to ensure pipe design flows are not exceeded. The summary should include segment number, full-flow capacity, design flow, location and type of ICDs installed, and computed or modelled cumulative flows (refer to ***Table 11-9***).

The minor system must be adequately designed in terms of hydraulics (refer to ***CHAPTER 5: HYDRAULIC DESIGN***). The report must state that the resulting flows are within the rated hydraulic capacities of the individual segments, or identify where surcharge conditions occur. The impacts of surcharge conditions within the development and downstream system must be quantified. Refer to **ii) Surcharge (HGL) Analysis.**

Table 11-9: Results of Minor System Analysis

Pipe Design Method								Actual Flow Comparison							
Manhole Number		Area Number	Incremental Area	Cumulative Area	Unit Area Release Rate	Incremental Flow Rate	Cumulative Flow Rate	Type Catchbasin	Location	Type Inlet Control Device	Incremental Inlet Peak Flow Rate	Cumulative Inlet Peak Flow Rate	Cumulative Hydraulic Model Routed Flow Rate	Pipe Capacity	Spare Capacity
From	To		(ha)	(ha)	(L/s/ha)	(L/s)	(L/s)				(L/s)	(L/s)	(L/s)	(L/s)	(L/s)

ii) **Surcharge (HGL) Analysis**

An HGL analysis is required on a site-specific basis for areas impacted by the HWL from stormwater ponds or other conditions (refer to ***CHAPTER 5: HYDRAULIC DESIGN***). Where surcharge cannot be avoided, the maximum 1:100 year HGL must be at least 1.20 m below surface to avoid compromising CB interception. The HGL must be based on the pond at HWL and appropriate losses taken into account. A table indicating MH number, location, HGL elevation, depth of surcharge, and freeboard relative to ground and LTF elevations must be included with the analysis, refer to ***Table 11-10***.

Table 11-10: Summary of Surcharge Conditions

Manhole Number	Location	Elevations			LTF	HGL	Surcharge	Freeboard relative to	
		Invert (m)	Obvert (m)	Ground (m)	(m)	(m)	(m)	Ground (m)	LTF (m)

iii) **Trap Low Storage**

A table showing all of the trap lows in the phase, and those on the boundary, must be included. The table must include required 1:100 year volumes, spillover volumes, depths and elevations, design (also called maximum or spill) volumes, depths and elevations, and low point elevations (refer to ***Table 11-11***). Minimum Building Opening Elevations (MGs) and restrictive covenants (RMGs) should be included.

Table 11-11: Results of Trap Low Analysis

Number 1	Low Point Elevation	Spill Conditions			1:100 Year Event Results				MG Elevation 3	R4
		Capacity m^3	Depth m	Elevation m	Storage Volume2 m^3	Spillover Volume m^3	Depth m	Elevation m		
17-3	1084.198	128	0.323	1084.521	190.0	77.0	0.358	1084.556	1084.856	R
17-4	1083.977	203	0.348	1084.325	150.0	0.0	0.305	1084.282	1084.625	R
17-5	1083.935	272	0.353	1084.288	60.0	0.0	0.164	1084.099	1084.588	R
17-6	1084.692	128	0.368	1085.060	120.0	0.0	0.359	1085.051	1085.360	R

(1) Locations are indicated on Overland Drainage Drawing.

(2) At maximum 1:100 year depth of ponding

(3) MG denotes Minimum Building Opening Elevation

(4) R designates that a Restrictive Covenant is required.

iv) **Permissible Discharge Rates and Preliminary On-Site Storage Requirements for Private Sites**

A table showing permissible discharge rates ad on-site storage requirements for private sites must be included, if applicable (refer to ***Table 11-12***).

Table 11-12: Permissible Discharge Rates and Preliminary On-Site Storage Requirements for Private Sales

Location	Manhole Number	Invert	Obvert or Top	HGL	Area	Discharge Rate		Runoff Volume		Storage Volume	
		(m)	(m)	(m)	(ha)	(L/s/ha)	(L/s)	(m^3)	(mm)	(m^3/ha)	(m^3)

v) **Overland Flows**

Q, v and d must be shown and tabulated (refer to ***Table 11-13***) for key overland flow routes, including spill and critical concrete drainage gutter or vegetated drainage swale segments. Flows entering and leaving phase boundaries must also be shown. Spillover into natural areas such as ravines should be avoided.

Table 11-13: Overland Flow Assessment

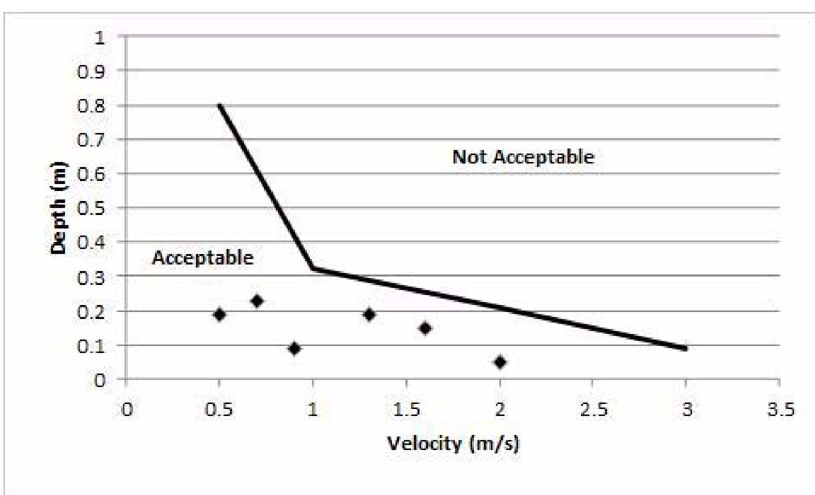
Street Segment Number	Peak Discharge (L/s)	Maximum Depth (mm)	Maximum Velocity (m/s)	Specific Energy (mm)	Gutter Type and Depth
S#1	52	51	0.79		
Traplow #1 - Spill	0	0	0.00		
S#2	112	64	1.08		
Traplow #2 - Spill	0	0	0.00		

Note: Specific Energy and Gutter Type and Depth only need to be provided for concrete drainage gutters/ swales in back of or between lots.

Flows should not exceed Alberta Environment depth-velocity guidelines, refer to ***Table 3-18*** and ***Figure 3-10***. Graphing the proposed flows against permissible values will quickly indicate any potential problems. Values outside of these limits must be approved by Water Resources.

It must be confirmed that all drainage gutters/swales fully contain the 1:100 year peak flow rate without overtopping/spillover.

Figure 11-3: Example of Verification against Alberta Environment's Depth vs. Velocity Criteria



vi) **Boundary Conditions**

Show overland flows (Q, v and d) and minor system flows entering and leaving the subdivision from adjacent land or phases.

Summarize all assumed major and minor systems flows entering the phase or development from external areas, and assumed or resulting major and minor systems flows exiting the phase or development (refer to ***Table 11-14***, ***Table 11-15***, ***Table 11-16***, and ***Table 11-17***).

Compare the major and minor system flows entering and leaving the site relative to the specific design objectives, and justify where they do not meet the objective. Where major and/or minor system flows leave the subdivision, Water Resources might request that the impact on downstream areas be assessed.

Table 11-14: Major System Boundary Conditions - Assumed Inflow from External Areas

Location	Area Size	Flow Rate		Runoff Volume		Design Storm
	(ha)	(L/s)	(L/s/ha)	(m^3)	(mm)	

Table 11-15: Minor System Boundary Conditions - Assumed Inflow from External Areas

Location	Manhole Number	Invert	Obvert or Top	HGL	Area Size	Flow Rate		Runoff Volume		Design Storm
		(m)	(m)	(m)		(L/s)	(L/s/ha)	(m^3)	(mm)	

Note: Information for invert, obvert, and HGL is only required in case of surcharge conditions.

Table 11-16: Major System Boundary Conditions - Outflows

Location	Area Size	Flow Rate		Runoff Volume	
	(ha)	(L/s)	(L/s/ha)	(m^3)	(mm)

Table 11-17: Minor System Boundary Conditions - Outflows

Location	Manhole Number	Area Size	Flow Rate		Runoff Volume	
		(ha)	(L/s)	(L/s/ha)	(m^3)	(mm)

vii) **Input and Output**

Computer modelling files must be included in hardcopy format in all SWMRs. Digital files do not replace the need for hardcopies. To facilitate the review and communications with the consultant, the digital files should be formatted as follows:

- Use header with the following info: project name, page x of y.
- Use footer with following info: filename/date-time.
- Use a coloured sheet to separate data files.
- Text in data files should not wrap at end of line - consider using “Courier New” font in WORD.

A computer model schematic with size commensurate with the number of model elements must be included. The model identification numbering system must match the Overland Drainage and Storm Drainage Drawings to the greatest extent possible.

viii) **Overland Drainage Drawing**

A full-size overland drawing must be included in all SWMRs. Refer to ***11.2.1.2 Drawing Requirements*** for drawing requirements.

ix) **Storm Drainage Drawing**

A full-size storm drainage must be included in all SWMRs. Refer to ***11.2.1.2 Drawing Requirements*** for drawing requirements.

x) **Storm Pond and Source Control Practice Drawings**

Drawings must be included, if applicable.

11.1.8 Development Site Servicing Plans (DSSPs)

Generally, detailed SWMRs are **not** required for the majority of DSSPs. The following situations require computer modelling and reports:

- Serviced sites larger than 2 ha.
- Sites smaller than or equal to 2 ha and without stormwater servicing.
- Sites smaller than or equal to 2 ha where BMPs and SCPs are proposed to reduce on-site storage requirements, control run-off volume and/or enhance water quality.
- The re-development of sites smaller than or equal to 2 ha, but part of a larger private site.

A DSSP-SWMR Template to guide consultants in the preparation of DSSP-SWMR is being prepared by Water Resources. Until this document has been published, it is recommended that the applicant uses the relevant sections from the Subdivision SWMR Template (refer to ***11.1.6 Stormwater Ponds***). For the latest version of submission and technical requirements, including report templates and checklists, refer to the *Development Approvals Submissions* page on The City of Calgary’s website.

Submission and technical requirements for DSSPs include the following:

i) Serviced sites less than (or equal to) 2 ha do not require detailed stormwater management reports for determining required storage volumes. Storage volumes can be determined through manual calculations and graphs. Refer to ***4.7.1 Serviced Sites***.

ii) Non-serviced sites less than (or equal to) 2 ha do not require detailed Pond Reports for determining required storage volumes. Storage volumes for zero-discharge ponds and evaporation ponds can be determined through the procedures outlined in ***4.8.4 Zero-Discharge Facilities***. Contact Water Resources for more information.

iii) Serviced sites greater than 2 ha require detailed stormwater management reports for determining required storage volumes. Submission and technical requirements for Subdivision Reports (SWMR) should be followed. Refer to ***11.1.6 Stormwater Ponds***.

iv) Non-serviced sites greater than 2 ha require detailed zero-discharge and/or evaporation pond reports for determining required storage volumes. Submission and technical requirements for Pond Reports should be followed. Refer to ***11.1.6 Stormwater Ponds***. The computer modelling should adhere to the requirements stipulated in ***4.8.4 Zero-Discharge Facilities***. Since there should be no discharge from a zero-discharge pond or an evaporation pond, water quality modelling can be eliminated.

11.1.9 Special Projects and Contracts (SPs)

All special projects and contracts (SPs) are required to conform to provincial and City of Calgary stormwater management designs and policies, whether they are designed within The City by other business units or through external consultants.

Submission and technical requirements for special projects and contracts should conform to the requirements for reports corresponding to MDPs, SMDPs, Subdivision SWMRs, Pond Reports, and/or SWMRs supporting DSSPs. All relevant Construction Drawings should be included, as required. For more information, contact Water Resources.

11.1.10 Biophysical Impact Assessments (BIAs)

The purpose of the BIA is to examine the potential impacts of future development on biophysical elements (ecosystems, landforms, and habitats) and to successfully integrate stormwater management (utilities and facilities) within the planning area.

The City of Calgary Parks' *Open Space Plan* provides the basis on which the consultant should begin the process of creating the BIA. The BIA is to be done in collaboration with Parks and Water Resources to meet mutual objectives, specifically related to the river and creek valleys, wetlands, and ravines. The consultant is to contact Parks **first** for the BIA scope, requirements, and issues to be addressed. A BIA could be simple or complex, depending on the area (community) and/or size. Environmental strategies might be provided in the Natural Area Management Plan (NAMP) prepared by Parks. Natural habitat types might also be identified on a small scale in the NAMP; however, further inventory could be required.

11.1.10.1 Submission Requirements

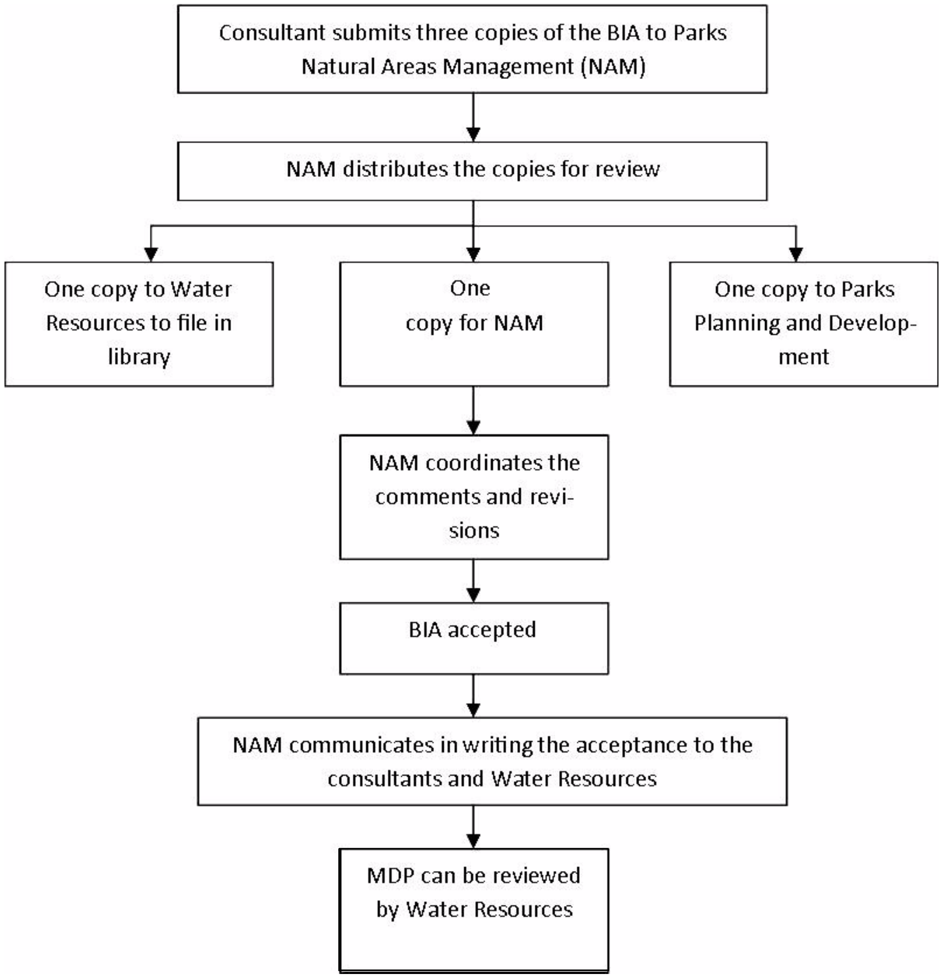
i) Submission of a BIA is required **prior** to, or in conjunction with, the MDP Report. Where a BIA has not been previously completed, one will be required with the SMDP and/or Pond Report.

ii) The BIA must be referenced in the MDP, SMDP and/or Pond Report. In those reports, where required, relevant recommendations from the BIA should be identified. In addition, it should be identified how those recommendations were addressed in the MDP, SMDP, and/or Pond Report.

iii) The BIA report will typically be a stand-alone report. However, when warranted, it can be included in the MDP or SMDP report. The consultant must submit **two** (2) copies of the BIA report to Parks' Natural Area Management and **one** (1) copy to Water Resources. A period of **three** weeks minimum is required for review and comments by Parks' Natural Area Management.

iv) Alberta Environment, Water Sciences branch, must review BIAs where ponds are adjacent to watercourses as a requirement of the provincial stormwater pond approval process. Water Resources will forward a copy of the BIA along with the application to Alberta Environment; the consultant must provide an extra copy of the BIA in these circumstances.

Figure 11-4: Review Process for BIAs



11.1.10.2 Technical Requirements

The BIA should dovetail with the The City of Calgary Parks *Open Space Plan* and the *Calgary Wetland Conservation Plan* by Parks (as amended by Council). A competent consultant with expertise in this area is required for the report or as a subconsultant for the report; generally a professional biologist is required.

The BIA should be a collaborative effort between Parks and the consultant to determine the scope and extent of the study. If sufficient information exists, the BIA will be relatively simple. Where more investigation is required, the evaluation should be conducted over a minimum of one growing season (May to October). BIAs should be done as far in advance as possible to avoid unnecessary delays. BIAs are subject to approval by Parks.

All BIAs should include, at minimum, the information outlined in Appendices D, E, and F in the The City of Calgary Parks *Open Space Plan* (as amended by Council) along with any additional information required by Parks.

11.1.10.2.1 Descriptions

i) **Overall Site Description**:

- Overall description of study area, location, section number (and/or legal description where required), maps, total area.
- Reference to any existing Watershed Plans or MDPs, reference to MDPs for adjacent areas.

ii) **Purpose**: Detailed background information for the proposed activity (i.e., stormwater pond, outfall, storm and sanitary sewer alignment).

iii) Existing Impacts and Policies: Identify current land use, any existing NAMPs, and any existing internal or external policies that may direct or influence the proposal, etc.

iv) **Objectives**: Identify biophysical management objectives.

v) **Miscellaneous**: Where applicable identify capital cost and financing constraints, use of natural resources or disruption during construction, etc.

11.1.10.2.2 Inventory of Biophysical Environment

i) **Topography/Physiography**: Physical description of existing land forms, slopes, aspects and position within the landscape.

ii) **Geology/Hydrogeology/Geomorphology/Soils**: Description of surficial and subsurface geological features and soils; emphasis should be on the impacted site(s) and immediate environment. Identify glacial land forms and stability issues.

iii) **Vegetation**: Identify on-site flora with emphasis on habitat value, wildlife corridor importance, and the role of resident vegetation within the localized system. Include a rare species summary where necessary.

iv) **Wildlife**: Identify on-site fauna with emphasis on habitat value, wildlife corridor importance, and the role of wildlife within the localized system. Include a rare species summary where necessary.

v) **Hydrology/Fisheries**: Identify all streams, rivers, lakes, wetlands, other wet bodies, springs or other natural hydrological resources. Also identify surficial drainage patterns, water table, water quality, fish habitat, and other features.

vi) **Aesthetics**: Subjective description of how the site fits into the landscape and/or cityscape, and other significant features, such as approved City policies and plans. This could include prominent views, human disturbance, aesthetic features, hydrological/biological/geological resources, etc.

vii) C**ultural Resources (Prehistoric, Historic and Current)**: Identify existing historical, interpretive, or recreational features and the potential for developing recreational, interpretive, or educational facilities at the site.

viii) **Other Features**: Descriptions or other features that may be of importance or interest to the site but are not included in the above categories (i.e., power lines, buildings, roads).

11.1.10.2.3 Impacts

i) **Biological Resource Impacts**: Comprehensive account of actual and potential risks/benefits from development activity to wildlife habitat, overall biodiversity, sensitive plant and animal populations, movement corridors, rare or threatened plants and animals, long-term flora, and fauna community stability.

ii) **Geographical and Geological Impacts**: Physical impact of the development activity, including elimination/alteration of unique land forms, alteration of drainage patterns, micro-climate effects, erosion processes, paleontological (surface and subsurface) alterations, and slope stability.

iii) **Visual Impacts**: Physical impact of the development activity including elimination/alteration of unique land forms, alteration of drainage patterns, micro-climate effects, erosion processes, paleontological (surface and subsurface) alterations, and slope stability.

iv) **Cultural Impacts**: Actual and potential impacts of project from a heritage perspective, loss/gain of interpretive resources, impact on historical or archaeological sites, etc.

v) **Social/Economic Impacts**: Actual and potential costs, loss/gain of recreational resources, localized community impacts, long-term cost (in dollars), capital, manpower, and problems created/solved in perception of community.

vi) **Cumulative Impacts**: Summary of combined impacts and how this affects rehabilitation, protection, and operation of the site in the future.

vii) **Residual (Unmitigable) Impacts**: Summary of actual and potential impacts to the site that are inevitable, yet permanent. This could include long-term species diversity, loss of habitat, loss of system connectivity, loss of public access, obstruction of wildlife movement, introduction of weeds or pests, long-term maintenance requirements, removal of natural features, aesthetic impacts, etc.

11.1.10.2.4 Recommendations

i) **Proposed Stormwater Utilities and Facilities**: Integration with the Biophysical Inventory and impacts. Identify advantages, disadvantages, alternatives, financial constraints, etc.

ii) **Mitigation**:

- Identify accepted methods available to mitigate damage and encourage recovery. This could include signage and fencing, grading and loaming, stockpiling, seeding with native mixtures, native plantings, limited-impact construction, etc.
- Identify experimental methods available to mitigate damage and encourage recovery. This could include sod transplants, loam shredding and re-application, specialized seed/plant harvesting and application, use of organic fertilizers and erosion control methods, etc.

iii) **Significance of Impacts**:

- Regional - Cumulative assessment of impacts to the regional area based on biophysical parameters previously identified. Provide loss/gain of regional resources and long-term effects.
- City-Wide - Cumulative assessment of impacts to Calgary's urban natural area system. Include details of habitat loss/improvement, effects on system continuity and contiguous natural areas, effects of wildlife movement, large-scale aesthetic impact, and social, cultural, and economic impacts to Calgarians.
- Park-Wide - Cumulative assessment of impacts to individual parks but with a focus on identified environmentally significant areas, unique habitats, and representation within the park. Identify impacts on habitats, system connectivity, and system viability.
- Local - Small scale approach to impact assessment. This should include impacts on adjacent vegetation communities, loss/gain of community recreational or natural resources, community economic/social impacts, long-term maintenance requirements, aesthetic impacts, introduction of weeds/ pests to community, isolation/connection to city-wide system, etc.

11.1.11 Report Re-Submissions

Once a report has been reviewed, an e-mail will be sent by Parks to the consultant outlining issues to be resolved for report acceptance. This e-mail will indicate whether re-submission is required in the form of a letter (when only a few, or minor, revisions are needed), or a revised report.

i) If a letter is sufficient to address outstanding issues, a review period of **one week** is generally required.

ii) If a revised report is required to address outstanding issues, a minimum review period of **three weeks** is required.

11.2 Engineering Drawings

Engineering (construction) drawings are required for approval by Water Resources prior to construction permission. Where required, reports must be submitted prior to the engineering drawings. The drawings should reflect the stormwater management concepts and details approved in the reports. The following sections outline the stormwater criteria required for the drawings. For the latest version of the Submission and Technical Requirements, refer to the *Development Approvals Submissions* page on The City of Calgary's website, where the latest version of relevant report templates and checklists are provided.

11.2.1 Subdivision

11.2.1.1 Preliminary, Final, and Revised Final Construction Drawings (CDs)

Currently, there are two drawing submissions required for subdivisions: Preliminary Construction Drawings (CDs) and Final CDs. Revised Final CDs are required when there are significant changes or corrections to the final construction drawings. Revisions to specific drawings can also be requested. **All construction drawing circulations must be submitted to Urban Development for internal circulation to the various approving business units.** Please refer to the *Guide to Development Approvals Applications* on the *Development Approvals Submissions* page on The City of Calgary's website for more information about the approvals process.

i) The **preliminary** construction drawing submission must be accompanied by a cover letter, and a completed *Checklist #1:Preliminary/Final Construction Drawings*.

ii) The **final** construction drawing submission must be accompanied by a cover letter (with responses to Development Approval's comments on the previous submission), a completed *Checklist #1: Preliminary/Final Construction Drawings,* and a full set of modified Construction Drawings.

iii) The **revised final** construction drawings must be accompanied by a cover letter (with responses to Development Approval's comments on the previous submission), a completed *Checklist #2: Revised Final Construction Drawings*, (with all revisions and comments addressed), and a full set of modified Construction Drawings.

If design changes to the final or revised final construction drawings constitute changes to the contents of the approved SWMR, an amendment to the SWMR must be submitted directly to Water Resources, Development Approvals.

11.2.1.2 Drawing Requirements

A set of construction drawings typically includes several drawings. The drawings should include stormwater management information and details as described:

11.2.1.2.1 Preliminary Construction Drawings

i) **Storm**: The storm drawing must show the layout of the storm sewer system including MH size and type, pipe material and size, invert elevations, length and slope, installation type, and location and type of CBs The storm sewer system must be designed with hydraulic considerations as required.

ii) **Storm Drainage and Design Calculations**: The storm drainage drawing must show overall catchment boundaries (including off-site and upstream areas) and (unit area) release rates. The location and type of CBs must also be shown. The boundaries and (unit area) release rates must conform to the approved MDP or SMDP. Storm sewer design tables (excluding modelled cumulative flows) are included.

iii) Overland Drainage: The overland drainage drawing must show contours, slope of road, drainage gutter or swale, and preliminary traplow outline at spill elevation.

iv) **Erosion and Sediment Control**:

- Erosion control features for subdivision phase and overall drainage area (as required).
- Details of erosion and sediment control features.

v) **Surface Improvements**: This drawing must show the location and type of curbs and sidewalks, including the alignment and type of drainage gutters and swales and gutter and swale details. The location and type of CBs must also be shown.

vi) **SCPs (BMPs)**: Prior to submission of the drawings, refer to the *Development Approvals Submissions* page on The City of Calgary's website, where SCP drawing requirements are provided (or will be provided in the near future - contact Water Resources for more information).

vii) **Profile Drawings**: The profile drawings must show pipe design information, including pipe material and size, invert elevations, length and slope, design flow and capacity, installation type, and location and type of CBs.

Underground and Surface construction permission for storm drainage systems is generally not granted based on preliminary drawing submissions, since not all of the stormwater management and design information is normally included at this stage. Underground approval can be issued separately, at the discretion of Water Resources, if it is deemed low risk, but surface approval will **not** be given until the SWMR is approved. **Any changes required to underground infrastructure as a result of changes to the SWMR will be the responsibility of the proponent to complete.**

11.2.1.2.2 Final Construction Drawings

When Final Construction drawings are submitted, the SWMR must already have been submitted to Development Approvals. The drawings should include stormwater management information and details as described below:

i) **Surface/Sidewalk**:

- Construction and development boundaries.
- All ICDs, CB types and locations, and interconnected CBs.
- Alignment of drainage gutters or swales (concrete and grass) and details, as required. For concrete drainage swales, requirements for deep and highback swales should be indicated. Type and extent of erosion protection (i.e., riprap classes) should be indicated as required.
- Drainage crossing locations.
- Splash-pads from or equivalent erosion protection at rear yard drainage gutters or swales into Environmental Reserves (ERs), Municipal Reserves (MRs), or open areas.
- Road subdrains (if approved).
- Extent of asphalt on lanes where there are trap lows.
- Cross sections and details as required. These can include spillover elevations, clearance details for overland flows, etc.
- SCP details.

ii) **Sanitary**: Sanitary sewer MHs requiring seals or one-hole MH lids must be identified.

iii) **Storm**:

- The layout of the storm sewer system, including MH type and sizes, pipe material and size, invert elevations, length and slope, installation type and bedding, minimum drops at deflections, pipe radii, allowable horizontal bends for bell and spigot connections, crossing conflicts, and separation from adjacent utilities and right-of-ways (RoWs).
- All ICDs, CB types and locations, and interconnected CBs.
- Special hydraulic requirements (i.e., benching details, HGLs, etc.).
- SCPs and details (i.e., oil/grit separators). A separate drawing could be required, depending on the extent of the provisions.

All piping is to be rubber gasketed unless approved otherwise.

If Standard Installation Direct Design (SIDD) installations are required, separate design sheets by the design manufacturer are required to be submitted directly to Water Resources, Development Approvals for approval.

iv) **Storm Drainage**:

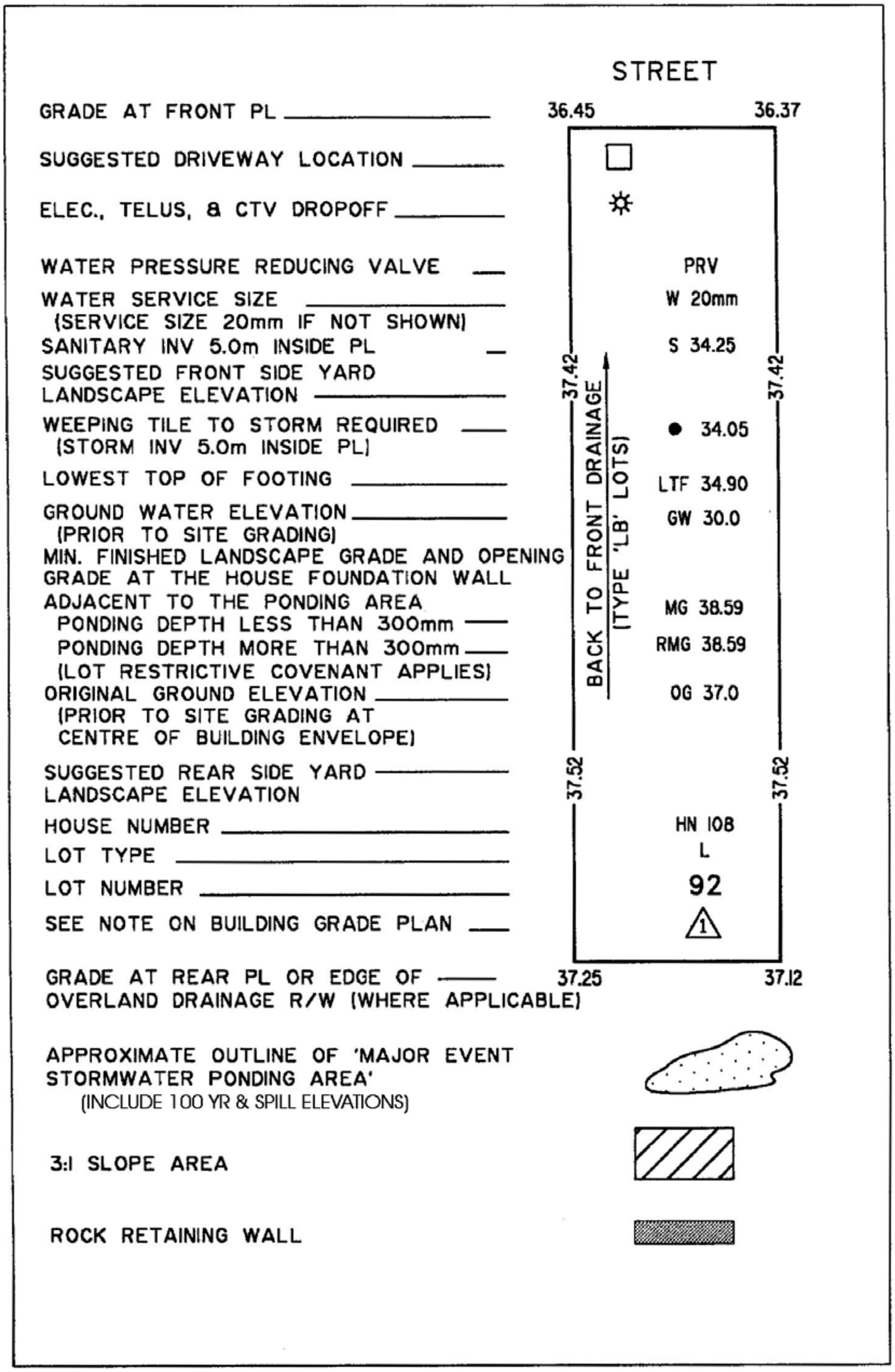
- Drainage areas boundaries, sizes and release rates. Drainage areas must coincide with the approved SWMR.
- Pipe layout including pipe sizes and MH numbers. A pipe numbering system should be added, if applicable.
- Minor System Table, as per ***Table 11-3***.
- Permissible Discharge Rates and Preliminary On-Site Storage Requirements for Private Sites Table, as per ***Table 11-12***.
- ICDs, CB types and interconnected CBs.
- Road subdrain (if approved), any other subdrains and detailed connections.
- SCP details.

v) **Building Grade Plan (BGP)**:

- Weeping tile drainage requirements. Weeping tile drains are required on all lots unless water table readings are submitted showing that a weeping tile drain is not required. Refer to ***3.3.6 Weeping Tile Drains (Foundation Drain)*** for more information.
- Trap lows and corresponding information (i.e., 1:100 year and spillover elevations and depths).
- MGs/RMGs for affected lots.
- Flood fringe and overland flow elevations, as required.
- Side yard elevations to ensure overland flow does not spill through private property.
- HGL elevation information, as required (MHs and lots).
- Lowest Top of Footing elevations must be shown.
- Driveway locations must be shown. Refer to ***3.3.4.2 Types*** (Item iii).
- CB location and type (i.e., C, K2, GT, K3, ICD).
- Retaining and Wing Walls (typically on the surface drawing).
- Sump pump and details, if required.
- Service locations and details, and offsets.
- Front and back corner grades, front sideyard, and rear side yard landscape elevations.
- Lot drainage type ((BF, split, FF, etc.).

Refer to ***Figure 11-5*** for an example of a Building Grade Plan.

Figure 11-5: Building Grade Plan Example



vi) **Overland:**

- Subdivision phase and construction boundary.
- Direction of drainage flow (arrow) including slopes, high points, and low points.
- Overland escape routes must be clearly delineated.
- Trap low location and outline at spill elevation.
- Trap low storage table, as per ***Table 11-11*****.**
- Q/v/d's for all critical segments (i.e., into and out of trap lows, roads, drainage gutters, swales, etc.). Alberta Environment's depth-velocity guidelines must be met.
- ICDs, CB types and any interconnected CBs.
- Concrete drainage gutter locations and details for deep or non-standard gutter sections.
- Details/Cross-sections for spill elevations as required.
- Original ground contours.
- SCP details.

vii) **SCPs (BMPs)** (if needed): Prior to submission of the drawings, refer to the *Development Approvals Submissions* page on The City of Calgary's website, where SCP drawing requirements are provided (or will be provided in the near future - contact Water Resources for more information).

viii) **Erosion and Sediment Control**:

- Refer to The City of Calgary's *Guidelines for Erosion and Sediment Control* for requirements and information.
- Erosion and sediment control features for subdivision phase and overall drainage area (as required).
- Details for erosion and sediment control features.
- Trap lows, CB location and type.
- Cross-section of pertinent controls (such as sediment basins), as required.
- Maintenance protocol (notes regarding scheduling, maintenance, inspection, and repairs).

ix) **Block Profiles**:

- Relevant construction and development boundaries.
- Show sanitary, storm and all other deep utilities.
- Show pipe design information including pipe material and size, invert elevations, length and slope, design flow and capacity, installation type, and location and type of CBs.
- MH type and size.
- ICDs, CB location and type, leads, and interconnected CBs.
- Original ground elevations.

- Road grades including low and high point elevations for trap lows. Spill elevations and depths for trap lows must coincide with approved SWMR.
- Concrete and vegetated swale requirements including grades and details (i.e., deep, highback, etc.). Riprap or other erosion protection must be shown.

x) **Details** (as required):

- Gutters.
- Grass swales
- Structures (i.e., outfalls, splash pads and aprons, etc.).
- Water quality enhancements (as required).
- BMP designs (as required).
- Geotechnical designs (as required).
- Subdrains.
- SCP details.
- Corner detail on major intersections).
- Cross sections as required.

Surface approval will **not** be given until the subdivision SWMR has been submitted, reviewed, and approved. **Twenty business days** is required for report review. Underground approval is at the discretion of Water Resources. Water Resources will return, without review, all final construction drawings for which an SWMR has not been submitted and reviewed.

11.2.2 Stormwater Ponds

11.2.2.1 Preliminary, Final, and Revised Final Construction Drawings

Engineering drawings for stormwater ponds should be submitted as a separate set of drawings from the subdivision drawings for the purpose of circulation. **All stormwater pond circulations must be submitted to Urban Development for internal circulation.** Please refer to the *Guide to Development Approvals Applications* on the *Development Approvals Submissions* page on The City of Calgary's website for more information about the approvals process.

i) The **Preliminary** construction drawing submission must be accompanied by:
- A cover letter, including highlights of any issues or areas of design that are not consistent with the approved SMDP report or Pond Report, the Development Agreement Number, the Pond Report, SMDP, and/or SWMR title(s) associated with the pond, and the legal land description and municipal address.
- A completed *Checklist #1: Preliminary/Final Construction Drawings* (Sections A and I).

ii) The **Final** construction drawing submission must be accompanied by:
- A cover letter, including responses to Development Approval's comments on the previous submission, highlights of any issues or areas of design that are not consistent with the approved SMDP report or Pond Report, the Development Agreement Number, the Pond Report, SMDP, and/or SWMR title(s) associated with the pond, and the legal land description and municipal address.
- The marked-up Pond Construction Drawings from the previous submission.
- A completed *Checklist #1: Preliminary/Final Construction Drawings* (Sections A and I).
- A full set of modified Construction Drawings.

Development Approvals will not review the final pond construction drawing application until the Pond Report is approved.

iii) The **revised final** construction drawing must be accompanied by:
- A cover letter with responses to Development Approval's comments on the previous submission.
- A completed *Checklist #2: Revised Final Construction Drawings* with all revisions and comments addressed.
- The marked-up pond Construction Drawings from the previous submission.
- A full set of modified Construction Drawings.

If the design changes to the final or revised final construction drawings constitute changes to the contents of the approved Pond Report, an amendment to the Pond Report must be submitted directly to Water Resources, Development Approvals.

11.2.2.2 Drawing Requirements

Several drawings are required for stormwater ponds. Where feasible, drawings can be combined. The drawings should include the following information:

i) **Site/Overall**:

- Site location within the city of Calgary including nearby roadways.
- Quarter section lines and street names.
- Legal boundaries.
- Construction boundary.

ii) **Storm Drainage**:

- Drainage boundaries, areas, and sizes. Drainage areas must coincide with approved SMDP, Pond Report, and/or SWMR.
- Stage - Storage - Discharge Table as per ***Table 11-8*****.**
- Minor System Design Table for storm trunk(s) as per ***Table 3-1***.
- Storm sewer system layout and MH locations, pipe material and size, invert elevations, length and slope, installation type, and location and type of CBs.
- Location and type of CBs and ICDs (as required).
- Location of outlet control structure.
- SCP details (if within pond boundary).

iii) **Site/Pond Coversheet**:

- Pond outline with pond bottom, NWL, (L)NWL, (U)NWL, HWL, FB and 1:100 year elevations (if different than HWL), where applicable.
- Area of inundation corresponding to non-operational water re-use system for zero-discharge facilities
- Sediment forebay(s) or alternative (design and sediment storage capacity)
- Pond staging shown when permitted
- Land use for surrounding area
- Location of structures
- Location of monitoring panel
- Access road to inlet and outlet structures and boat ramp: location, width and structure requirements
- Pathway: locations, width and structure requirements
- Overland escape route and details (longitudinal profile and cross sections)
- Signage locations and type
- Details of SCPs (if within pond boundary)

iv) **Storm Coversheet**:

- Layout of the storm sewer system including MH type and size, pipe material and size, invert elevations, length and slope, installation type and bedding, minimum drops at deflections, pipe radii, allowable horizontal bends for bell and spigot connections, crossing conflicts, and separation from adjacent utilities and RoWs.

- Location of structures (inlet/outlet, control, skimming MHs/weirs)
- Special hydraulic requirements (benching details, HGLs, etc.)

All piping connections are to be rubber gasketed unless approved otherwise.

v) **Block Profiles** (as required).

vi) **Inlet Structures**:

- Details, invert and rim elevations
- Gratings, bolting and coating
- Riprap or other erosion protection
- Overland flow inlet details and erosion protection

vii) **Catchbasins (CBs)/Drain Inlets (for Dry Ponds)**:

- Details, inverts
- Gratings, bolting and coating

viii) **Outlet Control Structure**:

- Invert and rim elevations
- Bypass gate
- Weir wall
- Trash rack
- Orifice: material, size, elevations
- Gratings, bolting and coatings (as required)
- Access hatch
- Location of monitoring panel and sensors, elevations for alarm and dead band

ix) **Subdrainage System**: Layout and details of subdrainage system (if required)

x) **Contour and Cross-Sections**:

- Include contour plan and indicate pond bottom, NWL, (L)NWL, (U)NWL, HWL, FB, and 1:100 year elevations (if different than HWL), where applicable.
- Property line elevation surrounding the pond.
- Include side slopes and bottom slopes (as required).
- Forebay berm longitudinal profile, cross-sections and details.
- Show liner and warning barriers (as required).
- Overland escape route and details (cross-section and longitudinal section).
- Cross sections including maintenance access and pathways.

A minimum of four cross sections are required: one longitudinally through the entire pond (including the forebay); one perpendicularly through the forebay; one longitudinally through the forebay berm; and one perpendicularly through the main cell (if there are multiple cells, a cross section perpendicular through each cell is required).

xi) **Monitoring Equipment**:
- Location of monitoring instrumentation panel and access to panel.
- Location and elevation of sensors.
- Elevations for alarms and dead band.

xii) **Water Re-Use Details** (as required):
- Intake.
- Pretreatment.
- Pump Station.
- Discharge Line.
- Controls and alarms.

xiii) **Miscellaneous Details** (as required):
- Water quality enhancements.
- Geotechnical designs including retaining walls, liner and warning barrier, toe and french drains, and forebay berm.
- Culverts.

xiv) **Landscaping and Vegetation**:
- Details of perimeter landscaping and vegetation.
- Details of pond landscaping and vegetation.
- Details of benching and side slope changes.
- Wetland vegetation.
- Setbacks from utility easements.

xv) **Irrigation**: Layout and details of irrigation system.

xvi) **Sedimentation and Erosion Control Plan Details**:
- General notes (refer to ***Technical Requirements for ESC Reports and Drawings*** and The City of Calgary's *Guidelines for Erosion & Sediment Control*), post construction.
- ESC measures and details.
- RUSLEFAC calculations for sediment yield, as required.

Ponds must be constructed prior to, or in conjunction with, the first phase of development. Pond staging is **not** permitted for dry ponds; staging for wet ponds and wetlands requires the approval of Water Resources.

11.2.3 Development Site Servicing Plans (DSSPs)

Drawing requirements are generally not as stringent for DSSPs as for subdivisions, unless the site is large and/or complicated. The conditions for when to submit a DSSP-SWMR are outlined in ***11.1.8 Development Site Servicing Plans (DSSPs)***. The drawings should include stormwater management information and relevant details as described in ***11.2.3.1*** and ***11.2.3.2***.

11.2.3.1 Overall Servicing

i) Overall site, including property boundaries or vicinity map in case of large sites (such as SAIT or University of Calgary), section, address, legal description, etc.

ii) Construction and development boundaries.

iii) Building outlines, parking lots (paved and gravelled), driveways and parking garage access routes.

iv) Layout and details of existing and proposed utilities including storm and sanitary systems and connection(s) including:

- MH type and size.
- Pipe material and size.
- Invert elevations.
- Rim elevations.
- Length and slope.
- Installation type and bedding.
- Minimum drops at deflections.
- Pipe radii.
- Allowable horizontal bends for bell and spigot connections.
- Pipe cover.
- Crossing conflicts.
- Separation from adjacent utilities and RoWs.

Note: *National Plumbing Code of Canada* requirements must be met.

v) Subcatchments and Minor System Table, as per ***Table 11-9***.

vi) Sanitary sewer MHs requiring seals or one-MH lids must be identified.

vii) All ICDs, CB type and location, and interconnected CBs.

viii) Outlet control (service connection) and applicable details (flow restrictors).

ix) Sump pump and details, if required.

x) Pump start and stop elevations, and pump rating curve, if applicable.

xi) Special hydraulic requirements (i.e., benching, HGLs, backwater valves, etc.).

xii) Minimum main floor (MF/MMF/MSE/TOS) elevation(s) required for building(s).

xiii) Flood fringe and overland flow elevations, as required.

xiv) Details of SCPs (i.e., oil/grit separators including type and model number, installation details, etc.). A separate drawing may be required depending on the extent of the provisions.

11.2.3.2 Grading and Overland:

i) Drainage area boundaries and sizes, including (interim) external drainage areas flowing onto the site.

ii) Adjacent properties and streets (show contours and (critical) trap low spillover elevations).

iii) Direction of drainage flow (arrow) including slopes, high points, and low points.

iv) Permitted release rate (expressed in L/s/ha and L/s).

v) Imperviousness and runoff coefficients as required.

vi) On-site storage volume calculations and requirements (1:100 year event).

vii) Details of stormwater storage:

- Trap lows (low point, 1:100 year and spill) elevations, depths, and volumes), including outline at spill elevation.
- Roof top (capacity required, discharge rate, design details).
- Underground (capacity required, discharge).
- Stormwater ponds, including zero-discharge facilities (refer to ***11.2.2 Stormwater Ponds*** and following section).
- Any other applicable details.

viii) Overland escape routes must be clearly delineated,

ix) Water quality requirements and applicable details (as required).

x) BMPs and applicable details (as required).

xi) Erosion and Sediment Control requirements and applicable details (if applicable).

xii) Grading showing landscaping, berms, escape routes, ponds, and applicable elevations. Details of the overland escape route to be provided. Stormwater must be contained on-site.

- Alignment of drainage gutters or swales (concrete and grass) and details, as required. For concrete drainage swales, requirements for deep and highback swales should be indicated. Type and extent of erosion protection (i.e., riprap classes) should be indicated, as required.
- Drainage crossing locations.
- Other details (as required).
- Reference to applicable stormwater report(s).
- Cross sections and other details as required. These can include spillover elevations, clearance details for overland flows or BMPs, etc.

11.2.3.2.1 Stormwater Ponds (including zero-discharge facilities):

i) Pond drawings should follow the requirements in ***11.2.2 Stormwater Ponds***. Smaller and less complex ponds may require less details.

ii) Geotechnical requirements must be addressed.

iii) Monitoring equipment is not required unless the facility is transferred to the City of Calgary at some time in the future.

For all drawings, refer to applicable DDSP-SWMR and preceding Subdivision-SWMR or Community Drainage Study reports to verify catchment boundaries.

11.2.4 Special Projects and Contracts (SPs)

Drawing requirements for special projects and contracts should conform to the requirements for subdivisions, stormwater ponds, or Development Site Servicing Plans as required. Refer to ***11.1.6 Stormwater Ponds***, ***11.1.6 Stormwater Ponds***, or ***11.1.8 Development Site Servicing Plans (DSSPs)***, or contact Water Resources, for more information.

11.3 Inspections

Ongoing inspections by Water Resources are required for underground utilities and lift stations, surface drainage facilities, surface improvements, stormwater ponds, and Special Projects and Contracts during construction. Contact Water Resources, Inspection Services or refer to The City of Calgary's *Consulting Engineers Field Services Guidelines* for more information regarding inspections in subdivisions. Contact Water Resources, Project Engineering Underground for more information regarding Special Projects and Contracts.

DSSP sites require inspections from Water Resources, Inspection Services if the total length of the sanitary and storm systems exceeds 200 m or if the diameter of the water main exceeds 50 mm. Contact Water Resources, Inspection Services for more information.

11.4 Certificates

Construction Completion Certificates (CCCs) and FACs are required for underground utilities and lift stations, surface drainage facilities, surface improvements, stormwater ponds, and stormwater SCPs (BMPs) that will ultimately be taken over by the City. Special Projects and Contracts also require CCCs and FACs. Prior to the issuance of certificates, all storm infrastructure must be clean and functional. All required testing must be submitted and approved by Water Resources, Inspection Services.

DSSP sites do not require CCCs or FACs, since the properties are privately owned. However, all Development Permit (DP) conditions must be met.

Underground utilities and lift stations, surface drainage facilities, surface improvements, stormwater ponds, and SCPs require separate certificates. Maintenance periods can vary, ranging from one year (storm sewer systems) to two years (retrofit projects and subdivisions) to three years (stormwater ponds and wetlands, automatically controlled gate systems, and SCPs). Refer to ***6.1.11 Maintenance Periods*** for more information on maintenance periods for stormwater ponds.

An operations and maintenance (O&M) report/manual must be submitted to Water Resources at the time of FAC for any SCPs located on public lands, as well as a list of all maintenance activities performed during the maintenance period. Contact Water Resources for more information on the contents of the O&M manual. In addition, refer to ***APPENDIX J: Operation And Maintenance Activities for Stormwater Source Control Practices***. For private lands, an O&M manual and sample maintenance log must be provided to the owner of the SCPs. Refer to ***4.13 Best Management Practices (BMPs)*** for more information.

11.5 Lot Grading Verification

Each residential lot adjacent to a trap low where a Minimum Grade (MG) or Registered Minimum Grade (RMG) elevation is indicated on the BGP will show a requirement for "Lot Grading Verification" on the Building Grade Slip issued to the builder. An "As Constructed Grade Certificate", prepared by a Professional Engineer, Alberta Land Surveyor, or registered Architect must be submitted to the Director, Water Resources certifying that garage slab and house openings are above the MG or RMG elevation specified. For more information, refer to *Lot Grading Bylaw 32M2004*.

11.6 Record (As-Built) Drawings

11.6.1 Purpose

As part of the CCC and FAC process, Record Drawings (also commonly known as As-built Drawings) are required for subdivisions, stormwater ponds, BMPs, and Special Projects and Contracts. All record drawings should be forwarded to Water Resources for review and approval.

11.6.2 Underground Utilities and Lift Stations, Surface Drainage Facilities, and Surface Improvements

Contact Infrastructure & Information Services, Utility Records for record drawing requirements. To control grading for stormwater management, the following additional as-builts are required:

- As-built elevations of the critical spill locations for trap lows during construction. Locations that are not within tolerance must be corrected before the contractor leaves the site. The allowable tolerance is +/- 50 mm.
- The actual as-built capacity of the trap low (corresponding to spillover conditions) shall not be more than 5% below the design capacity (corresponding to spillover conditions) unless the trap low still has spare capacity. In that case, the actual as-built capacity (corresponding to spillover conditions) shall be greater than the design 1:100 year trap low volume. If the actual as-built capacity is less than 95% of the design capacity (corresponding to spillover conditions) and the trap low now spills or spills more, impacts on adjacent and/or downstream development must be quantified and mitigated or the grading of the trap low remedied.
- Minimum building opening elevations (MGs) might need to be adjusted to ensure that an appropriate minimum level of freeboard remains effective at all times.
- Where the spill elevations of several trap lows in an area are similar, a tighter tolerance will be required to ensure overland flows spill in the required direction.

11.6.3 Stormwater Ponds

Stormwater ponds undergo a more extensive as-built review due to water quantity, water quality, and safety requirements. The construction of **all** stormwater ponds must meet the following tolerances:

- Spillover Elevation must be within +/- 50 mm for the overland emergency escape route and within +/- 25 mm for the weir wall in the outlet control structure.
- Freeboard Elevation must not be more than 50 mm below the design elevation.
- Width of the crest of the overland emergency escape route must be within +/- 100 mm.
- Live storage capacity must be no less than 99% of the required 1:100 year storage capacity.
- Discharge at 1:100 year elevation must be within +/- 1.0%.
- (U)NWL of wet ponds must be within +/- 25 mm.
- The crest elevation of the forebay must be within +/- 150 mm.

The sediment accumulation in **wet ponds** must be such that, at FAC:

- The sediment storage capacity in the forebay(s) must be greater than or equal to The design 25-year sediment accumulation.
- The top of the sediment accumulation in the forebay(s) is at least 300 mm below the lowest invert of the incoming pipe(s).
- The wet pool capacity is greater than the design capacity.
- The sediment accumulation in the main cell(s) of the wet pond relative to CCC is less than 150 mm.

The sediment accumulation in **constructed stormwater wetlands** must be such that, at FAC:

- The sediment storage capacity in the forebay(s) must be greater than or equal to the design 25-year sediment accumulation.
- The top of the sediment accumulation in the forebay(s) is at least 300 mm below the lowest invert of the incoming pipe(s).
- The sediment accumulation in the main cell(s) of the wetland relative to CCC is less than 25 mm.

In the case of **engineered natural stormwater wetlands**, the tolerances must be as agreed to by Water Resources and Parks as part of the Pond Report.

Refer to ***APPENDIX I: Stormwater Pond Inspection Requirements*** and the *Guide to Development Approvals* (on the *Development Approvals Submissions* page on The City of Calgary's website) for additional as-built and inspection requirements. Record drawings must be forwarded as part of the CCC approval process to Water Resources, Development Approvals.

As part of the record drawing submission, a letter from the alarm panel installer identifying that the system has been installed and is operating as intended must also be submitted to Development Approvals. Once the letter is received, Development Approvals will contact Field Services to confirm that the monitoring system is in good working order. Contact Water Resources for more information.

11.6.4 Development Site Servicing Plans (DSSPs)

Record drawings for stormwater ponds, including zero-discharge facilities, must be submitted to Water Resources, Development Approvals, The owner must ensure that sufficient on-site storage has been constructed to contain overland flows on site, up to the1:100 year event.

11.6.5 Source Control Practices (SCPs)

The development of record drawing and CCC/FAC requirements for SCPs is in progress. Typically, record drawings are submitted to Infrastructure & Information Services, Utility Records, and then forwarded to Water Resources, Development Approvals for review. A separate CCC/FAC for SCPs could be required, unless it can be included with the underground utilities, surface drainage facilities, or surface improvements CCC/FAC. Refer to the *Development Approvals Submissions* page on The City of Calgary's website or contact Development Approvals for more information prior to submission of the drawings.

WORKS CITED

Alberta Environment. 2006 *Nose Creek Flood Risk Mapping Study*. 2006. Print.

Alberta Environment. *Application Form and Guide for Registration to Construct and Operate a Municipal Storm Drainage System*. 2009. Web: http://environment.alberta.ca/01176.html

Alberta Environment. *Approved Water Management Plan for the South Saskatchewan River Basin (Alberta).* August 2006. Web: http://environment.alberta.ca/documents/SSRB_Plan_Phase2.pdf

Alberta Environment. *City of Calgary Floodplain Study - including 1996 model updates.* February 1996. Print.

Alberta Environment. *City of Calgary Floodplain Study.* April 1983. Print.

Alberta Environment. *Municipal Policies and Procedures Manual*. April 2001. Web: http://environment.alberta.ca/02174.html

Alberta Environment. *Provincial Wetland Restoration and Compensation Guide*. February 2007. Web: http://environment.alberta.ca/documents/Provincial_Wetland_Restoration_Compensation_Guide_Feb_2007.pdf

Alberta Environment. *Snow Disposal Guidelines for the Province of Alberta*. Air & Water Approvals Division, 1994. Web: http://environment.gov.ab.ca/info/library/5871.pdf

Alberta Environment. *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage System*. 2006.Web: http://www.environment.alberta.ca/01249.html

Alberta Environment. *Stormwater Management Guidelines for the Province of Alberta*. 1999. Web: http://www.environment.alberta.ca/01251.html

Alberta Environment. *Surface Water Quality Guidelines for Use in Alberta*. 1999. Print.

Alberta Environment. *Wetlands Management in the Settled Area of Alberta - an Interim Policy*. 1990. Web: http://environment.gov.ab.ca/info/library/6169.pdf).

Alberta Environmental Protection. *Evaporation and Evapotranspiration in Alberta. Report 1912-1985, Data 1912-1996. Data extended to 2001.* Water Sciences Branch, 2001. Print.

Alberta Municipal Affairs. *Alberta Guidelines for Residential Rainwater Harvesting Systems*. 2010. http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/plumbing/AlbertaGuidelines2010.pdf

The Alberta Native Plant Council. *Native Seed Source List.* Edmonton: 2010. Web: http://www.anpc.ab.ca/assets/ANPC_2010_Native_Plant_Source_List.pdf

The Alberta Native Plant Council. *Plant Collection Guidelines for Horticultural Use of Native Plants.* Edmonton: April 2007. Web: http://www.anpc.ab.ca/assets/gardener_guidelines.pdf

Alberta Transportation & Alberta Environment. *Water Control Structures - Selected Design Guidelines*. November 2004. Web: http://www.transportation.alberta.ca/Content/doctype125/Production/DesignGuidln.pdf

Alberta Transportation. *Design Guidelines for Bridge Size Culverts*. Technical Standards Branch, November 2004. Web: http://www.transportation.alberta.ca/Content/docType30/Production/DsnGdlClvNov04.pdf

Alberta Transportation. *Design Guidelines for Erosion and Sediment Control for Highways*. 2003. Web: http://www.transportation.alberta.ca/1812.htm

Alberta Transportation. *Engineering Consultant Guidelines for Highway and Bridge Projects: Volume 1 - Design and Tender*. 2002. Web: http://www.transportation.alberta.ca/930.htm

Alberta Transportation. *Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta*. August 2009. Web: http://www.transportation.alberta.ca/Content/docType245/Production/Complete_Fish_Habitiat_Manual.pdf

Alberta Transportation. *Hydrotechnical Design Guidelines for Stream Crossings*. September 2006. Web: http://www.transportation.alberta.ca/Content/doctype30/Production/HyDgnGLStCr.pdf

Alberta Transportation.*Culvert Sizing Considerations*. January 2004. Web: http://www.transportation.alberta.ca/Content/doctype30/Production/ClvSizConsid.pdf

American Iron and Steel Institute (AISI). *Modern Sewer Design*. Washington DC: 1996. Print.

American Public Health Association, American Water Works Association, and Water Environment Federation. *Standard Methods for the Examination of Water and Wastewater-20th Edition.* Washington, D.C.:1998. Print.

American Public Works Association, *Urban Stormwater Management - Special Report No. 49*. Chicago: 1981. Print.

American Society of Civil Engineers (ASCE) and CSCE. *Best Management Practices for Municipal and Industrial Stormwater Control*. ASCE, 1994. Print.

American Society of Civil Engineers (ASCE) and Water Environment Federation. "Design and Construction of Urban Stormwater Management Systems". *ASCE Manual and Reports of Engineering Practice No. 77 and WEF Manual of Practice FD-20.* New York: ASCE, 1992. Print.

AMK Associates International Ltd. *Dual Drainage Storm Water Management Model-Program Documentation and Reference Manual.* Ottawa: 1996. Print

Azous, Amanda L. and Horner, Richard R. *Wetlands and Urbanization-Implications for the Future: Final Report of the Puget Sound Wetlands and Stormwater Management Research Program*. Olympia: Washington State Department of Ecology,1997. Print.

Bartoldus, Candy C., Garbisch, Edgar W. and Kraus, Mark L. *Evaluation for Planned Wetlands - A Procedure for Assessing Wetland Functions and a Guide to Functional Design*. St. Michaels: Environmental Concern Inc., 1994. Print.

Baudo, R., Giesy, J., and Muntau, H. *Sediments: Chemistry and Toxicity of In-Place Pollutants*. Boca Raton: CRC Press, Inc., 1990. Print.

BC Environment. *Urban Runoff Quality Control Guidelines for The Province of British Columbia*. 1992. Print.

Bow Basin Watershed Management Plan Steering Committee. *Bow Basin Watershed Management Plan, Phase One: Water Quality*. 2008. Web: http://www.brbc.ab.ca/index.php?option=com_content&view=article&id=96&Itemid=210

Brown, W. and Schueler, T. *The Economics of Stormwater BMPs in the Mid-Atlantic Region.* Center for Watershed Protection, 1997. Web: http://www.cwp.org/documents/cat_view/76-stormwater-management-publications.html.

Canadian Dam Association. *Dam Safety Guidelines 2007 and Technical Bulletins*. 2007. Web: http://www.cda.ca/cda_new_en/publications/dam%20safety/dam%20safety.html

Cappiella K., Fraley-McNeal, L., Novotney, M., and Schueler, T. *Article 5:The Next Generation of Stormwater Wetlands*. Center for Watershed Protection, 2008. Web: http://www.cwp.org/documents/cat_view/73-wetlands-and-watersheds-article-series.html

Caraco, D. and Claytor, R. *Stormwater BMP Design Supplement of Cold Climates.* Center for Watershed Protection, 1997. Web: http://www.cwp.org/documents/cat_view/76-stormwater-management-publications.html

Chang, F.M., Kilgore, R.T., Woo., D.C., and Mistichelli, M.P. *Energy Losses Through Junction Manholes, Volume I: Research Report and Design Guide*. FHWA-RD-94-080, 1994. Print.

Chow, Ven te. *Open-Channel Hydraulics*. New York: McGraw-Hill, 1959. Print.

City of Austin. *Drainage Criteria Manual.* American Legal Publishing Corporation: 2010. Web: http://austintech.amlegal.com/nxt/gateway.dll/Texas/drainage/cityofaustintexas

City of Bellevue. *Water Quality Protection for Construction Businesses.* Bellevue: Storm and Surface Water Utility, 1990. Print.

City of Bellevue. *Water Quality Protection for Landscaping, Building Maintenance, Food, and Automotive Businesses.* Bellevue: Storm and Surface Water Utility, 1991. Print.

The City of Calgary. *2007 Pine Creek Drainage Study*. Water Resources, 2007. Print.

The City of Calgary. *2008 Calgary Total Loading Management Plan*. Water Resources, 2008. Print.

The City of Calgary. *2009 Environmental Performance Plan*. Water Resources, 2009. Print.

The City of Calgary. *2009-2011 UEP Business Plan - Mission Statement.* Utilities and Environmental Protection, 2008. Print.

The City of Calgary. *2010 Bow and Elbow River Updated Model Project*. 2010. Print.

The City of Calgary. *A Policy on Stormwater Lakes*. 1981. Print.

The City of Calgary. *Calgary Wetland Conservation Plan*. Parks, 2004. Web: http://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/Natural-Areas-and-Wetlands/wetland_conservation_plan.pdf

The City of Calgary. *Community Standards Bylaw 5M2004*. 2009. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Comparison Between DDSWMM and SWMHYMO.* Wastewater & Drainage, 2000. Print.

The City of Calgary. *Consulting Engineers Field Services Guidelines*. Urban Development, 2004. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Design Guidelines for Development Permits, Development Site Servicing Plans and Waste & Recycling Services for Commercial/Industrial Applications*. 2008. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Design Guidelines for Subdivision Servicing.* Urban Development, 2004. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Development Guidelines and Standard Specifications- Landscape Construction.* Parks, 2011. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Drainage Bylaw 37M2005.* 2009. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Field Manual for Effective Erosion & Sediment Control*. Wastewater & Drainage, 2001. Print.

The City of Calgary. *Guidelines for Erosion & Sediment Control.* Wastewater & Drainage, 2011. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *ICD Testing Results.* Sewer Division, 1995. Print.

The City of Calgary. *Integrated Pest Management Plan*. Parks, 1998. Web: http://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/Pest-Management/ipm.pdf

The City of Calgary. *Land Use Bylaw 1P2007*. 2007. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Lot Grading Bylaw 32M2004.* 2007. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Natural Area Management Plan*. Parks, 2003. Web: http://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/Natural-Areas-and-Wetlands/natural-area-management-plan.pdf

The City of Calgary. *Open Space Plan*. Calgary: Parks, 2003. Web: http://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/open-space-plan.pdf

The City of Calgary. *Pine Creek Watershed Study-Preliminary Report*. Wastewater (AMEC Earth & Environmental), 2006. Print.

The City of Calgary. *Principles for Stormwater Wetlands Management in The City of Calgary*. Parks/Water Resources, 2009. Web: http://www.calgary.ca/UEP/Water/Pages/Specifications/Submission-for-approval-/Development-Approvals-Submissions.aspx.

The City of Calgary. *Public Participation in the Development and Maintenance of the Calgary River Valley System*, *CS90-44-01.* 1990. Print.

The City of Calgary. *Regulatory Review and Responsibilities: Erosion and Sediment Control*. Water Resources, 2006. Print.

The City of Calgary. *Sewer Service Bylaw 24M96*. 2008. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Standard Practice for the Design and Construction of Flexible Plastic Pipe*. Water Resources, December 2007. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Standard Practice for the Design and Installation of Rigid Gravity Sewer Pipe.* Water Resources, January, 2008. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Standard Specifications Roads Construction*. Roads, 2007. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary. *Standard Specifications Sewer Construction*. Water Resources, 2011. Web: http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

The City of Calgary*. Stormwater Management Strategy.* Wastewater, 2005. Print.

The City of Calgary. *Stormwater Source Control Practices Handbook*. Water Resources, 2007. Web: http://www.calgary.ca/UEP/Water/Pages/Specifications/Submission-for-approval-/Development-Approvals-Submissions.aspx.

The City of Calgary. *Street Bylaw 20M88*. 2008. Web: http://www.calgary.ca/CA/City-Clerks/Pages/Legislative-services/Bylaws.aspx

The City of Calgary. *Technical Report on Dry Ponds*. 1988. Print.

The City of Calgary*. The City of Calgary Stormwater Runoff.* Water Resources, 2004. Print.

The City of Calgary*. Utilities & Environmental Protection - Approved Business Plans and Budgets 2009-2011*. Utilities and Environmental Protection, 2008. Print.

The City of Calgary. *Wet Ponds: Policy Review, OE-96-52.* 1996.Print.

City of Edmonton. *Design and Construction Standards-Volumes 1, 2 & 3.* 1999. Print.

Corrugated Steel Pipe Institute. *Modern Sewer Design.* Canadian Edition. Ontario: CSPI, 1996. Print.

CSCE and ASCE. *Best Management Practices for Municipal and Industrial Stormwater Control*. 1994. Print.

Databases&path=/en/ab/laws/regu/alta-reg-212-1976/latest/alta-reg-212-1976.html

Dillon Consulting. Memo: “Pine Creek Drainage Study Recommendations - Alternatives to the 20 mm Source Volume Capture Criteria”. April 30, 2009. Print.

drainagecriteriamanual?f=templates$fn=default.htm$3.0$vid=amlegal:austin_drainage

Eastlick, Brian Kim. *Constructing Wetlands for Water Quality Enhancement in Western Canada: Technical Literature Review.* 1993. Print.

Eastlick, Kim. *An Introduction to Wetlands Wastewater Treatment and Potential Western Canadian Applications-A Brief Technology Overview.* Calgary: Reid Crowther & Partners Ltd., 1997. Print.

Elbow River Watershed Partnership. *Elbow River Basin Water Management Plan*. 2008. Web: http://www.erwp.org/index.php/water-management-plan/plan

EPA. *SWMM User's Manual Version 5.0*. 2004. Print'

Ettema, R., Jain, S.C., Kennedy, J.F. *Hydraulic Design of Drop Structures-A State-of-the-Art Review.* Iowa Institute of Hydraulic Research, 1982. Print.

Golder. *Final Report: Bow River Impact Study – Phase 2: Development of Total Loading Management Targets for the City of Calgary.* 2004. Print.

Government of Alberta. *Approvals and Registrations Procedure Regulation, Alta. Reg 113/93.* Web: http://canlii.org/eliisa/highlight.do?text=Approvals+Procedure+Regulation+113%2F93&language=en&searchTitle=Search+all+CanLII+Databases&path=/en/ab/laws/regu/alta-reg-113-1993/latest/alta-reg-113-1993.html

Government of Alberta. *Calgary Restricted Development Area Regulations, Alta. Reg. 212/76*. Canadian Legal Information Institute, 2008. Web: http://www.canlii.org/eliisa/highlight.do?text=212%2F76&language=en&searchTitle=Search+all+CanLII+

Government of Alberta. *Code of Practice for Outfall Structures on Water Bodies*. Canadian Legal Information Institute, 2008. Web: http://www.canlii.org/eliisa/highlight.do?text=Code+of+Practice+for+Outfall+Structures+on+Water+Bodies&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-205-1998/75821/part-3/alta-reg-205-1998-part-3.html

Government of Alberta. *Environmental Code of Practice for Pesticides*. Canadian Legal Information Institute, 2010. Web: http://www.canlii.org/eliisa/highlight.do?text=code+of+practice+for+pesticides&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-118-1993/42950/part-4/alta-reg-118-1993-part-4.html

Government of Alberta. *Environmental Code of Practice for Watercourse Crossings*. Canadian Legal Information Institute, 2003. http://www.canlii.org/eliisa/highlight.do?text=Code+of+Practice+for+watercourse&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-205-1998/75821/part-2/alta-reg-205-1998-part-2.html

Government of Alberta. *Environmental Protection and Enhancement Act, R.S.A 2000, c. E-12.* Canadian Legal Information Institute, 2008. Web: http://canlii.org/en/ab/laws/stat/rsa-2000-c-e-12/latest/rsa-2000-c-e-12.html

Government of Alberta. *Environmental Protection and Enhancement Act; Approvals and Registrations Procedure Regulation, Alta. Reg. 113/93*. Canadian Legal Information Institute, 2001. Web: http://canlii.org/eliisa/highlight.do?text=approvals&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-113-1993/latest/alta-reg-113-1993.html

Government of Alberta. Environmental Protection and Enhancement Act: Activities Designation Regulation, Alta. Reg. 276/2003. Canadian Legal Information Institute, 2009. Web: http://canlii.org/en/ab/laws/regu/alta-reg-276-2003/latest/alta-reg-276-2003.html

Government of Alberta. *Environmental Protection and Enhancement Act: Release Reporting Regulation, Alta. Reg. 117/1993*. Canadian Legal Information Institute, 2003.Web: http://www.canlii.org/eliisa/highlight.do?text=117%2F1993&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-117-1993/latest/alta-reg-117-1993.html

Government of Alberta. *Environmental Protection and Enhancement Act: Wastewater and Storm Drainage (Ministerial) Regulation, Alta. Reg. 120/93*. Canadian Legal Information Institute, 2003.Web: http://www.canlii.org/eliisa/highlight.do?text=120%2F1993&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-120-1993/latest/alta-reg-120-1993.html

Government of Alberta. *Environmental Protection and Enhancement Act: Wastewater and Storm Drainage Regulation, Alta. Reg. 119/93*. Canadian Legal Information Institute, 2003. Web: http://www.canlii.org/eliisa/highlight.do?text=+Wastewater+and+Storm+Drainage+Regulation+%28119%2F93%29&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-119-1993/44276/part-1/alta-reg-119-1993-part-1.html

Government of Alberta. *Government Organization Act, R.S.A. 2000, c G-10.* Canadian Legal Information Institute, 2010. Web: http://www.canlii.org/eliisa/highlight.do?text=Government+Organization+Act%2C&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/stat/rsa-2000-c-g-10/latest/rsa-2000-c-g-10.html

Government of Alberta. *Municipal Government Act, R.S.A 2000, c. M-26*. Canadian Legal Information Institute, 2010. Web: http://www.canlii.org/eliisa/highlight.do?text=Municipal+Government+Act&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/stat/rsa-2000-c-m-26/latest/rsa-2000-c-m-26.html

Government of Alberta. *Native Plant Revegetation Guidelines for Alberta*. Edmonton: Agriculture, Food and Rural Development, February 2001. Web: http://www.srd.alberta.ca/MapsPhotosPublications/Publications/documents/NativePlantRevegetationGuidelinesForAlberta-Feb2001.pdf

Government of Alberta. *Public Lands Act, R.S.A 2000, c. P-40*. Canadian Legal Information Institute, 2008.Web: http://www.canlii.org/eliisa/highlight.do?text=Public+Lands+Act&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/stat/rsa-2000-c-p-40/latest/rsa-2000-c-p-40.html

Government of Alberta*. Soil Conservation Act, R.S.A 2000, c. S-15*. Canadian Legal Information Institute, 2002.Web: http://www.canlii.org/eliisa/highlight.do?text=Soil+Conservation+Act&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/stat/rsa-2000-c-s-15/latest/rsa-2000-c-s-15.html

Government of Alberta. *Water Act, R.S.A. 2000, c. W-3*. Canadian Legal Information Institute, 2008.Web: http://www.canlii.org/en/ab/laws/stat/rsa-2000-c-w-3/latest/rsa-2000-c-w-3.html

Government of Alberta. *Water Act: Water (Ministerial) Regulation, Alta. Reg. 205/1998*. Canadian Legal Information Institute, 1998. Web: http://www.canlii.org/eliisa/highlight.do?text=Water+%28Ministerial%29+Regulation&language=en&searchTitle=Statutes+and+Regulations+of+Alberta&path=/en/ab/laws/regu/alta-reg-205-1998/75821/part-1/alta-reg-205-1998-part-1.html

Government of Alberta. *Water Act: Water (Ministerial) Regulation, Part 6: Dam and Canal Safety Guidelines*. Alberta Environment, March 1999. Web: http://www.environment.gov.ab.ca/info/library/6294.pdf

Government of Canada. "Pollution Prevention." Environment Canada, 2011. Web: http://www.ec.gc.ca/p2/.

Government of Canada. *Canadian Environmental Assessment Act, S.C. 1992, c. 37.* Canadian Legal Information Institute, 2005. Web: http://laws-lois.justice.gc.ca/eng/acts/C-15.2/

Government of Canada. *Canadian Environmental Protection Act, S.C. 1999, c. 33.* Canadian Legal Information Institute, 2006. Web: http://www.canlii.org/en/ca/laws/stat/sc-1999-c-33/latest/sc-1999-c-33.html

Government of Canada. *Fish Habitat Conservation and Protection-What the Law Requires.* Fisheries and Oceans, 1995.

Government of Canada. *Fisheries Act, R.S.C. 1985, c. N-22.* Canadian Legal Information Institute, 2008. Web: http://laws-lois.justice.gc.ca/eng/acts/F-14/

Government of Canada. *Inclusion List Regulations (SOR-94/637)*. Department of Justice Canada, 1994. Web: http://www.laws.justice.gc.ca/eng/regulations/SOR-94-637/index.html

Government of Canada. *Modernizing the Fisheries Act: Bill C-32*. Fisheries and Oceans Canada. 2008. Web: http://www.dfo-mpo.gc.ca/far-rlp/c32-presentation-eng.htm

Government of Canada. *National Plumbing Code of Canada (NPC)*. National Research Council of Canada. 2010. Web: http://www.nrc-cnrc.gc.ca/eng/ibp/irc/codes/2010-national-plumbing-code.html

Government of Canada. *Navigable Waters Protection Act, R.S.C. 1985, c. N-22*. Canadian Legal Information Institute, 2009. Web: http://laws-lois.justice.gc.ca/eng/acts/N-22/. May 27, 2011.

Greenland International Consulting Inc. *Storm Water Management Facility Maintenance Guide.* Job #97-G-1149. 1999.

Haan, C.T., Barfield, B.J., and Hayes, J.C. *Design Hydrology and Sedimentology for Small Catchments.* London: Academic Press, Inc.,1994. Print.

Hager, W. *Wastewater Hydraulics: Theory and Practice. Berlin: Springer-Verlag, 1994.* Print.

Herrin, G. *Practical Guide Hydraulics and Hydrology*. Waterbury: Haestad Press. 1997. Print.

Imbrium Systems. "Stormceptor® Oil & Sand Removal (OSR) system". Web: http://www.stormceptor.com/en/products/stormceptor-osr/index.html

J.F. Sabourin & Associates Inc. *SWMHYMO Storm Water Management Hydrologic Model-User's Manual.* Ottawa: 1998. Print.

Jago, Dr. Richard. TRIALS OF A NEW RAPID CLARIFICATION PROCESS. CDS Technologies, 2003. Web: http://www.wioa.org.au/conference_papers/2003/pdf/1wioa2003.pdf

JNMacKenzie Engineering Ltd. *Overland Flow Methodology.* 1992.

Kadlec, Robert H. and Knight, Robert L. *Treatment Wetlands.* Boca Raton: Lewis Publishers, 1996. Print.

Kassem, A. and Wisner, P. *OTTSWMM-The University of Ottawa Storm Water Management Model.* Ottawa: Department of Civil Engineering, University of Ottawa, 1983. Print.

King County (Washington) Department of Public Works. *Surface Water Design Manual.* 1994. Print.

Krenkel, Peter A. and Novotny, Vladimir. *Water Quality Management.* New York: Academic Press,1980. Print.

Lanarc Consultants Ltd., Kerr Wood Leidal Associates Ltd., and Ngan, Goya, ed. *Stormwater Source Control Design Guidelines 2005*. Greater Vancouver Regional District (GVRD), 2005. Print.

Maine Department of Environmental Protection. *Stormwater Management for Maine: Best Management Practices.* Augusta: 1995. Print.

Marsalek, J. and Greck, B.J. “Head Losses at Manholes with a 90^{o} Bend”. *Canadian Journal of Civil Engineering - Volume 15, Number 5*, 851-858. 1988. Print.

Marsalek, J. *Head Losses at Selected Sewer Manholes.* Burlington, Ontario: National Water Research Institute 85-15, 1985. Print.

Maryland Department of the Environment. *Maryland Stormwater Design Manual - Volumes I & II-REVIEW DRAFT.* 1998. Print.

Massachusetts Department of Environmental Protection and Massachusetts Office of Coastal Zone Management. *Stormwater Management-Volumes One and Two.* 1997. Print

Metropolitan Washington Council of Governments. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* 1992. Print.

Mitsch, W.T. and Gosselink, J.G. *Wetlands*. 2nd Edition. Van Nostrand Reinhold Company, 1992.

Mitsch, W.T. and Gosselink, J.G. *Wetlands*. New York: Van Nostrand Reinhold Company, 1986.

New Jersey Department of Environmental Protection. *Protocol for Manufactured Hydrodynamic Sedimentation Devices for Total Suspended Solids Based on Laboratory Analysis - Dated August 5, 2009, Revised December 15, 2009*. 2009.

Northern Virginia Planning District Commission. *Nonstructural Urban BMP Handbook-A Guide to Nonpoint Source Pollution Prevention and Control through Nonstructural Measures.* Annandale: 1996. Print.

Northern Virginia Planning District Commission. *Northern Virginia BMP Handbook Addendum: Sand Filtration Systems.* 1996. Print.

Northern Virginia Planning District Commission. *Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia.* 1992. Print.

Northern Virginia Planning District et al. *Outlet Hydraulics of Extended Detention Facilities.* 1989. Print.

Nose Creek Watershed Partnership: Palliser Environmental Services Ltd. *Nose Creek Watershed Management Plan.* 2007. Web: http://nosecreekpartnership.com/our-plan

Oberts, G.L. “Influence of Snowmelt Dynamics on Stormwater Runoff Quality.” *Watershed Protection Techniques, Volume 1, Number 2*. Center for Watershed Protection, 1995. Print.

Ohio Department of Natural Resources. *Keeping Soil on Construction Sites: Best Management Practices.* 1991. Print.

Ohio Department of Natural Resources. *Rainwater and Land Development: Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection.* 1996. Print.

Ontario Concrete Pipe Association. *Concrete Pipe Design Manual.* Web: http://www.ocpa.com/_resources/OCPA_DesignManual.pdf

Ontario Ministries of Natural Resources, Environment, Municipal Affairs and Transportation & Communications, et al. *Guidelines on Erosion and Sediment Control for Urban Construction Sites.* Toronto: 1987. Print.

Ontario Ministry of Environment and Energy (MOEE). *Stormwater Management Practices Planning and Design Manual.* 1994. Print.

Ontario Ministry of the Environment. *Guidelines for Evaluating Construction Activities Impacting on Water Resources.* Toronto: 1995. Print.

Ontario Ministry of the Environment. *Stormwater Management Planning and Design Manual.* Toronto: 2003.Print.

PanAmerica Environmental. “Oil Water Separator Operational Theory”. Web: http://www.panamenv.com/separators-coalescing-theory.html

Paul Wisner & Associates Inc. *INTERHYMO/OTTHYMO 89.* Ottawa: 1989. Print.

Prince George’s County. *The Bioretention Manual*. Maryland: Department of Environmental Resources, Environmental Services Division, December 2007. Web: http://www.princegeorgescountymd.gov/Government/AgencyIndex/DER/ESG/Bioretention/pdf/Bioretention%20Manual_2009%20Version.pdf

Rabani and Grizzard. 1996. Print.

Reid Crowther & Partners Ltd. *Discovery Ridge Sedimentation Pond No. 1 Design Brief-Revised.* Calgary, 1999. Print.

Reid Crowther & Partners Ltd. *Stormwater Management Methodology.* Calgary, 1992. Print.

Rowney, A.C. and Macrae, C.R. *QUALYMO User Manual-Release 2.2.* 1994. Print.

Sansalone, J., et al. “Experimental and Field Studies of Type I Settling for Particulate Matter Transported by Urban Runoff”. *Journal of Environmental Engineering, Volume 135, Issue 10.* Page 953. ASCE, October 2009.

Sawyer, Clair N. and McCarty, Perry L. *Chemistry for Environmental Engineering.* New York: McGraw-Hill, 1978. Print.

Scheaffer et al. *Urban Storm Drainage Management.* New York: Marcel Dekker Inc., 1982. Print.

Schueler, T. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. Washington, D.C.: Metropolitan Washington Council of Governments, 1987. Print.

Schueler, T. R. "Impact of Suspended and Deposited Sediment". *Watershed Protection Techniques, Volume 2, Number 3*. Center for Watershed Protection, February 1997. Print.

Schueler, T. R. *Design of Stormwater Filtering Systems*. Silver Spring: Center for Watershed Protection. 1996. Print.

Schueler, T. R. *Site Planning for Urban Stream Protection.* Washington, D.C.: Metropolitan Washington Council of Governments, 1995. Print.

Schueler, Thomas R. et al. *Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region.* Anacostia Restoration Team, Department of Environmental Programs, and Metropolitan Washington Council of Governments, 1992. Print.

Smith, C.D. *Hydraulic Structures.* University of Saskatchewan: Saskatoon, 1985. Print.

Stantec Consulting Ltd. (formerly IMC Consulting Group). *Application of DDSWMM with EXTRAN Linkage.* Calgary, 1996. Print.

Strathcona County. *Engineering Servicing Standards.* 1998. Print.

Transportation Association of Canada. *Drainage Manual: Volume 2, Culverts and Storm Sewers.*1987. Print.

U.S. Department of Transportation. *Design of Roadside Channels with Flexible Linings: Hydraulic Engineering Circular No. 15, Third Edition.* Federal Highway Administration, September 2005. Web: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/05114/index.cfm

U.S. Department of Transportation. *Hydraulic Design of Energy Dissipators for Culverts and Channels: Hydraulic Engineering Circular No. 14, Third Edition*. Federal Highway Administration, July 2006. Web: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/

U.S. Department of Transportation. *Hydraulic Design of Highway Culverts - Hydraulic Design Series No. 5.* FHWA-NHI-01-020, 2005. Web: http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13

U.S. Department of Transportation. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* Federal Highway Administration, 2002. Web: http://environment.fhwa.dot.gov/ecosystems/ultraurb/index.asp

U.S. Department of Transportation. *Urban Drainage Design Manual-Hydraulic Engineering Circular No. 22.* FHWA-SA-96-078, 1996 and Third Edition, FHWA-NHI-10-009, 2009. Web: http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=22&id=140

United States Department of Agriculture (USDA). *A Handbook of Constructed Wetlands - Volume 1: General Considerations.* Natural Resource Conservation Service and the United States Environmental Protection Agency-Region III. 1995. Web: http://www.epa.gov/owow/wetlands/pdf/hand.pdf

United States Department of Agriculture (USDA). *Handbook of Channel Design for Soil and Water Conservation*. Soil Conservation Service,1966. Web: ftp://ftp.wcc.nrcs.usda.gov/wntsc/H&H/TRsTPs/TP61.pdf

United States Department of Agriculture (USDA). *Hydrology: Engineering Handbook*. Soil Conservation Service, 1968. Print.

United States Department of Agriculture (USDA). *Ponds - Planning, Design, Construction.* 1982. Print.

United States Environmental Protection Agency (USEPA). 1983. Print.

United States Environmental Protection Agency (USEPA). *Natural Wetlands and Urban Stormwater: Potential Impacts and Management.* Office of Wetlands, Oceans and Watersheds, 1993. Print.

United States Environmental Protection Agency (USEPA). *Protecting Natural Wetlands-A Guide to Stormwater Best Management Practices.* Office of Water, 1996. Print.

United States Environmental Protection Agency (USEPA). *Storm Water Management for Construction Activities-Developing Pollution Prevention Plans and Best Management Practices.* Office of Water, 1992. Print.

Urban Drainage and Flood Control District (Denver, Colorado). *Urban Storm Drainage Criteria Manual -Volumes 1, 2 and 3.* Denver: 1999. Web: http://www.udfcd.org/downloads/pdf/critmanual/USDCM%20Vols%201%202%203%202010.pdf

Usher, Robyn and Scarth, Jonathan. *Alberta's Wetlands: Water in the Bank!* Edmonton: Environment Council of Alberta, 1990. Print.

Viessman, W., Knapp, J., Lewis, G., and Harbaugh, T. *Introduction to Hydrology.* New York: Harper and Row, 1977. Print.

Washington State Department of Ecology. *Stormwater Management in Washington State-Volumes I, II, III, IV and V.* 1999. Print.

Washington State Department of Ecology. *Stormwater Management Manual for the Puget Sound Basin.* 1992. Print.

Westhoff Engineering Resources Inc.and IBI Group. *Residential LID Subdivision Study.* Calgary: 2009. Print.

Williams, James. *Rules for Responsible Modelling.* Fourth Edition. Guelph, Ontario: CHI, 2005. Print.

Wilson, S, Bray R., and Cooper, P. *Sustainable drainage systems: Hydraulic, structural and water quality advice (C609B).* London: CIRIA, 2004. Web: *http://www.ciria.org/service/bookshop/core/orders/product.aspx?prodid=100*

Wright, K. K., *Urban Storm Drainage Criteria Manual, Volume I*. Denver: Wright-McLaughlin Engineers,1969. Print.

APPENDIX A:
Alberta Environment Registration Process

This Appendix outlines the process for Registration of Municipal Storm Drainage Activities (stormwater ponds and outfalls) under Alberta's *Environmental Protection and Enhancement Act (EPEA)*.

1. Applications to Alberta Environment

1.1 New Subdivisions and Re-Developed Subdivisions

For the construction of a storm drainage system, The City of Calgary's Development & Building Approvals business unit applies for the Letter of Authorization (LoA).

1.2 Stormwater Ponds

For the construction of a stormwater pond, The City of Calgary, Water Resources (on behalf of the applicant) submits an application for registration to amend Municipal Approval 17531-00-58. The application must include the completed Alberta Environment *Application Form and Guide for Registration to Construct and Operate a Municipal Storm Drainage System*.

- For ponds adjacent to water courses, a Biophysical Impact Assessment (BIA) Report must be submitted.
- For ponds that might be assessed as dams, a geotechnical report must be submitted.

1.3 Outfalls

For the construction of an outfall, The City of Calgary, Water Resources (on behalf of the applicant) submits an application for:

- **Notification** under the *Code of Practice for Outfall Structures on Water Bodies* under the *Water Act*.
- **Registration** of the outfall under the *EPEA*.
- A disposition under the *Public Lands Act* (where required)

Notes: a) Where more than one registration and/or approval is required under the *EPEA*, the *Water Act,* or under other legislation administered by the provincial government, Alberta Environment might use a "single window" (one-window) approach to streamline review of the application. The "single window" approach could include one-point contact, a single application form, and a coordinated application review process.

b) The City of Calgary will typically make the application to Alberta Environment on behalf of the applicant. The applicant is responsible for completing the *Application Form and Guide for Registration to Construct and Operate a Municipal Storm Drainage System.* and any applicable checklists, as well as providing reports and drawings as required. All appropriate information must be submitted, otherwise the application and/or checklist will be returned.

c) For further information refer to:

- *EPEA* for information on approvals, registrations and certificates, release of substances (i.e, Part 5) and enforcement (i.e., Part 10).
- *Wastewater and Storm Drainage Regulation 119/93* and *Wastewater and Storm Drainage (Ministerial) 120/93.*
- *Approvals Procedure Regulation 113/93*

2. Review of Applications

Alberta Environment reviews Applications for completeness. If an Application is not complete, the applicant will be requested to provide additional information or the application might be returned.

Note: The application cannot be processed until all information has been received.

3. Advertising

- The Applicant **might** be requested to advertise the application.
- AENV reviews any comments received from the public.
- The Applicant might be requested to meet with the public to address concerns that have been raised.

4. Technical Review

- Alberta Environment conducts a technical review, to review the Application for technical content and deficiencies.
- The technical review determines whether the impact of the activity on the environment is in accordance with the *EPEA* or the *Water Act*.
- With respect to storm outfalls, a concurrent review of any application under the *EPEA* and notification under the *Code of Practice for Outfall Structures on Water Bodies* under the *Water Act* is carried out through the "one-window" process, where required.

5. Decision

The Director decides whether to issue or refuse a registration and/or approval.

- When a registration is issued, an amending approval is issued for the new pond and/or outfall, and the Wastewater and Storm Drainage Approval 17531-00-58 for The City of Calgary is appended.
- A letter of acknowledgement and a copy of the amending approval is issued, indicating the pond and/or outfall registration number.
- When a registration is issued, the activity (i.e., construction activities) must occur in accordance with the latest version of the Code of Practice for the particular activity, or as otherwise stipulated by the Director. **The activity may not proceed until the registration is issued.**
- Objections to any Notice of Decision can be filed with the Environmental Appeal Board. It is in every stakeholder's best interest to have all concerns addressed at the pre-approval stage to minimize the time-frame to approval.

APPENDIX B:
Storm Retention Calculations For DSSPs

Water Resources uses the following method to check storm sewer retention systems for Development Site Servicing Plans (DSSPs) that are based on the Rational Method Design (where permitted).

1. Retention

$Q1$ = allowable discharge to main (L/s)

Q_a = actual discharge to main from retention area ($Q_a \leq Q1$)

$C1$ = runoff coefficient used to design public main; usually given at the time of the DP (C)

$C1'$ = runoff coefficient of discharge

$C2$ = actual runoff coefficient from site, including future development.
Refer to ***4.2.2.3 Rational Method*** for runoff coefficients

i = intensity (82.55 mm/hr)

A = area of site (ha)

n = roughness coefficient (PVC=0.011, concrete=0.013)

H = head on pipe [(top of pond elevation) - (pipe invert + $^1/_2$ pipe dia.)] (m)

$V100$ = storage volume required for 1:100 year event (m^3)

SVF = storage volume factor

2. Hydraulic Slope

HS = hydraulic slope

$H1$ = pipe obvert elevation at end of retention system (pipe invert + diameter) (m)

$H2$ = top of pond/trap low elevation (m)

L = length of retention pipe (from centre of manhole to end of pipe)

3. Steps

1) Calculate C2:

$$C2 = \frac{(1.0 \times \text{Roof area}) + (0.9 \times \text{Pavement area}) + (0.5 \times \text{Gravel area}) + (0.3 \times \text{Landscaping area})}{A}$$

2) Calculate Q1:

$$Q1 = C1 \times 82.55 \times A \times 2.78 \text{ (L/s)}$$

3) Calculate HS:

$$HS = \frac{H2 - H1}{L}$$

4) Calculate Q_a:

a) Manning's Equation:
$Q_a = [(1/n) \times (\text{pipe dia.}/4)^{2/3} \times HS^{1/2} \times (\pi\,(\text{pipe dia.})^2/4)] \times 1000$

b) ICDs: (refer to ***3.3.5.2 Discharge***)

- **R30 ICD: $Q_a = 17.10\ H^{0.5}$**
- **R50 ICD: $Q_a = 30.05\ H^{0.5}$**
- **R70 ICD: $Q_a = 49.4\ H^{0.5}$**
- **R100 ICD: $Q_a = 89.8\ H^{0.5}$**

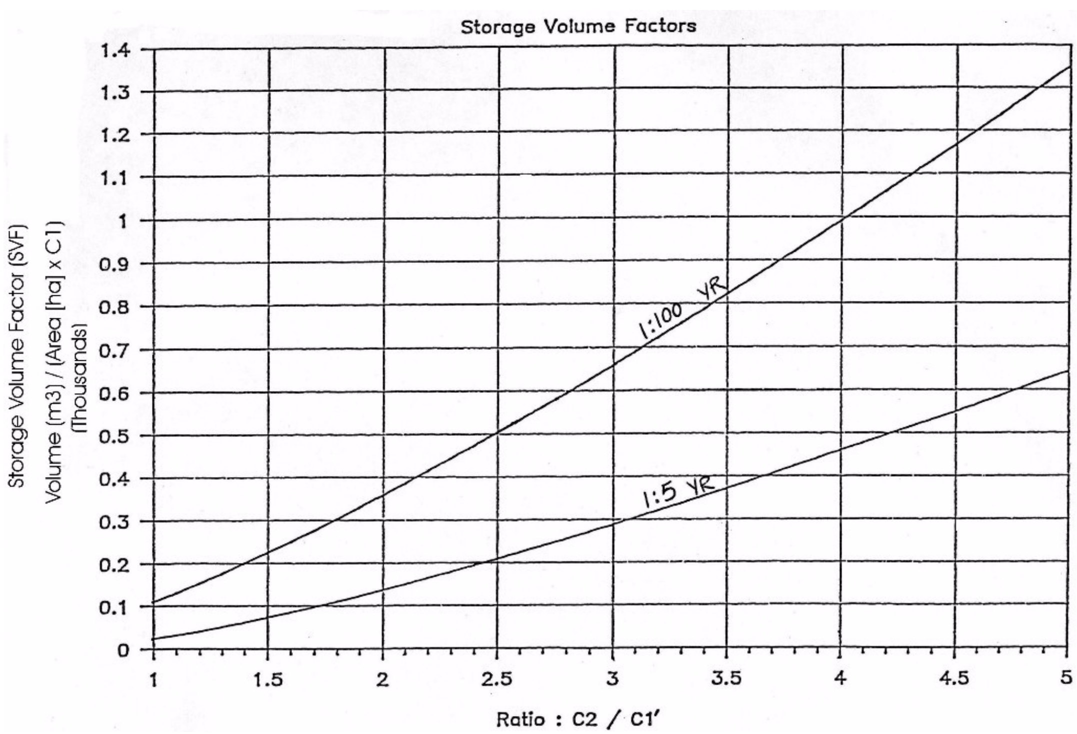
5) Calculate C1':
$C1' = Q_a/82.55 \times A \times 2.78)$

6) Determine Storage Volume Factor (SVF):

a) Determine C2/C1'.

b) Look up SVF from graph below.

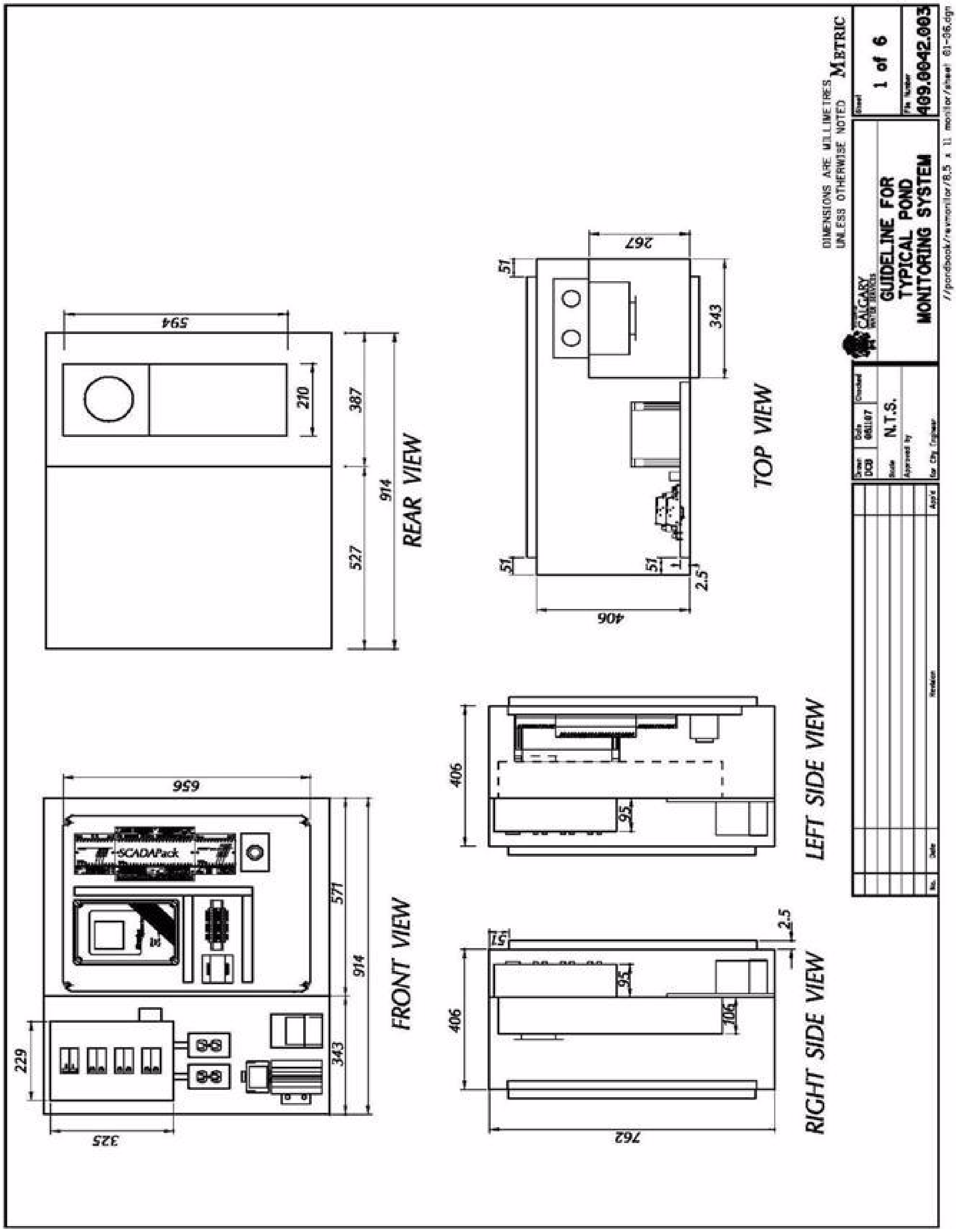
Figure B-1: Storm Sewer Retention

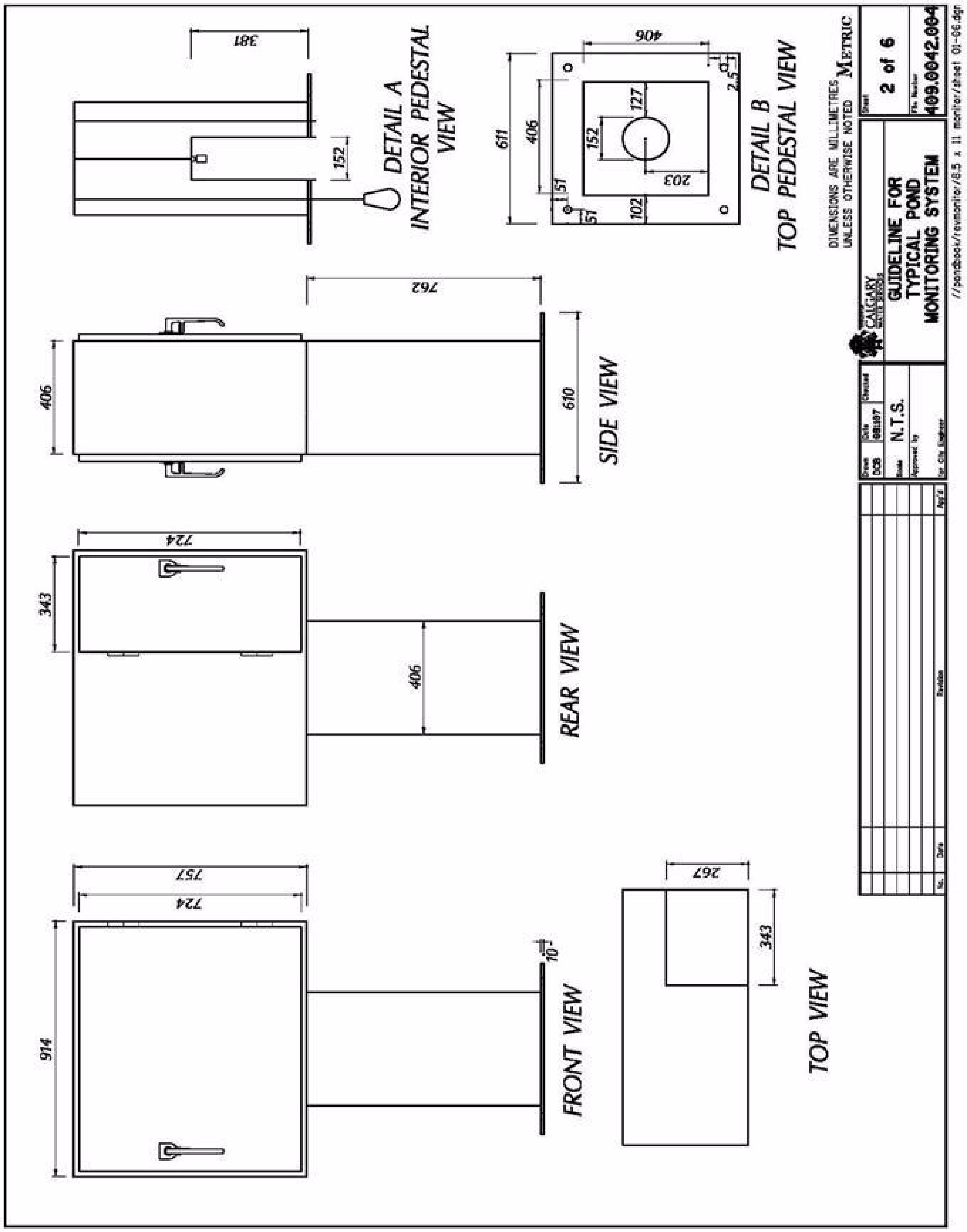


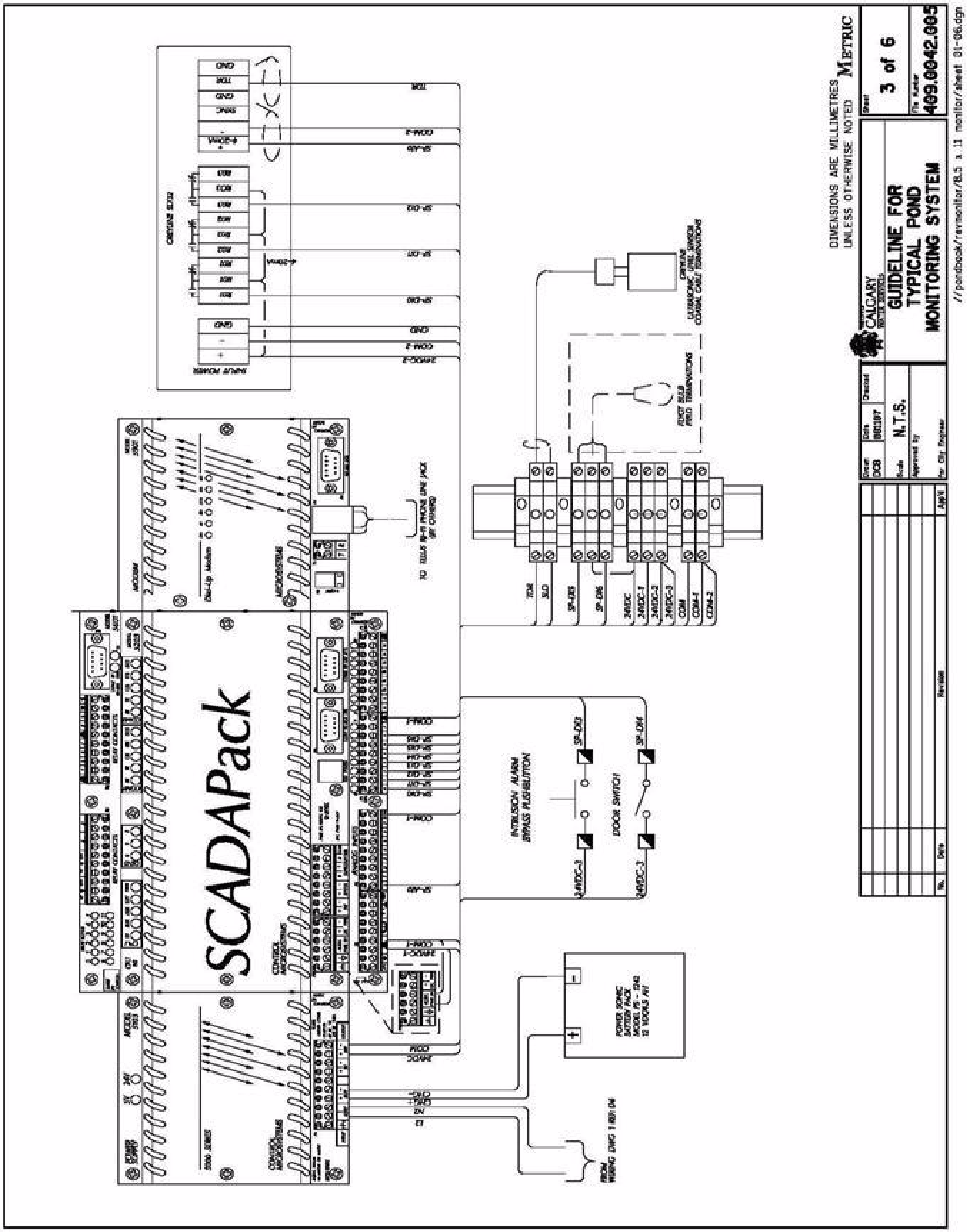
7) Determine V100:

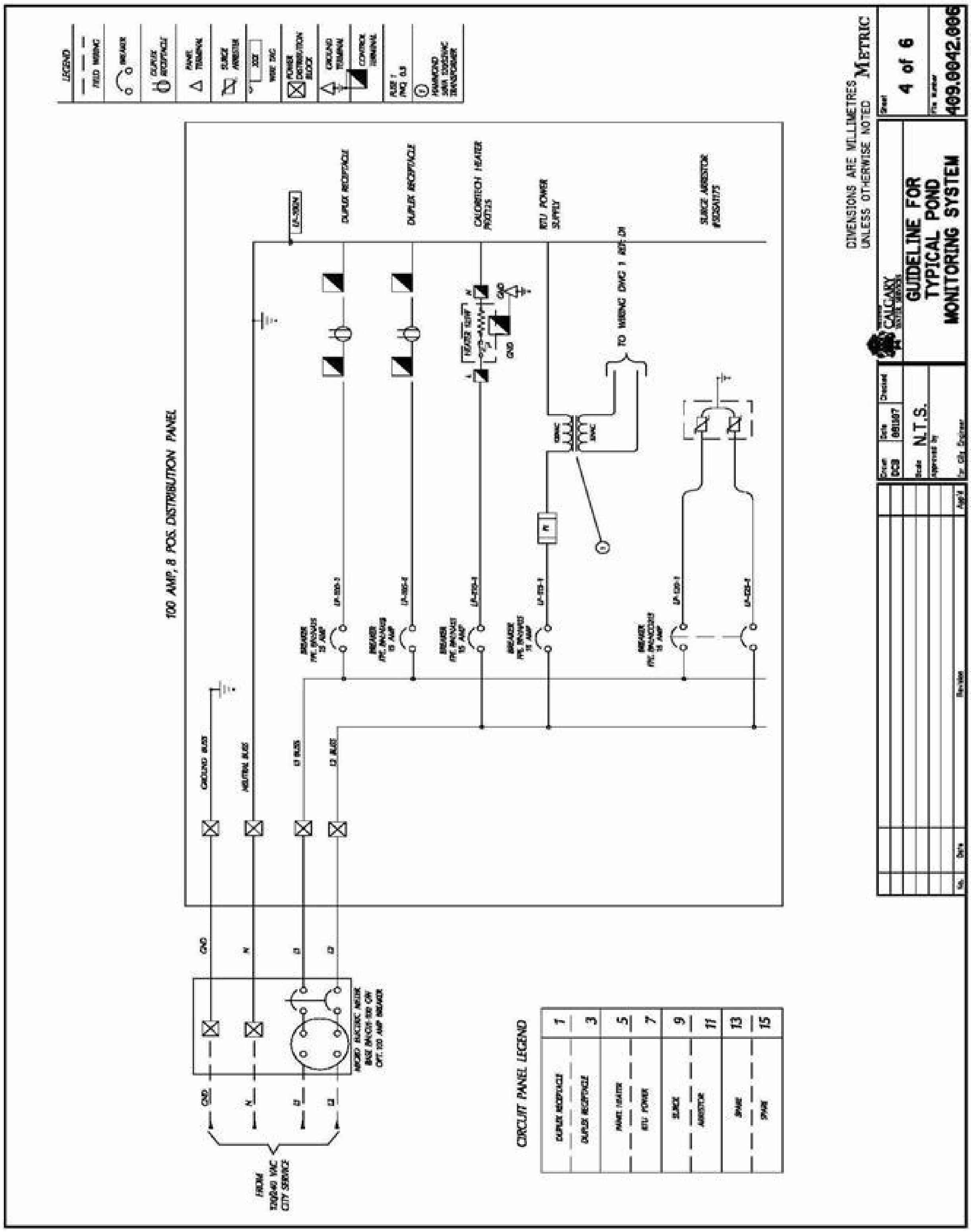
$V100 = SVF \times A \times C1' \times 100\ (m^3)$

APPENDIX C:
Monitoring Equipment for Ponds




DETAIL A
INTERIOR PEDESTAL VIEW
DETAIL B
TOP PEDESTAL VIEW
SIDE VIEW
REAR VIEW
FRONT VIEW
TOP VIEW
DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED
METRIC
GUIDELINE FOR TYPICAL POND MONITORING SYSTEM
N.T.S.
2 of 6
409.0042.004


SCADAPack
DIMENSIONS ARE MILLIMETRES
UNLESS OTHERWISE NOTED
METRIC
3 of 6
GUIDELINE FOR
TYPICAL POND
MONITORING SYSTEM
N.T.S.
409.0042.005


100 AMP, 8 POS. DISTRIBUTION PANEL
CIRCUIT PANEL LEGEND
DIMENSIONS ARE MILLIMETRES
UNLESS OTHERWISE NOTED
METRIC
GUIDELINE FOR
TYPICAL POND
MONITORING SYSTEM
N.T.S.
4 of 6
409.0042.006

NOTES

1. ALL WORK TO BE DONE IN ACCORDANCE WITH CANADIAN ELECTRICAL CODE.
2. HIGH LEVEL REGULATOR SWITCH AND ULTRASONIC LEVEL TRANSMITTER SHALL BE CONNECTED TO THE RTU PACKAGE.
3. THE RTU SHALL BE PROGRAMMED TO LOG THE FOLLOWING CONDITIONS AND RESPOND TO POLLING BY THE **SCADA** SYSTEM: △
   (i) ULTRASONIC-POND FILLING (POND BOTTOM) ALARM AT ELEVATION_____m.
   (ii) ULTRASONIC-HIGH WATER LEVEL (HWL) ALARM AT ELEVATION ______m.
   (iii) REGULATOR SWITCH-HIGH WATER LEVEL (HWL) ALARM AT ELEVATION _____m, AS A BACKUP SYSTEM TO THE ULTRASONIC LEVEL MONITOR.
   (iv) POWER FAILURE CONDITION. (THE RTU AND THE ULTRASONIC UNIT MUST BE ON THE SAME BREAKER.) △
   (v) INTRUSION CONDITION.
4. THE CONTRACTOR SHALL ARRANGE FOR INSTALLATION OF <u>ONE</u> TELEPHONE LINE TO THE CONTROL PANEL ENCLOSURE BY TELUS. THE LINE MUST BE SUITABLE FOR VOICE TOUCH-TONE COMMUNICATION. THE RJ-II BOX MUST BE LABELLED WITH PROPER PHONE NUMBER WITH A PERMANENT LABEL.
5. THE CONTRACTOR SHALL INSTALL THE LEVEL TRANSMITTERS (ULTRASONIC LEVEL SENSOR AND REGULATOR SWITCH) IN APPROPRIATE LOCATIONS. THE REGULATOR SWITCH MUST BE SECURED IN AN AREA SUBJECT TO MINIMAL WATER TURBULENCE OUTSIDE THE TRASH RACK AND **THE ULTRASONIC LEVEL SENSOR MUST BE LOCATED SUCH THAT THERE IS 0.3m OF RADIAL CLEARANCE PER 3.0m DEPTH IN THE CONTROL CHAMBER.** (NO INTERFERENC WITH TRASH RACK, WALLS ETC.)
   THE UNIT SHOULD BE MOUNTED TO THE CEILING AND ABOVE THE LEVEL OF THE WEIR WALL. **A MINIMUM CLEARANCE OF 0.50m IS REQUIRED BETWEEN THE BOTTOM OF THE UNIT AND THE TOP OF THE WEIR WALL (PWL) TO ACCOMMODATE THE SENSOR'S DEAD ZONE (BLANKING DISTANCE).**
6. THE CONTRACTOR SHALL ENSURE ALL NECESSARY EQUIPMENT CAN BE INSTALLED IN THE EQUIPMENT ENCLOSURES.
7. THE CONTRACTOR SHALL ENSURE PROPER OPERATION OF THE RTU MONITORING AND COMMUNICATION FUNCTIONS. THE ULTRASONIC LEVEL SENSOR MUST BE CALIBRATED. **ALL ALARM CONDITIONS MUST BE TESTED.**
8. INSTALLATION AND OPERATING MANUALS MUST BE SUPPLIED.
9. THE CONTRACTOR MUST ENSURE THAT THE ALARM SYSTEM IS TIED INTO THE STORM POND MONITORING SYSTEM. △
   CALIBRATION AND TESTING OF EQUIPMENT TO BE COMPLTETED BY SERVICE PROVIDER.
10. THE AUTODIALER, RTU AND DATALOGGER ARE ONE INTEGRATED UNIT.
    FOR RTU AUTODIALER, ULTRASONIC AND DATALOGER CONTACT: <u>SIMARK CONTROLS LTD.</u>
    <u>CALGARY, ALBERTA</u>
    <u>1-800-565-7431</u>
11. THE MINIMUM MAINTENANCE PERIOD SHALL BE 2 YEARS FOR CITY OF CALGARY RETROFIT PROJECTS AND 3 YEARS (FOR FINAL ACCEPTANCE CERTIFICATE) FOR NEW SUBDIVISIONS UNLESS SPECIFIED OTHERWISE.

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED **METRIC**

No.	Date	Revision	App'd
△	2002/04/[illegible]	GENERAL REVISIONS	

Drawn: DCB	Date: 08110?	Checked:
Scale: N.T.S.		
Approved by: for City Engineer		

CALGARY WATER SERVICES

GUIDELINE FOR TYPICAL POND MONITORING SYSTEM

Sheet: 5 of 6

File Number: 409.0042.007

//pondbook/revmonitor/8.5 x 11 monitor/sheet 01-06.dgn

LIST OF MATERIALS

MAIN CONTROL PANEL

1. MAIN CONTROL PANEL: NEMA 3 ENCLOSURE 1500mm (60") H x 1200mm (48") W x 550mm (22") D c/w 19mm (3/4") PLYWOOD BACK PLATE. ENCLOSURE MUST BE VENTED. AIR INTAKE FAN MUST HAVE A FILTER.
2. 100 AMP METER BASE:
3. METER BASE ENCLOSURE: NEMA 3 ENCLOSURE 675mm (27") H x 325mm (13") W x 250mm (10") D (ACE WMC27) c/w LOCKABLE COVER.
4. MAIN CIRCUIT BREAKER: NEMA 1 BE108-16 OR APPROVED EQUIVALENT.
5. 100 AMP MAIN BREAKER: TYPE NA2P100.
6. BREAKERS: A MINIMUM OF FIVE 15A BREAKERS (TYPE NA15). GROUND FAULT INTERRUPTER CIRCUIT BREAKERS (GFIC) ARE NOT TO BE USED.
7. SURGE PROTECTOR: SQUARE D MODEL SDSA1175 c/w ONE 15A BREAKER (NC0215)
8. INTRUSION ALARM BYPASS TIMER: INTERMATIC TIME SWITCH F30M.
9. FAN TEMPERATURE CONTROL SWITCH: HOFFMAN A-TEMNO.
10. DUPLEX RECEPTACLES: A MINIMUM OF TWO.
11. TELEPHONE: ONE WALL-MOUNTED TOUCHTONE RJ-11 JACK (VOICE).
12. GROUND BUS

WATER LEVEL CONTROL PANEL

1. WATER LEVEL CONTROL PANEL: NEMA 12 750mm (30") H x 750mm (30") W X 200mm (8") D c/w 675mm x 675mm (27" x 27") BACKPLATE.
2. ULTRASONIC LEVEL TRANSMITTER: GREYLINE SLT-PLUS OR APPROVED EQUIVALENT WITH 12V 10AH BATTERY BACKUP.
3. HEATER: HOFFMAN D-AH2001A 200W
4. TWO DUPLEX RECEPTACLES -HUBBELL 5262S TVSS RECEPTACLE (ONE) c/w HUBBELL SPJ-26 BLUE COVER PLATE (ONE)
5. CONTROL MICROSYSTEMS SCADAPack, (CONTAINING INTEGRATED MODEM, AUTODAILER, DATALOGGER, RTU AND POWER SUPPLY)

   SPECIFICATIONS:

   - ⚠ 16MB ROM, 4MB CMOS STATIC RAM WITH LITHIUM BATTERY BACKUP
   - (3) RS-232 SERIAL PORTS
   - ⚠ I/O EXPANSION PORT-ALLOWS UP TO 20 EXPANSION MODULES, WITH A MAXIMUM EACH OF 16 DI, 16AI, 16 AO AND 16 COUNTER MODULES
   - CLOCK/CALENDAR
   - INTERNAL TEMPERATURE SENSOR
   - INTERNAL RAM BATTERY VOLTAGE
   - ⚠ 3 COUNTER INPUTS
   - ⚠ 8 DIGITAL I/O, INDIVIDUALLY CONFIGURABLE AS A DRY CONTACT DIGITAL INPUT OR AN OPEN-DRAIN DIGITAL OUTPUT
   - ⚠ 5 ANALOG INPUTS, 14 BIT RESOLUTION, 0-20 mA, +/- 0.2% ACCURACY
   - ⚠ 2 ANALOG OUTPUTS, 12 BIT RESOLUTION 0-20 mA, +/- 0.25% ACCURACY
   - LADDER LOGIC FIRMWARE
   - MODBUS PROTOCOL EMULATION WITH MASTER, SLAVE AND STORE-AND-FORWARD OPERATION
   - ⚠ INTEGRATED POWER SUPPLY 12-24 VDC INPUT

MISC

1. ULTRASONIC LEVEL SENSOR: GREYLINE PZ25T OR APPROVED EQUIVALENT.
2. HIGH LEVEL REGULATOR SWITCH: FLYGT ENM-10.
3. CABLE AS REQUIRED.

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED **METRIC**

No.	Date	Revision	App'd
⚠	2012/04/23	GENERAL REVISIONS	

Drawn: DCB | Date: 081107 | Checked:
Scale: N.T.S.
Approved by: for City Engineer

CALGARY

GUIDELINE FOR TYPICAL POND MONITORING SYSTEM

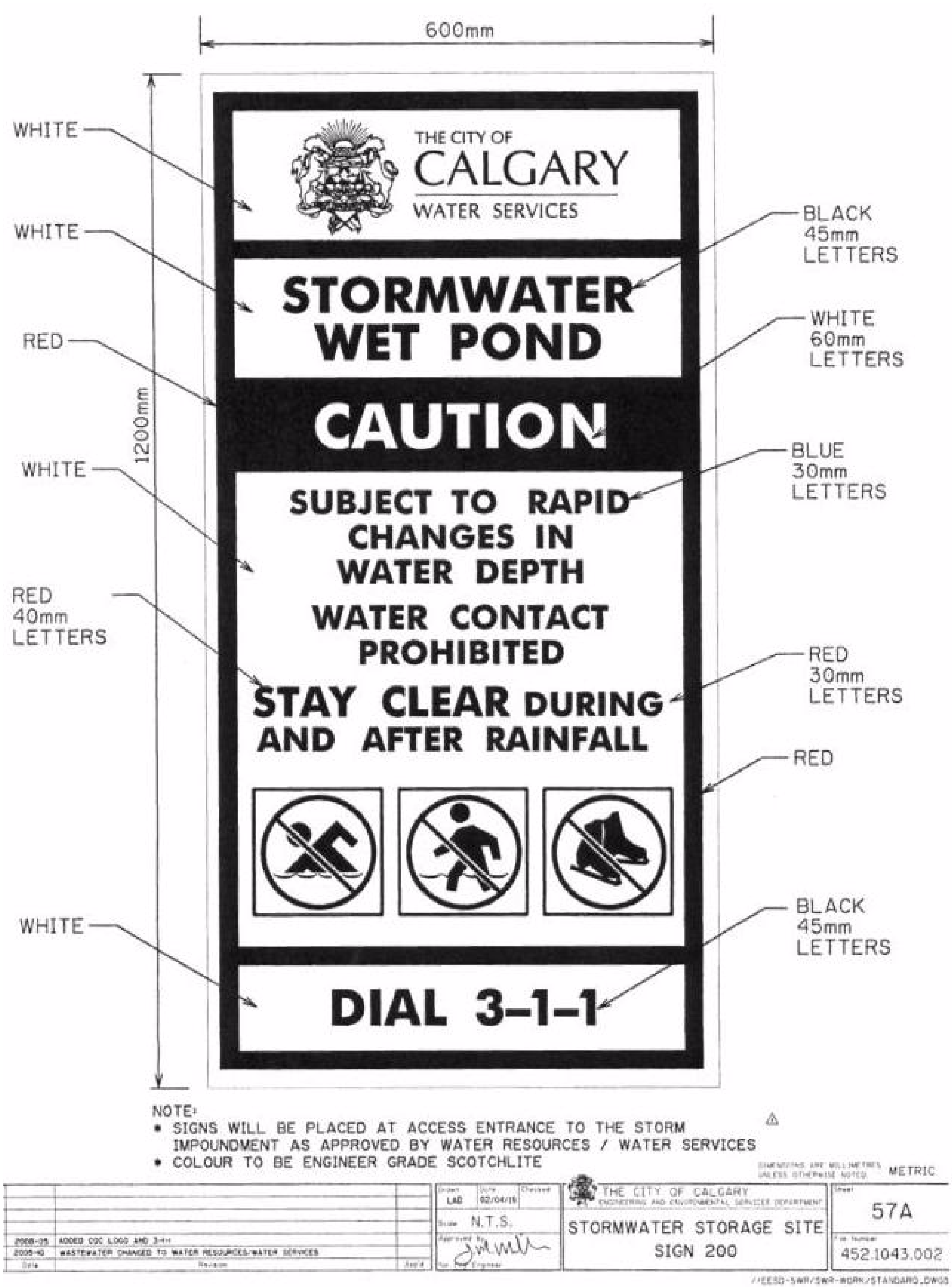
Sheet: 6 of 6
File Number: 409.0042.008

//pondbook/revmonitor/8.5 x 11 monitor/sheet 01-06.dan

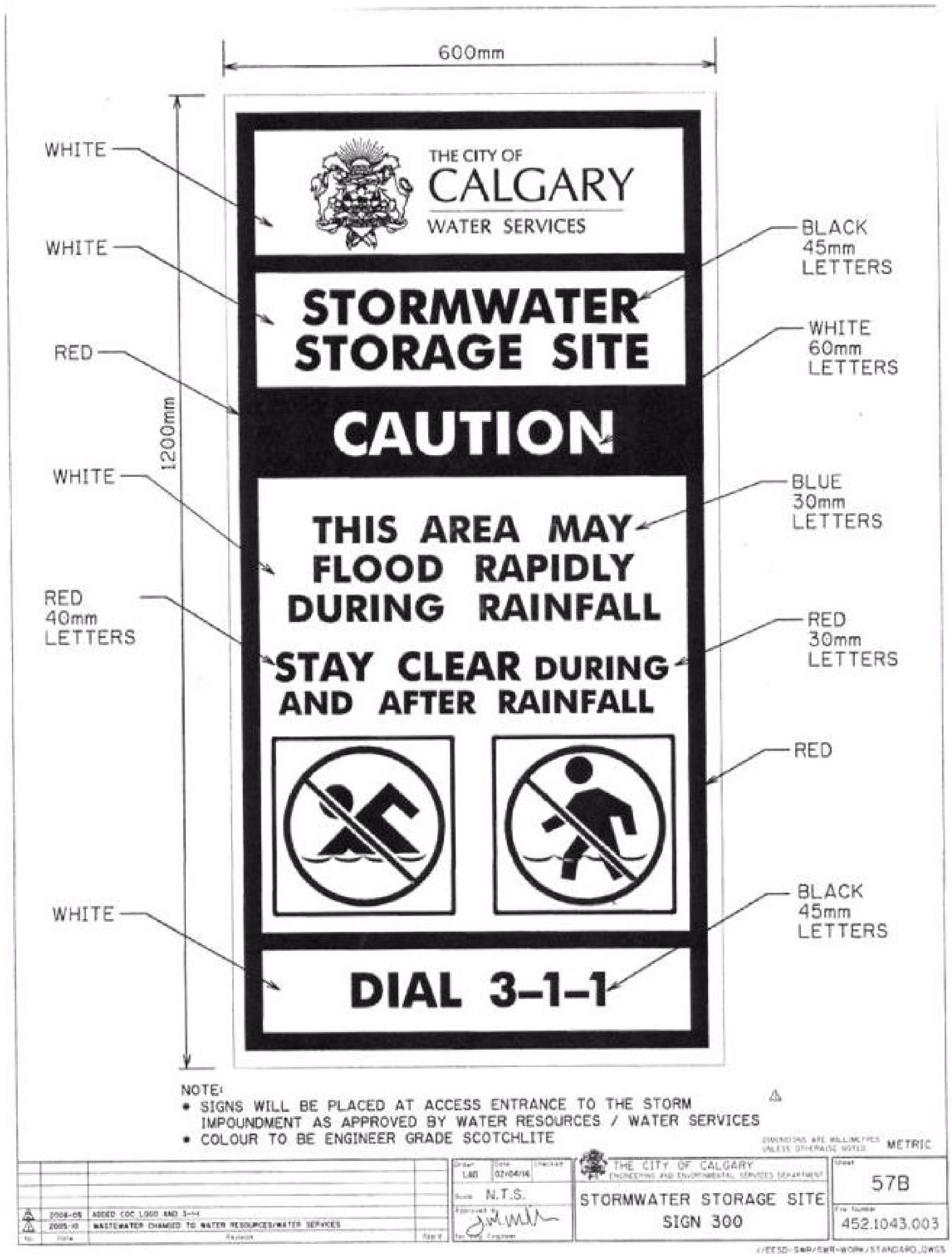
APPENDIX D:
Signage for Ponds

.

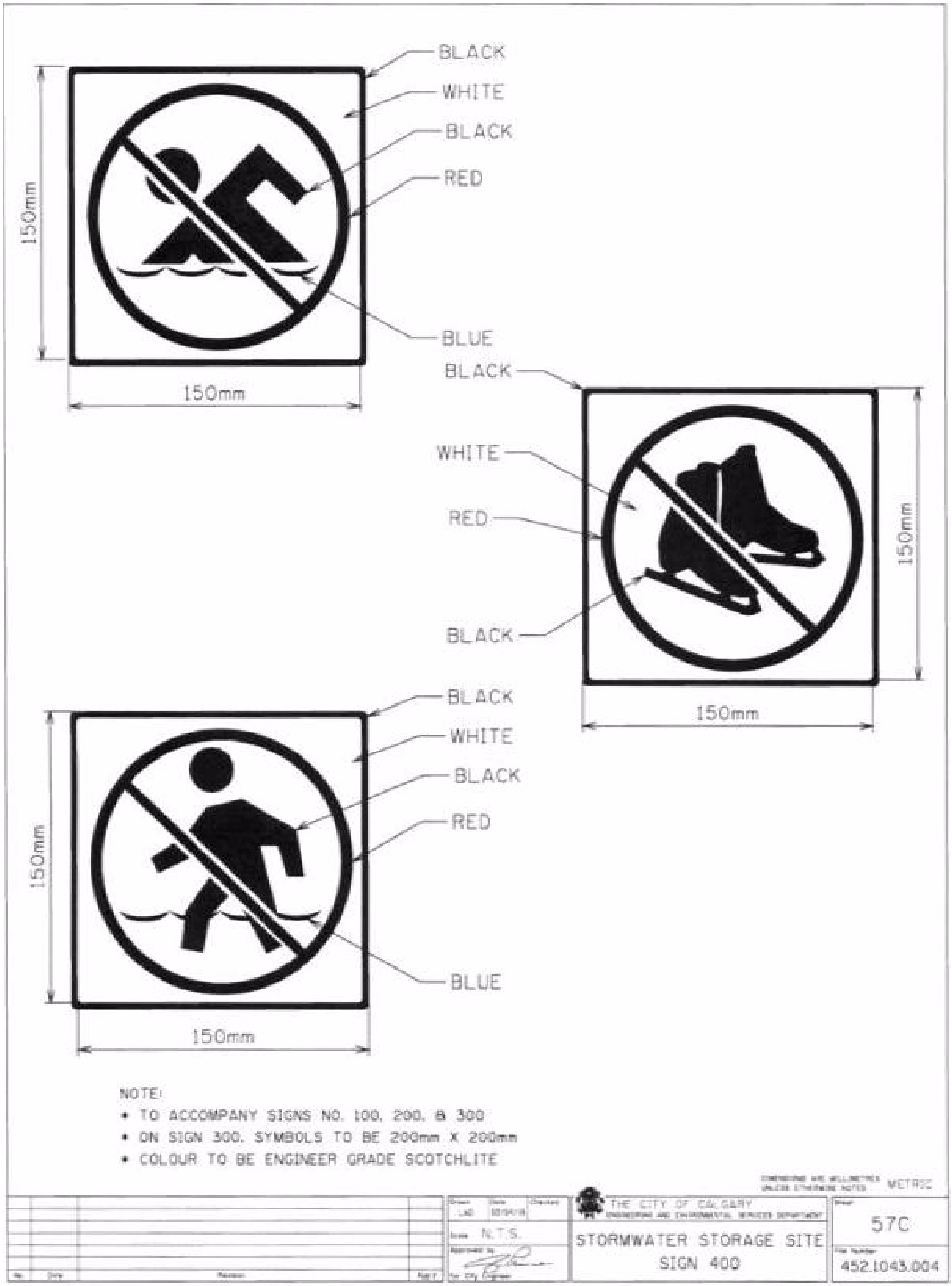
.


600mm
1200mm
WHITE
WHITE
RED
WHITE
RED 40mm LETTERS
WHITE
BLACK 45mm LETTERS
WHITE 60mm LETTERS
BLUE 30mm LETTERS
RED 30mm LETTERS
RED
BLACK 45mm LETTERS
THE CITY OF CALGARY
WATER SERVICES
STORMWATER WET POND
CAUTION
SUBJECT TO RAPID CHANGES IN WATER DEPTH
WATER CONTACT PROHIBITED
STAY CLEAR DURING AND AFTER RAINFALL
DIAL 3-1-1
NOTE:
• SIGNS WILL BE PLACED AT ACCESS ENTRANCE TO THE STORM IMPOUNDMENT AS APPROVED BY WATER RESOURCES / WATER SERVICES
• COLOUR TO BE ENGINEER GRADE SCOTCHLITE
METRIC
LAD
02/04/15
N.T.S.
THE CITY OF CALGARY
STORMWATER STORAGE SITE
SIGN 200
57A
452.1043.002

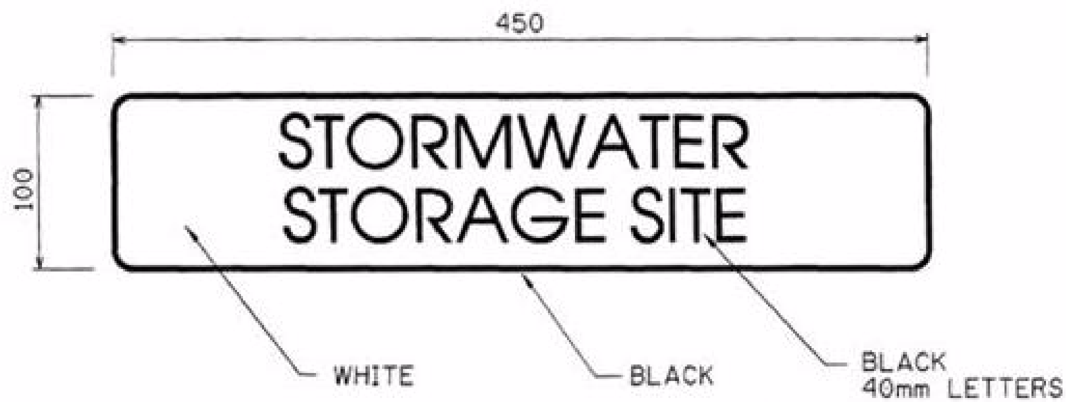
.


600mm
1200mm
WHITE
WHITE
RED
WHITE
RED 40mm LETTERS
WHITE
THE CITY OF
CALGARY
WATER SERVICES
STORMWATER
STORAGE SITE
CAUTION
THIS AREA MAY
FLOOD RAPIDLY
DURING RAINFALL
STAY CLEAR DURING
AND AFTER RAINFALL
DIAL 3-1-1
BLACK 45mm LETTERS
WHITE 60mm LETTERS
BLUE 30mm LETTERS
RED 30mm LETTERS
RED
BLACK 45mm LETTERS
NOTE:
• SIGNS WILL BE PLACED AT ACCESS ENTRANCE TO THE STORM IMPOUNDMENT AS APPROVED BY WATER RESOURCES / WATER SERVICES
• COLOUR TO BE ENGINEER GRADE SCOTCHLITE
METRIC
2008-05 ADDED COC LOGO AND 3-1-1
2005-10 WASTEWATER CHANGED TO WATER RESOURCES/WATER SERVICES
LAO
02/04/16
N.T.S.
THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT
STORMWATER STORAGE SITE
SIGN 300
57B
452.1043.003

.


BLACK
WHITE
BLACK
RED
BLUE
150mm
150mm
BLACK
WHITE
RED
BLACK
150mm
150mm
BLACK
WHITE
BLACK
RED
BLUE
150mm
150mm
NOTE:
• TO ACCOMPANY SIGNS NO. 100, 200, & 300
• ON SIGN 300, SYMBOLS TO BE 200mm X 200mm
• COLOUR TO BE ENGINEER GRADE SCOTCHLITE
METRIC
THE CITY OF CALGARY
N.T.S.
STORMWATER STORAGE SITE
SIGN 400
57C
452.1043.004

Drawing has been superceded. Use only for repair or replacement of existing signs.



NOTE:
- TO ACCOMPANY SIGNS NO. 200, 300, 400 & 500
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED — METRIC

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

STORMWATER STORAGE SITE
SIGN 100

Drawn: LC
Scale: N.T.S.
Sheet: 57
File Number: 452.1043.001

Drawing has been superceded. Use only for repair or replacement of existing signs.

NOTE:
* COLOUR TO BE ENGINEER GRADE SCOTCHLITE

METRIC

THE CITY OF CALGARY

Scale N.T.S.

STORMWATER STORAGE SITE
SIGN 200

57A

452.1043.002

Scale N.T.S.

STORMWATER STORAGE SITE
SIGN 100

452.1043.001

Drawing has been superceded. Use only for repair or replacement of existing signs.

NOTE:

- SIGNS WILL BE PLACED AT ACCESS ENTRANCE TO THE STORM IMPOUNDMENT AS INDICATED BY THE CITY ENGINEER.
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE.

METRIC

THE CITY OF CALGARY

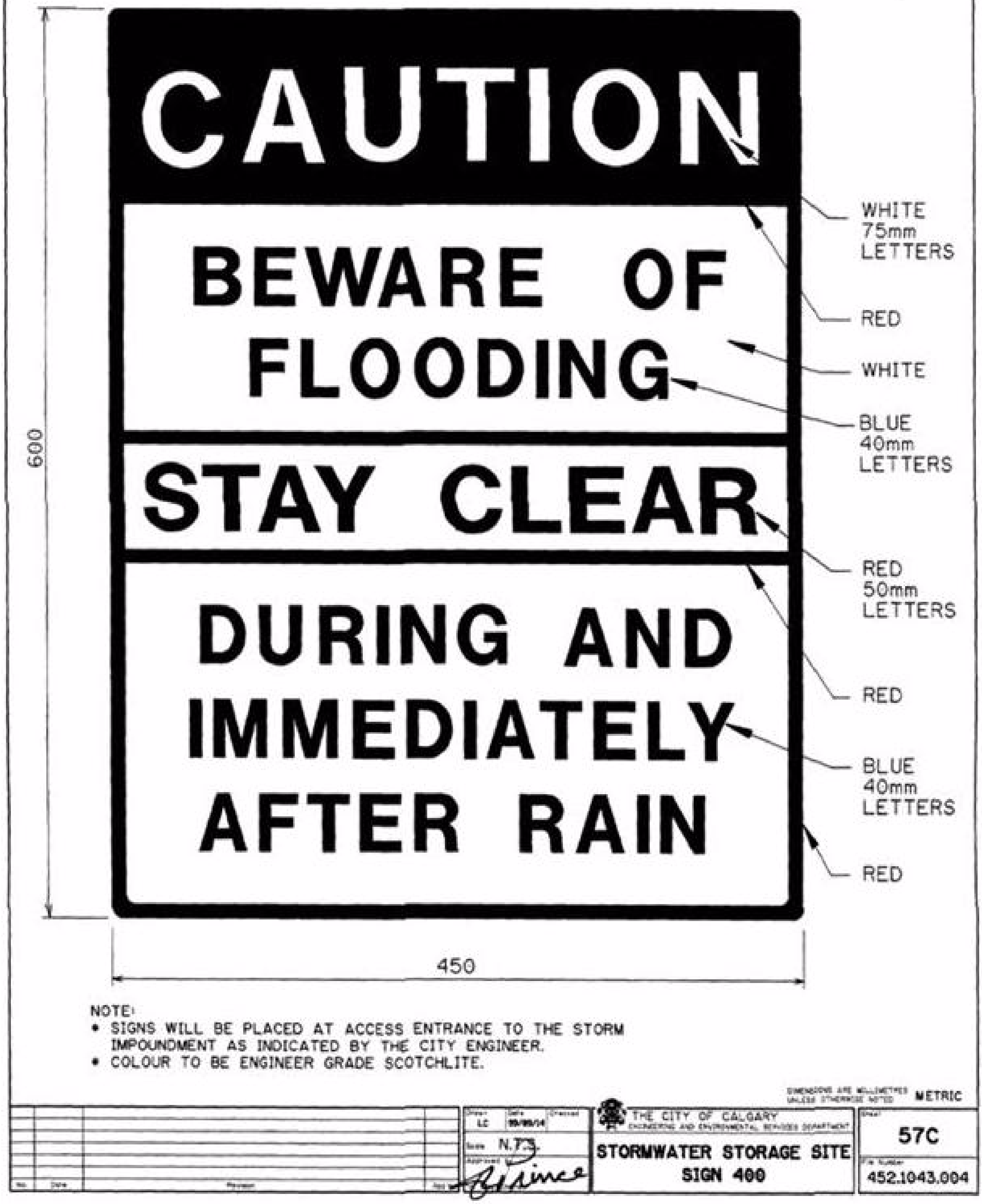
STORMWATER STORAGE SITE
SIGN 300

Drawn: LC
Scale: N.T.S.

57B

452.1043.003

Drawing has been superceded. Use only for repair or replacement of existing signs.



Drawing has been superceded. Use only for repair or replacement of existing signs.

NOTE:
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

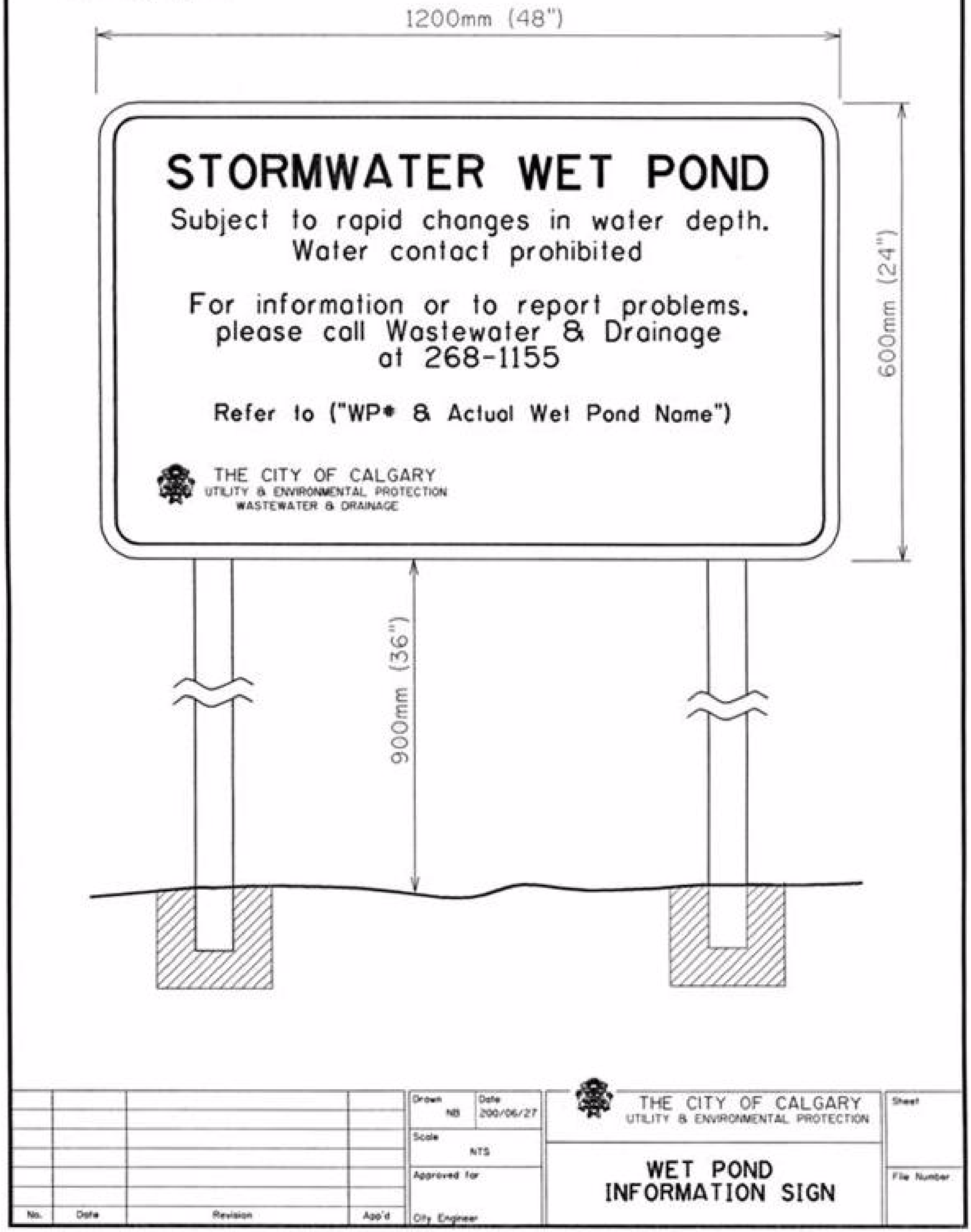
Drawn: LC | Scale: N.T.S.

STORMWATER STORAGE SITE SIGN 500

Sheet: 57D

File Number: 452.1043.005

Drawing has been superceded. Use only for repair or replacement of existing signs.



APPENDIX E:
Recommended Plant Species

The list provided in this Appendix is intended as a guide only. It is not an exhaustive list of the native plants available for use in restoration projects in the Calgary area. The list covers species in all habitats from wetlands through to dry prairie habitats. These species should be available commercially, but there are many more species native to wetlands. This list was developed by The City of Calgary Parks, and will be revised as necessary. It is recommended that Parks be contacted to determine if an updated list is available.

Native species used in any project must be native to the Calgary area and appropriate for the site conditions. This means, for example, that you would not plant white spruce on a south-facing slope, since this is an inappropriate site for this species, although it is native to Calgary.

Locally sourced materials should be used (stock should originate from within 1-200 km of the restoration site). The success of the project will depend greatly upon the selection of appropriate species to establish a native cover. Horticultural varieties developed from native species are not appropriate.

The intent of restoration, and to a limited extent naturalization, is a process which seeks to emulate the structure, function, diversity, and dynamics of a particular ecosystem. This differs fundamentally from a landscaping project, and as a result the species used, planting stock, and methods often differ in restoration projects.

Qualified personnel should be retained to make the determination of suitable species for a given project. It is not enough to simply select species from this list; a detailed understanding of the site conditions and the ecology of the selected restoration species, as well as a detailed project plan and set of objectives are required. An environmental specialist such as a botanist, plant ecologist, or range ecologist who is familiar with wetlands and restoration ecology should be retained to select species and assist in planning the project.

General guidelines for restoration and naturalization in Alberta can be found in *Native Plant Revegetation Guidelines for Alberta*, available online or from:

Sustainable Resource Development
Information Centre
Main Floor, 9920-108 Street NW
Edmonton, AB T5K 2M4
Ph: 1-877-944-0313 [toll free]
Fax: 780-427-4407
Email: srd.infocent@gov.ab.ca

The Alberta Native Plant Council (Garneau P.O. Box 52099, Edmonton, AB T6G 2T5) publishes the *Native Plant Source List*, which provides a list of commercially available native plant materials, and *Plant Collection Guidelines for Horticultural Use of Native Plants*.

Most of the species listed should be commercially available. Given that the intent of this list is for stormwater pond restoration/naturalization, they have been broadly classified in terms of moisture regime to serve as a general guide for selecting species. However, other considerations such as soil type, nutrient regime, aspect, and slope position could be of equal or greater importance.

Figure E-1: Moisture Regimes along Water Bodies

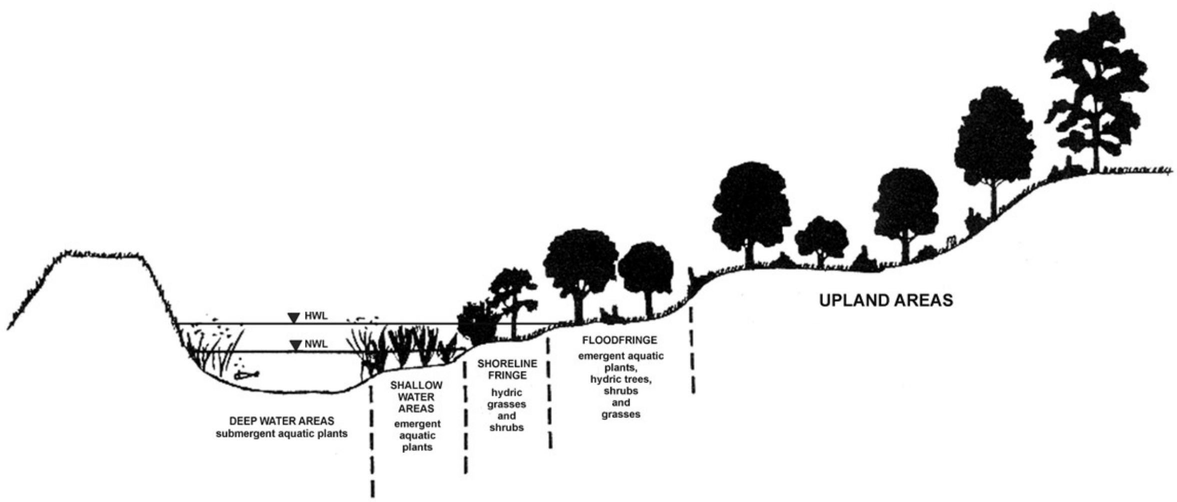


Table E-1: Native Plant Moisture Regime Classifications

Moisture Regime	Typical Habitat
Aquatic	Floating-leaved and submerged plants. Generally must be in water throughout the growing season.
Emergent	Rooted in the substrate, but with leaves and stems generally growing out of the water.
Hydric-mesic Upland	Plants growing in saturated through to moist soils.
Mesic-xeric Upland	Plants growing in moist soils through to dry soils.

Some species in the following list are potentially invasive; they should be used with some caution, since they have the potential to significantly alter the specie composition of a site and could exclude or eliminate other species.

Table E-2: Moisture Regimes for Native Plant Species

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Grasses						
Agropyron riparium	steambank wheat grass			●	●	
Beckmannia syzigachne	slough grass		●	●		
Bouteloua gracilis	blue grama				●	
Calamagrostis canadensis	bluejoint grass		●	●		Potentially invasive
Calamovilfa longifolia	sand grass prairie sand reed				●	
Cinna latifolia	slenderwood grass			●		
Danthonia caespitosa	California oat grass				●	
Danthonia parryi	Parry oat grass				●	
Deschampsia caespitosa	tufted hair grass			●		
Distichlis stricta	alkali grass		●	●		
Elymus canadensis	Canada wild rye			●	●	
Elymus cinereus (E. piperi)	giant wild rye				●	
Festuca campestris	foothills rough fescue				●	
Festuca halli	plains rough fescue				●	
Glyceria grandis	tall manna grass		●	●		
Helictotrichon hookeri	Hooker's oatgrass				●	
Hierochloe odorata	sweet grass			●	●	Potentially invasive
Muhlenbergia richardsonis	mat muhly		●	●		
Oryzopsis hymenoides	indian rice grass				●	
Phalaris arundinacea	reed canary grass		●	●		Potentially invasive
Poa canbyi	early bluegrass			●	●	
Poa juncifolia	alkali bluegrass		●			
Poa palustris	fowl bluegrass			●		
Poa sandbergii	Sandberg's bluegrass				●	
Puccinellia distans	slender salt-meadow grass			●		
Sagittaria cuneata	arrowhead		●			
Sanicula marilandica	snakeroot			●		
Schizachyrium scoparium	little bluestem				●	
Spartina gracilis	alkali cord grass		●	●		
Spartina pectinata	prairie cord grass		●	●		
Stipa comata	needle and thread, spear grass				●	
Stipa curtiseta	western porcupine grass				●	
Stipa richardsonii	richardson's needle grass				●	
Stipa spartea	porcupine grass				●	
Stipa viridula	green needle grass			●	●	
Sedges, rushes, and broad-leaved aquatics						
Alisma plantago-aquatica	broad-leafed water plantain		●			
Alisma triviale	watern water plantain		●			
Carex aqatilis	water sedge		●	●		
Carex atherodes	awned sedge		●	●		
Carex rostrata	beaked sedge		●	●		

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Sedges, rushes, and broad-leaved aquatics						
Ceratophyllum demersum	hornwort	●				
Eleocharis acicularis	least spike-rush	●				
Eleocharis palustris	creeping spike-rush	●				
Equisetum hyemale	horsetail rush	●	●			
Hippuris vulgaris	mare's-tail		●	●		
Juncus balticus	wire rush		●	●		
Juncus nodosus	knotted rush		●	●		
Juncus torreyi	Torrey's rush		●	●		
Lemna minor	duckweek	●				
Mentha arvensis	Canada mint			●		
Myriophyllum exalbescens		●				
Polygonum amphibium	water smartweed	●				
Ranunculus cymbalaria	creeping buttercup		●	●		
Scirpus acutus	hardstem bulrush		●			
Scirpus americanus	American bulrush		●			
Scirpus maritimus	alkali bulrush		●			
Scirpus microcarpus	small-ruited bulrush		●			
Scirpus validus	common great bulrush		●			
Triglochin maritima	arrow-grass	●	●			
Typha latifolia	cattail		●			Potentially invasive
Trees and shrubs						
Alnus crispa	green alder			●		
Amelanchier alnifolia	saskatoon				●	
Arctostaphylos uva-ursi	kinnikinnick, common bear-berry				●	
Artemisia campestris	plains wormwood				●	
Artemisia cana	sagebrush				●	
Betula occidentalis	water birch, black birch		●	●		
Chrysothamnus nauseosus	rabbit-brush				●	
Clematis ligusticifolia	western clematis			●		
Clematis occidentalis	purple clematis			●		
Cornus stolonifera	red osier dogwood			●	●	
Crataegus rotundifolia						
Elaeagnus commutata	silver-berry; wolf willow				●	
Juniperus communis	common juniper				●	
Juniperus horizontalis	horizontal juniper				●	
Lonicera dioica	twining honey suckle			●		
Philadelphus lewisii	mock orange				●	
Picea glauca	white spruce			●	●	
Populus tremuloides	trembling aspen			●	●	
Populus balsamifera	balsam poplar			●	●	
Potentilla fruticosa	shrubby cinquefoil				●	
Pseudotsuga menziesii	Douglas fir				●	
Ribes aureum	golden currant			●	●	

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Trees and shrubs						
Ribes lacustre	bristly black currant			●	●	
Ribes oxyacanthoides	wild gooseberry				●	
Rosa acicularis	prickly rose			●	●	
Rosa arkansana	prairie rose			●	●	
Rosa woodsii	common wild rose			●	●	
Rubus idaeus	wild red raspberry			●	●	
Rubus pubescens	dewberry			●	●	
Salix amygdaloides	peach-leaved willow			●		
Salix bebbiana	beaked willow			●	●	
Salix discolor	pussywillow; diamond willow			●		
Salix exigua	sandbar willow			●		
Salix glauca	smooth willow			●		
Salix lutea	yellow willow			●	●	
Sambucus racemosa	elderberry			●		
Shepherdia argentea	silver/thorny buffaloberry			●	●	
Shepherdia canadensis	Canada buffaloberry				●	
Spiraea betulifolia	white meadowsweet			●		
Symphoricarpos albus	snowberry			●	●	
Symphoricarpos occidentalis	buckbrush/wolfberry			●	●	
Viburnum edule	low bush cranberry			●	●	
Viburnum opulus	high bush cranberry			●	●	
Forbs						
Achillea millefolium	yarrow				●	
Agoseris glauca	false dandelion				●	
Allium cernuum	nodding onion				●	
Allium schoenoprasum	wild chives				●	
Allium textile	prairie onion				●	
Anaphalis margaritacea	pearly everlasting				●	
Androsace septentrionalis	fairy candelabra				●	
Anemone canadensis					●	
Anemone cylindrica	long-fruited anemone				●	
Anemone multifida	cut-leaved anemone				●	
Anemone occidentalis					●	
Anemone patens	prairie crocus				●	
Antennaria rosea	rosy everlasting				●	
Aralia nudicaulis	wild sarsaparilla				●	
Arnica fulgens	shining arnica				●	
Artemisia frigida	pasture sagewort				●	
Artemisia ludoviciana	prairie sagewort				●	
Aster conspicuus	showy aster				●	
Aster ericoides	trusted white prairie aster				●	
Aster falcatus	creeping white prairie aster				●	
Aster laevis	smoothing aster				●	
Aster sibiricus	arctic aster				●	
Astragalus alphinus	alpine milk vetch				●	

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Forbs						
Astragalus americanus	American milk vetch				●	
Astragalus bisulcatus	two-gooved milk vetch				●	
Astragalus canadensis	Canada milk vetch				●	
Astragalus crassicarpus	groundplum				●	
Astragalus drummondii	Drummond’s milk vetch				●	
Astragalus gilviflorus	cushion milk vetch				●	
Astragalus missouriensis	Missouri milk vetch				●	
Astragalus pectinatus	narrow-leaved milk				●	
Astragalus striatus	ascending purple milk vetch				●	
Astragalus tenellus	slender-leaved milk vetch				●	
Atriplex nuttallii	Nuttall’s atriplex, salt, sage		●	●		
Bidens cernua	nodding beggar-ticks		●	●		
Campanula rotundiolia	bluebell, harebell			●	●	
Castilleja lutescens	yellow indian paintbrush				●	
Castilleja miniata	red indian paintbrush				●	
Chenopodium capitatum	strawberry blite			●	●	
Chrysopsis villosa	hairy golden aster				●	
Cleome serrulata	bee plant				●	
Corydalis aurea	golden corydalis				●	
Delphinium glaucum	tall larkspur			●	●	
Disporum trachycarpum	fairy bells			●		
Dodecatheon conjugens	shooting star			●	●	
Dodecatheon pulchellum	shooting star			●	●	
Dryas drummondii	yellow drayad				●	
Epilobium angustifolium	fireweed; great willow-herb				●	
Epilobium ciliatum	northern willow-herb				●	
Erigeron caespitosus	tufted fleabane				●	
Erigeron compositus	compound fleabane				●	
Erigeron glabellus	smooth fleabane			●	●	
Erigeron philadelphicus	Philadelphia fleabane			●	●	
Erigeron speciosus	showy fleabane				●	
Eriogonum flavum	yellow umbrella-plant				●	
Eurotia lanata	winter fat				●	
Fragaria verginiana	wild strawberry			●	●	
Gaillardia aristata	gaillardia				●	
Galim boreale	northern bedstraw			●	●	
Gaura coccinea	scarlet butterfly weed				●	
Gentianella amarella	gentian				●	
Geranium richardsonii	wild white geranium				●	
Geranium viscosissimum	sticky purple geranium				●	
Geum aleppicum	yellow avens			●	●	
Geum macrophyllum	yellow avens			●	●	
Geum rivale	purple avens			●		
Geum triflorum	old man’s whiskers/prairie smoke				●	

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Forbs						
Glycyrrhiza lepidota	wild licorice				●	
Grindelia squarrosa	gumweed				●	
Gutierrezia sarothrae	broomweed				●	
Habenaria hyperborea	green orchid			●		
Haplopappus spinulosus	spiny iron plant				●	
Hedysarum boreale	northern hedysarum				●	
Hedysarum sulphurescens	yellow sweetvetch				●	
Helianthus annuus	common annual sunflower				●	
Helianthus laetiflorus var. *subrhomboideus*	rhombic-leaved sunflower				●	
Helianthus nuttallii	common tall sunflower				●	
Heracleum lanatum	cow parsnip			●		
Heuchera cylindrica	sticky alumroot				●	
Lathyrus ochroleucus	cream coloured vetchling			●		
Liatris punctata	dotted blazing star				●	
Lilium philadelphicum	western wood lily			●	●	
Linnaea borealis	twinflower				●	
Linum lewisii	wild flax				●	
Linum rigidum	yellow flax				●	
Lithospermum ruderale	woolly gromwell				●	
Lomatium dissectum	mountain wild parsley			●	●	
Lomatium macrocarpum	long fruited parsley			●	●	
Lupinus sericeus	flexile lupine				●	
Lygodesmia juncea	skeletonweed				●	
Lysimachia ciliata	fringed loosestrife			●		
Malanthemum canadense	wild lilly-of-the-valley			●		
Malvastrum coccineum	scarlet mallow				●	
Mitella nuda	bishop's cap			●		
Monarda fistulosa	wild bergamont			●		
Oenothera biennis	yellow evening primrose			●	●	
Orthilia secunda	one-sided wintergreen			●	●	
Orthocarpus luteus	owl's clover				●	
Oxytropis campestris	locoweed				●	
Oxytropis deflexa	reflexed locoweed				●	
Oxytropis monticola	late yellow locoweed				●	
Oxytropis sericea	early yellow locoweed				●	
Oxytropis splendens	showy locoweed				●	
Oxytropis viscida	viscid locoweed				●	
Parnassia palustris	grass of parnassia			●		
Penstemon confertus	yellow beardtongue				●	
Penstemon nitidus	smooth blue beardtongue				●	
Penstemon procerus	slender blue beardtongue				●	
Perideridia gairdneri	squaw root			●	●	
Petalostemon purpureus	purple prairie clover				●	
Petasites palmatus	palm-leaved coltsfoot				●	

Latin Name	Common Name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Forbs						
Petasites sagittatus	coltsfoot			●		
Physaria didymocarpa	twin bladderpod				●	
Polygala senega	seneca snakeroot			●	●	
Potentilla anserina	silverweed		●	●		
Potentilla arguta	white cinquefoil			●	●	
Potentilla gracilis	graceful cinquefoil			●	●	
Potentilla hippiana	woolly cinquefoil				●	
Potentilla pensylvanica	prairie cinquefoil			●	●	
Primula incana	mealy primrose			●		
Psoralea esculenta	indian breadroot			●	●	
Pyrola asarifolia	common pink wintergreen			●		
Ranunculus glaberrimus	shining leaved buttercup			●	●	
Ranunculus pedatifidus var *affinis*	northern buttercup			●	●	
Ratibida columnifera	prairie cone-flower				●	
Rumex occidentalis	western dock			●		
Rumex venosus	wild begonia				●	
Sagittaria latifolia	broadleaf arrowhead		●			
Senecio canus	prairie groundsel				●	
Sisyrinchium montanum	blue-eyed grass				●	
Sium suave	water parsnip		●			
Smilacina racemosa	false solomon's seal			●	●v	
Smilacina stellata	star-flowered solomon's seal			●	●	
Solidago canadensis	Canada goldenrod				●	
Solidago missouriensis	Missouri goldenrod			●	●	
Solidago mollis	velvety goldenrod				●	
Solidago rigida	stiff goldenrod				●	
Sphaeralcea coccinea	scarlet mallow				●	
Stachys palustris	hedge nettle			●		
Thalictrum dasycarpum	tall meadow rue			●	●	
Thalictrum venulosum	veiny beadow rue			●	●	
Thermopsis rhombifolia	golden bean				●	
Urtica dioica	stinging nettle		●	●		
Vicia americana	wild vetch			●	●	
Viola adunca	early blue violet			●	●	
Viola canadensis	Canada violet			●		
Viola nuttallii	yellow prairie violet				●	
Zigadenus elegans	white camas				●	
Zizia aptera	heart-leaved alexanders			●		

APPENDIX F:
Wetland Design Comparison

Table F-1: Attributes of Four Stormwater Wetland Designs[1, 2]

Attribute/Sizing Criteria	Shallow Marsh	Pond-Wetland	ED Wetland	Pocket Wetland
Treatment Volume (V_t) **Wetland: Watershed Ratio**	Capture 90% of runoff volume from contributing watershed 0.02:1	Capture 90% of runoff volume from contributing watershed 0.01:1	Capture 90% of runoff volume from contributing watershed 0.01:1	Capture 90% of runoff volume from contributing watershed 0.01:1
Pollutant Removal Capability	Moderate, reliable removal of sediments and nutrients	Moderate to high, reliable removal of sediment and nutrients	Moderate, less reliable than shallow wetland	Low to moderate; pollutants can be subject to re-suspension
Land Consumption	High, shallow wetland storage consumes space	Moderate, wet pond replaces shallow wetland storage	Moderate, vertical ED storage replaces shallow wetland storage	Moderate, but can be shoehorned in site
Surface Area Allocation **- forebay** **- micropool** **- deep pool** **- lo marsh(15-45 cm)** **- hi marsh(0-15 cm)** **- semi-wet**	 5 5 5 40 40 5	 0 5 40 25 25 5	 5 5 0 40 40 10	 0 0 5 50 40 5
Treatment Volume **- forebay** **- micropool** **- deep pool** **- lo marsh (15-45 cm)** **- hi marsh (0-15 cm)** **- semi-wet**	 10 10 10 45 25 0	 0 10 60 20 10 0	 10 10 -- 20 10 50	 0 0 20 55 25 0
Flow Path **- min. L:W** **- dry weather L:W**	 1:1 2:1	 1:1 2:1	 1:1 2:1	 N/A 2:1
Water Balance	Base flow $\geq$ 1.4 (10^{-4}) $m^3/s/ha$			
Extended Detention (ED)	N/A	N/A	$ED_v=50\%V_t$ ED rise<1m	N/A
Min. Drainage Area (ha) **Forebay** **Outlet Micropool**	10 required required	10 no required	4 required required	0.40<area<4 optional optional
Outlet Type	Rev. slope pipe or broad crest weir	Rev. slope pipe or broad crest weir	Rev. slope pipe or broad crest weir	Broad crest weir
Cleanout Frequency (yrs,)	2-5	10	2-5	10
Buffer Zone (m) Outlet Micropool	8-15 mulch/transplant	8-15 mulch/transplant	8-15 mulch/transplant	0-8 mulch/transplant

1. Source: Schueler et al 1992.
2. Adapted from: Cappiella 2008.

Attribute/Sizing Criteria	Shallow Marsh	Pond-Wetland	ED Wetland	Pocket Wetland
Construction Cost	Moderate to high, particularly when considering the cost of land	Moderate	Moderate, vertical ED storage reduces	Moderate to high
Runoff Volume and Peak Discharge Control	Moderate to high	High	High	Moderate to high
Runoff reduction	Moderate	Low to moderate	Moderate	Moderate
Risk of Thermal Impacts	Moderate to high, due to lack of shading	Moderate of high, due to lack of shading	Moderate to high, due to lack of shading	Moderate to high due to lack of shading
Pondscaping Emphasis	Wildlife habitat marsh topography buffer	Wildlife habitat hi marsh	ED zone stability pondscaping zones	Pondscaping optional
Native Plant Diversity	Moderate, with wetland complexity	Moderate with wetland complexity	Low to moderate, fluctuating water levels create difficult growing conditions	Low, due to small surface area and fluctuating water levels
Habitat Value	Moderate, with wetland complexity and buffer	Moderate, with wetland complexity and buffer	Low to moderate, due to fluctuating water levels and limited plant diversity	Low, due to small area and low plant diversity
Risk of Mosquito Proliferation	Variable, depending on design elements, perception of risk may be high	Variable, depending on design elements, perception of risk may be high	Variable, depending on design elements, perception of risk may be high	Variable, depending on design elements, perception of risk may be high
Maintenance Burden	Moderate, includes vegetation management and sediment removal	Moderate	Moderate	High
Safety and Aesthetics	Moderate to high	Moderate to high	Moderate, due to fluctuating water levels	Low to moderate, due to fluctuating water levels
Deep Water -	0.30 - 1.80 m below normal pool (includes forebays, micropools, pools and channels)			
Lo Marsh -	15 - 45 cm below normal pool			
Hi Marsh -	0 - 15 cm below normal pool			
Semi-wet -	0 - 0.60 m above normal pool (includes ED)			
Note: The allocation targets are general guidelines and will vary according to design and site constraints.				

1. Key Design Elements for Emergent Wetlands[3]

1) Wetland should consume approximately 3% or less of the contributing drainage area.
2) Wetland should have a minimum length to width ratio of 3:1, although a length to width ratio of 5:1 or 6:1 is preferred.
3) Include a separate sediment forebay cell to reduce the velocity runoff and promote sediment removal.The forebay should comprise at least 10% of the water quality storage volume and should be approximately 1.20 to 2.0 m deep.
4) Include a wet pond cell to provide initial treatment of the water quality storage volume.
   - The wet pond cell should retain at least 70% of the water quality storage volume in a permanent pool.
   - Extended detention time should be between 12 and 24 hours.
   - The maximum extended detention water quality surface elevation should be no greater than 45 cm above the water surface elevation of the permanent pool.
   - A flow rate of approximately 0.00014 m^3/s/ha must be supplied to the wetland cells to maintain adequate hydrology during dry weather.
5) Include a dissipation pool at the downstream end of the wet pond cell.The dissipation pool should comprise approximately 10% of the water quality storage volume and should be approximately 0.90 to 1.20 m deep.
6) Include wetland cells to provide additional treatment of soluble pollutants. A minimum of four wetland cells in series is recommended.
   - Limit water level fluctuations to increase native plant diversity and habitat value.
   - The water surface elevation of a wetland cell should increase by no more than 15 cm.
   - Wetland cells should have a minimum length to width ratio of 3:1. A length to width ratio of 5:1 or 6:1 is preferred.
   - Each wetland cell should be designed to consume about 25% of the total surface area of the entire wetland component.
   - First wetland cell should be deepest with a depth of 45 to 60 cm and can support emergent wetland plant species or species that live 7.5 to 45 cm below the water.
   - Second wetland cell should be shallow with a depth of 5 to 10 cm and can support emergent wetland plant species or species that prefer drier conditions, and live 2.5 to 7.5 cm above the water.
   - Third wetland cell should be 30 to 45 cm deep and can support emergent wetland plant species that live 7.5 to 45 cm below the water.
   - Fourth wetland cell should be 5 to 10 cm deep and located at the discharge point from the wetland cell. This cell should be equipped with an adjustable weir or flashboard riser to regulate water levels and release rates.

3. Source: Cappiella 2008 (pages 23-28).

- The transitional areas between the deep and shallow wetland cells should be designed with a maximum slope of 3:1 to ensure soil stability at the bottom of the wetland.
- Side slopes of the wetland cells adjacent to the wet pond cell should not be steeper than 3H:1V.
- Side slopes of the wetland cell not adjacent to the wet pond cell should not be steeper than 6H:1V.

7) Include a transitional cell located at the downstream end of the wet pond cell and the wetland cells. The water surface elevation should be approximately 30 cm deep, and a rock cross vane should be used to separate the transitional cell from the receiving water body.

8) Incorporate features that reduce mosquito breeding potential and provide a habitat for mosquito predators. Regular monitoring and public education might also provide some reassurance to local residents and officials about safety.

9) Select plant species based on tolerance of inundation and other site conditions. In general, trees and shrubs should be planted above the ED zone (with a few exceptions).

2. Key Design Elements for Wooded Wetlands[4]

1) Complete a water balance for the site to make sure it can sustain a permanent water surface in the wetland.
2) Include a separate-cell forebay for pre-treatment and to allow for cleanout without damaging wetland vegetation.
3) Limit the maximum extended detention water surface elevation to no more than 20 to 25 cm above the normal pool to reduce potential impacts to the wetland community from frequent water level fluctuations.
4) Wetland should have a minimum length to width ratio of 3:1. Wetland side slopes should be a minimum of 3H:1V.
5) Use an outlet control structure that resists clogging, and include backup measures in case clogging occurs.
6) Prohibit trees within 4.50 m of the embankment toe and maintenance access areas.
7) Use a micropool for outlet protection and to help enforce the setback between embankment and trees.
8) Create variable microtopography and water depths throughout the wetland. Include a mix of high marsh, low marsh, deep pools and shallow pool areas.
9) Deep pools should comprise 20 to 50% of the wetland area and be located perpendicular to flow. Locating a deep pool just below the forebay provides flow dissipation and some additional treatment.
10) Shallow pools should have a maximum depth of 30 cm and deep pools around 90 to 120 cm. A simple water balance equation can be used to determine the minimum depth necessary for deep pools to ensure they retain water during a drought.
11) Incorporate 2 or 3 tree planting peninsulas in each wetland to enhance treatment.
12) Locate planting peninsulas and marsh wedges perpendicular to flow so they extend the length of the internal flowpath.
13) Plant trees on side slopes in clusters based on inundation tolerance. Clusters allow trees to share rooting space and permit mowing around trees if required.
14) Incorporate features that reduce mosquito breeding potential and provide habitat for mosquito predators. Regulate monitoring and public education may also provide some reassurance to local residents and officials about safety.
15) Select plant species based on tolerance of inundation and other site conditions. In general, trees and shrubs should be planted above the ED zone (with a few exceptions).
16) In areas to be planted with trees, overplant with small stock of fast-growing sucesstional species to quickly establish canopy closure and shade out invasive species.
17) Have a landscape architect develop a landscaping plan for the wetland.

4. Source: Cappiella 2008 (page 30).

18) Emphasize long-term vegetation management in the wetland maintenance plan.

Figure F-1: Wetland Cross Sections

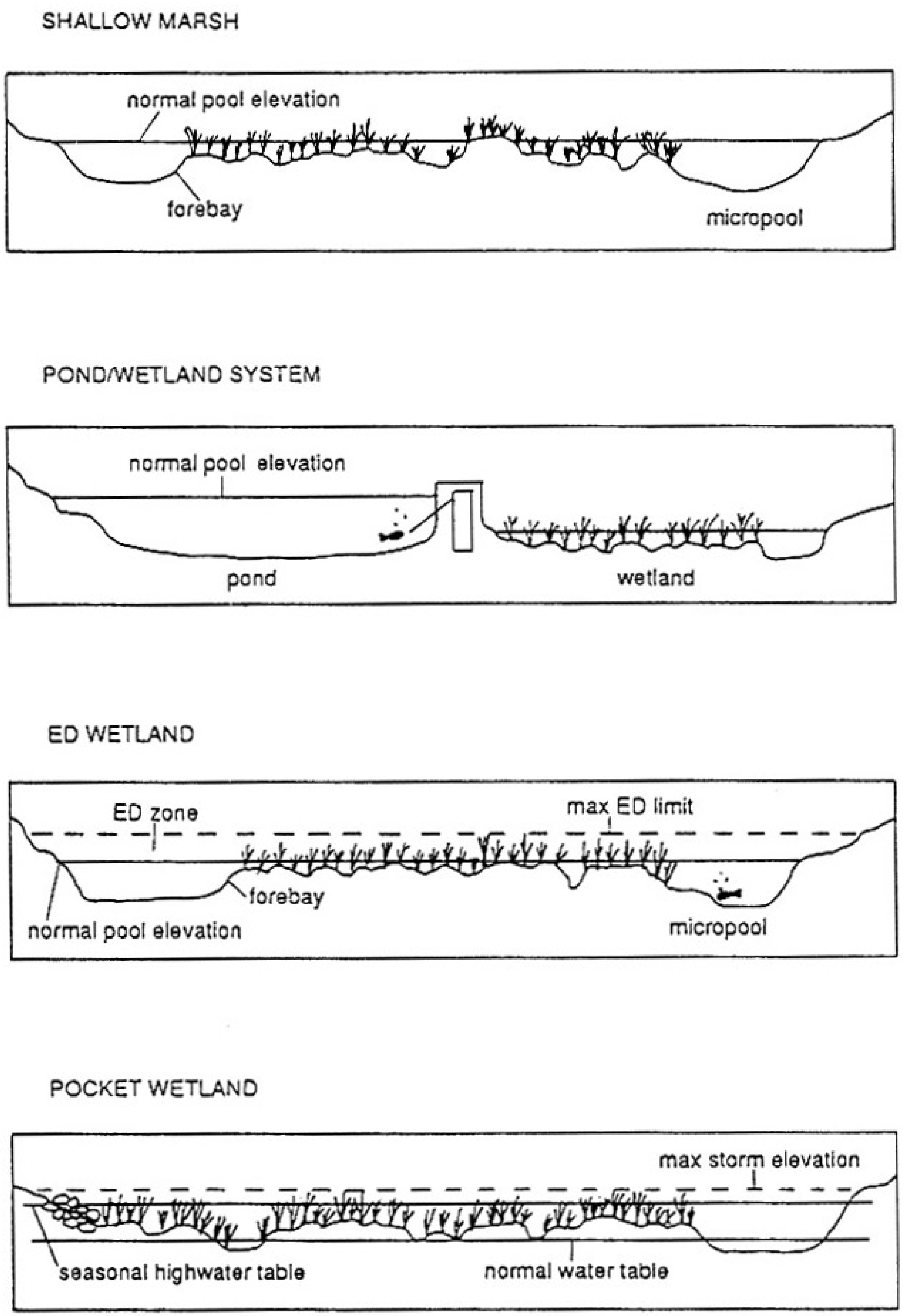


Figure F-2: Emergent Wetland

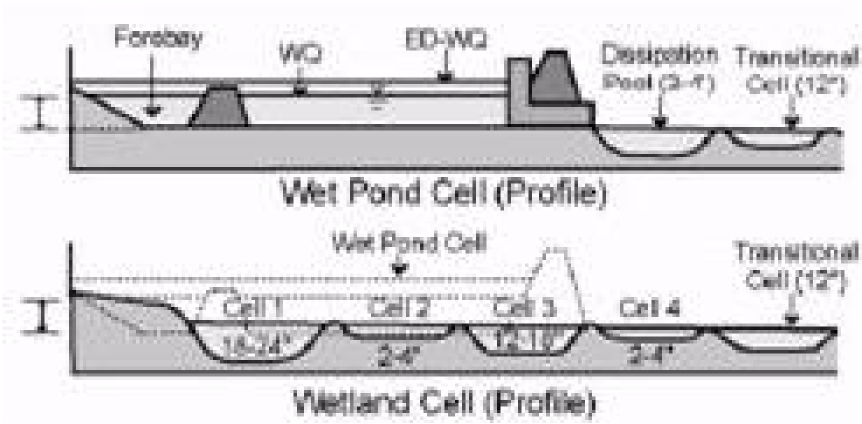
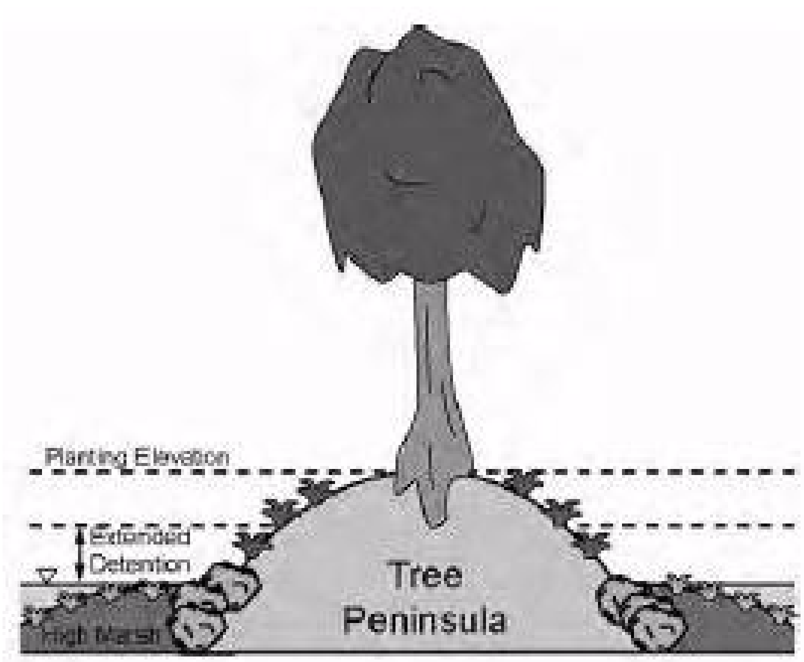


Figure F-3: Wooded Wetland



APPENDIX G:
Pollution Control Strategies

Table G-1: Good Housekeeping Practices

CONTAMINANT	SOURCES	BEST MANAGEMENT PRACTICES
Suspended solids	Exposed soils, organic and inorganic grit, and debris left on urban surfaces.	• Introduce and enforce litter control programs. • Control pet populations. • Introduce and enforce dog litter bylaws. • Promptly remove or properly store household garbage and yard wastes. • Sweep pavement and roofs rather than washing. • Stabilize exposed soils and banks.
Oxygen-demanding substances	Pet faeces, decaying household, and yard wastes.	• Properly dispose of or compost household and yard wastes. • Cover, clean and maintain trash can areas. • Clean up and properly dispose of pet wastes.
Toxic metals and organic compounds, oil and grease	Fluid leaks from vehicles, illicit dumping, household cleaners, paints, and pesticides.	• Repair fluid leaks in vehicles. • Wash vehicles on the lawn rather than on paved surfaces connected to storm drains. • Recycle used oil. • Use alternative, less hazardous household products. • Properly handle, store, and dispose of hazardous household products. • Implement household hazardous waste collection. • Sweep pavement and roofs rather than washing. • Absorb spills using kitty litter. • Minimize pesticide use (use Integrated Pest Management).
Nutrients	Decaying vegetation and animal wastes, fertilizers, detergents, and exposed soils.	• Stabilize exposed soils with vegetation or suitable cover. • Collect and properly dispose of or compost yard wastes and pet faeces. • Do not dump or compost plant debris near receiving water bodies. • Apply fertilizer sparingly and at the right time. • Use low-phosphate detergents. • Wash vehicles on the lawn rather than on paved surfaces connected to storm drains.
Bacteria	Pet faeces and decaying household and yard wastes.	• Collect and properly dispose of or compost yard wastes and pet faeces. • Cover, clean, and maintain trash can areas.
All	Illicit dumping, poor waste handling and disposal practices, and erosion.	• Comprehensive public education. • Erosion and sediment control.

Table G-2: Source Control Practices (SCPs) for Commercial and Industrial Activities[5]

CONTAMINANT	SOURCES	BEST MANAGEMENT PRACTICES
Suspended solids	Exposed soils, organic and inorganic debris left on urban surfaces, and washing of equipment, buildings, and pavement.	• Cover/stabilize exposed soils and soil/material stockpiles. • Clean and maintain business sites. • Sweep pavement and roofs rather than pressure washing. • Stabilize eroding banks and unpaved areas. • Preserve stream corridors. • Do not discharge impounded stormwater or groundwater from the site to a storm sewer without obtaining a permit (*Drainage Bylaw 37M2005*).
Oxygen-demanding substances	Decaying vegetation, animal wastes, food wastes, and chemical wastes.	• Fix, cover, or berm leaky dumpsters. • Promptly clean up outdoor spills. • Implement secondary containment for toxic chemicals. • Properly recycle, compost, and dispose of wastes. • Sweep pavement and roofs rather than pressure washing.
Toxic metals and organic compounds, oil and grease	Vehicle repair, paints, fuel and waste oil, antifreeze, brake fluid, battery acid, solvents, cleaners, sealers, pesticides, leaky dumpsters, cleaning vents, oil leaks in vehicles and equipment, steam cleaning, equipment maintenance.	• Maintain a clean and organized work area. • Do not sand or grind outside, unless on a tarp. • Clean up metal dust and shavings. • Cover containers and materials. • Cover or berm oily wastes and dumpsters. • Implement secondary containment for toxic chemicals. • Properly recycle and dispose of used and excess materials. • Handle toxic materials carefully. • Use care when filling and draining containers. • Plan for and control spills. • Cover and properly drain fuelling and loading areas. • Wash vehicles and parts in designated and properly drained areas. • Minimize pesticide use (use Integrated Pest Management). • Repair oil leaks on vehicles and equipment. • Recycle oil where possible. • Properly dispose of non-recyclable wastes. • Install and maintain oil-water separators.
Nutrients	Decaying vegetation and animal wastes, fertilizers, detergents, and exposed soils.	• Control erosion and sedimentation on site. • Plant cover vegetation on exposed soils. • Carefully choose plants and landscape features. • Properly dispose of or compost organic wastes. • Do not dump or compost plant debris near receiving water bodies. • Apply fertilizer sparingly and at the right time. • Wash only in designated and properly drained areas. • Use low-phosphate detergents.
All	Illicit dumping, improper connections to storm sewers, poor waste handling and disposal practices, and erosion.	• Comprehensive education and technical support. • Inspection, follow-up and enforcement of BMPs. • Eliminate improper and illegal connections to storm sewers. • Control erosion and sedimentation on site. • Obtain City permission prior to discharging impounded water (stormwater or groundwater) from a site to a storm sewer (*Drainage Bylaw 37M2005*).

5. Adapted from: City of Bellevue 1990.

Table G-3: Source Control Practices (SCPs) for Construction Activities[6]

CONTAINANT	SOURCES	BEST MANAGEMENT PRACTICES
Sediment, nutrients, particulate-associated metals and organics, oil and grease	Cleaning or grading land, and construction near a stream.	• Plan the development to fit the topography, soils, drainage patterns and natural vegetation of the site. • Avoid unnecessary modification of the site to suit a particular development design. • Preserve vegetation and cover/stabilize exposed soils. • Stage work to minimize the disturbed area and duration of exposure. • Establish permanent cover such as vegetation immediately after final grading. • Control runoff during construction (contain sediment-laden runoff on site in sediment traps/basins and divert clean runoff away from exposed areas). • Prevent off-site water (run-on) from running over disturbed areas. • Keep runoff velocities low so as to minimize erosion potential. • Stabilize disturbed areas with temporary cover or mechanical-structural methods. • Install sediment controls as insurance to runoff and erosion controls. Erosion controls should be the main priority. • Minimize off-site mud tracking and regularly inspect and clean adjacent streets and catchbasins. • Fix any oil leaks in equipment. • Preserve the stream corridor and take steps to enhance it.
Toxic and acidic pollutants, sediments	Handling fresh concrete or other cement-related mortars.	• Never wash fresh concrete mortar into a storm drain or stream - use designated wash-out areas. • When building concrete aggregate driveways, never allow washwater to enter streets and storm sewer catchbasins. Material must be collected on site and disposed of or treated appropriately.
Toxic metals and organics, oil and grease	Painting, sanding, plastering, applying drywall paper or tile, and any activities using paints, batteries, solvents, or adhesives.	• Keep residue such as paint chips from entering storm drains (e.g. catch chips on a tarp). • Keep paints, solvents, chemicals, waste containers, and soiled rags covered from the rain. Provide secondary containment for toxic chemicals. • Prepare for and clean up spills. Report all environmental spills immediately to Alberta Environment's 24 hour spill reporting line at 1-800-222-6514. • Minimize wastes and properly dispose of or recycle all wastes. • Fix any oil leaks in equipment.
All	General contracting and construction site management, and training employees.	• Include training about water quality BMPs. • Conduct frequent environmental site inspections, followed by any required maintenance or upgrades. Keep inspection and maintenance records on site. • Ensure all workers know proper BMP procedures. • Ensure all applicable BMPs are followed. • Obtain City permission prior to discharging impounded water (stormwater or groundwater) from a site to a storm sewer (*Drainage Bylaw 37M2005*).

6. Adapted from: City of Bellevue 1990

APPENDIX H:
Maintenance And Response Procedures For Stormwater Ponds (Water Resources And Water Services)

1. MAINTENANCE PROCEDURES

1.1 Preventive Maintenance by Field Services Group

Field Services, Asset Operations is responsible for preventive maintenance to ensure proper operation of stormwater ponds, including clearing and disposal of debris and garbage from the pond area and from the structures within the pond area. Ponds located on school sites must have highest priority.

Preventive maintenance is to be undertaken on all stormwater ponds at spring thaw and on affected storm ponds after each significant rainstorm. A significant rainstorm is generally one that will activate the first alarm in a monitored pond.

1) All catchbasins (CBs), inlet/outlet grates, trash racks and the orifice in the outlet control structure should be checked and cleaned.
2) All garbage and debris should be removed from the pond area.
3) Damage to the sod or pond area should be repaired.
4) Ensure that all gratings and manhole (MH) lids, both upstream and downstream of the stormwater pond, are in place. Gratings and lids that are subject to displacement should be secured as a safety measure.
5) Where available, the sluice gate or gate valve in the outlet control structure may be used to drain down the storm pond if it is established that the downstream storm sewer has capacity. The sluice gate or gate valve must be completely closed after the pond has been drained.
6) Heavy equipment is not allowed within the pond area immediately after the drain down to avoid damage to sod and underground pipe systems. In most cases, a 3.0 to 4.0 m path is provided for access to the outlet control structure.
7) Where there is a weeping tile drain or a subdrainage system, cleanouts must be provided and accessible to flusher trucks so that blockages can be cleared. Before leaving the site, ensure that all gratings and structures are secured, and the sluice gate or gate valve is completely closed.

1.2 Maintenance of Electrical and Alarm Systems

The preventive maintenance on the electrical system is undertaken at all stormwater ponds at spring thaw. A significant rainstorm is generally one that will activate the first alarm in a monitored pond.

Non-emergency problems can be addressed by contacting the Sr. Operations Engineer at 403-268-3486. Emergencies should reported to 3-1-1 immediately.

Alarm systems in the monitored ponds are polled periodically to ensure that the systems are operational and forwarded to the Duty Supervisor.

1) The electrical panel box that also houses the alarmed system in monitored ponds should be opened and checked for water infiltration. The box should be dry to prevent electrical hazards and to ensure proper operation of the electrical components.
2) All breakers in the electrical panel box should be checked, and tripped breakers returned to the “ON” position.
3) Desiccant tubes (applicable in some ponds) are located within the electrical panel boxes to control moisture. The desiccant should be blue in colour. When the desiccant is pink in colour, it should be removed, dried and replaced, or disposed of and replaced altogether.
4) All alarmed ponds have ultrasonic sensors installed in the outlet control structure. Low Water Level (LWL) and High Water Level (HWL) alarms should be checked on an annual basis, at the beginning of the rain season. The intrusion alarm should also be checked.
5) Before leaving the site, ensure that all lids, gratings, and electrical panels are secured.

Monitored ponds are equipped with an ultrasonic sensor in the outlet control structure and an intrusion alarm in the electrical cabinet.

1) The cabinet contains an intrusion alarm. An open door will activate the alarm in the storm pond monitoring system. Immediately press the by-pass button within 30 seconds of opening the door to deactivate the alarm.
2) The outlet control structure contains an ultrasonic sensor that activates the LWL and HWL alarms in the storm pond monitoring system. If work is being done inside the structure, a false alarm could be activated. Please notify the Duty Supervisor of any impending work.

2. RESPONSE PROCEDURES

2.1 Response by Field Services, Asset Assessment

Asset Assessment will respond to surcharging and other unacceptable conditions at stormwater ponds (i.e., wet ponds, wetlands, and dry ponds), secure the affected ponds, monitor the water level at the pond area, and provide proper actions to relieve the situation as expeditiously as possible. Ponds located on school sites must have the highest priority.

Unacceptable conditions include situations where, in the opinion of The City, there is danger to life, property, or the environment that requires immediate intervention or continuous supervision.

The storm retention pond will be secured by prohibiting public access to the site. The security will be provided either by City personnel or contract security staff. Because dry ponds normally do not contain water, they are secured when runoff is present in the pond area, as indicated by the pond alarm.

1) When a significant rainstorm is forecast, or during a rainstorm, the Field Services On-Duty Supervisor will initiate steps to monitor the progress of the rainstorm, and when necessary, to check water levels at the affected storm stormwater ponds.
2) All complaints, emergencies, or other unacceptable conditions at the stormwater ponds are directed to the On-Duty Supervisor.
3) With respect to monitored dry ponds, the Dispatch Centre will advise the On-Duty Supervisor of the activation of alarms in monitored dry ponds. The first alarm indicates entry of runoff into the dry pond; the second alarm indicates water at the maximum water level of the pond.
4) Crews responding from Field Services will act appropriately to relieve the surcharging or other unacceptable conditions in the affected ponds. These actions could include clearing of debris from CBs, outlet pipes, grates at inlet/ outlet structures, control structures, etc., but only where it is safe to do so. Pumping or release of the sluice gate to drain the pond will only be allowed when it is safe to do so, and when downstream capacity exists.
5) Field Services personnel will remain on site to secure the affected ponds by prohibiting public access to the pond. The personnel manning the pond might be asked to time the water levels in 0.50 m increments. Dry ponds are to be secured until the pond area is fully drained.
6) The On-Duty Supervisor will endeavour to establish the duration and severity of the rainstorm to make the necessary arrangements to secure the affected storm ponds after normal business hours, or when Field Services crews are unavailable due to the volume of emergency response requests.
7) Field Services will undertake all preventive maintenance on the affected storm ponds when field conditions permit.

2.2 Private Security Company

When the duration and severity of a rainstorm make it necessary to secure stormwater ponds after normal business hours, or when Field Services is unable to provide staff, the Duty Supervisor will make the arrangements with the private security company that is currently under contract with the City of Calgary (hereinafter called the Contractor), to provide the personnel to undertake the work.

1) The Duty supervisor will provide instructions directly to the Contractor by telephone at 403-244-4664. This is a 24 hour per day 7 days per week dispatch number.
2) Upon instructing the Contractor, the Duty Supervisor will provide the 2-way radios and the site maps from the pond map book for each of affected storm ponds for the contractor to pick up at the Dispatch Centre. An additional radio will be given to the duty officer at the Dispatch Centre for required communications with each assigned security officer.
3) One security officer is required full-time on site at each affected storm pond. The security officer will pick up the site map of the assigned pond and a 2-way radio from the Duty Supervisor or from the duty officer at the Dispatch Centre.
4) The security officer at each assigned pond will use the 2-way radio to check in every hour, on the hour, to the duty officer at the Dispatch Centre.
5) The Contractor's security supervisor will provide random checks on the security officers at the affected storm ponds. The security supervisor will confirm each random check to the duty officer at Manchester using the 2-way radio provided to the security officer at the assigned pond.
6) In the event of a problem or emergency, or when the water level at the stormwater pond reaches the HWL, the security officer will contact the duty officer at the Dispatch Centre without delay. The duty officer will then contact Field Services On-Duty Supervisor.
7) The Dispatch Centre also notifies the On-Duty Supervisor of pond second alarms, indicating that the pond is reaching the high water level.
8) Both the security officer and the duty officer at the Dispatch Centre will each maintain a timed log on all radio calls to and from one another, random checks by the Contractor's security supervisor, and any other radio calls during the security officer's shift at the assigned storm pond.
9) After the completion of the work shift, the timed logs created by the security officer will be delivered to the Field Services On-Duty Supervisor at the Field Services office (the following morning).
10) On-site services provided by the Contractor will end when the On-Duty Supervisor determines the unacceptable condition no longer exists. When the water level in the pond being watched returns to normal levels, the contract security officer will contact the On-Duty Supervisor. The Dispatch Centre must be made aware when this occurs.
11) Field Services will undertake all preventive maintenance on the affected ponds when weather conditions and resources permit.

APPENDIX I:
Stormwater Pond Inspection Requirements

CITY OF CALGARY-WATER RESOURCES
STORMWATER POND INSPECTION REQUIREMENTS

The following is a list of items which should be checked before application for Water Resources Construction Completion Certificates (CCCs) and Final Acceptance Certificate (FACs). All ponds must comply with the requirements outlined in this manual.

Relevant checklists need to be completed and included as part of the CCC and FAC application processes:

- *Checklist #7: Pond Construction Completion Certificate (CCC) Signoff*
- *Checklist #8: Pond Final Acceptance Certificate (FAC) Signoff*
- *Checklist #11: Dry Pond Inspection Check Sheet*
- *Checklist #12: Wet Pond/Wetland Inspection Check Sheet*

Refer to the *Development Approvals Submissions* page on The City of Calgary's website for copies of the latest version of these checklists.

1. CCC Inspection

1.1 Grading

The consultant must submit final as-built cross sections and contours of the entire pond. They should be plotted at the same stations and scale as the original design cross sections. Surveys from Parks may be submitted. Items to be checked include:

i) Dry Ponds:

- **Side slopes** - The side slope must be no steeper than 5H:1V from pond bottom to high water level (HWL), including the freeboard. Above the inundated area, side slopes no steeper than 4H:1V are permitted for inward facing slopes and 3H:1V for outward facing slopes.
- **Bottom slopes** - The pond bottom must have a minimum slope of 1.5%. A 2% slope is preferred.
- **Bottom grading** - must provide positive drainage towards the catchbasins (CBs) and inlet/outlet structure(s). There must be no areas of standing water. Wet soggy areas could also be a sign of irrigation system leaks.

ii) Wet Ponds:

- **Side slopes and bottom slopes** - below lower normal water level ((L)NWL), a 2.0 m wide 3H:1V side slope is required with the remainder being between 5H:1V and 7H:1V. Between the (L)NWL and HWL, the side slope should be no steeper than 5H:1V. Above HWL, slopes no steeper than 4H:1V to 5H:1V are permitted. Benches and other alterations are permitted as approved by Water Resources/Services.

Steeper side slopes are allowed above HWL, provided that a 2.0 m wide safety bench is provided above the freeboard elevation.

For wet ponds subject to water re-use, alternative side slope arrangements are permitted between (L)NWL and upper normal water level ((U)NWL) as approved by Water Resources.

- **Boat Ramp** - The boat ramp must extend to 0.50 to 1.0 m below the (L)NWL.
- **Access Road** - The access road to the outlet control structure and the top of the outlet control structure must be above the freeboard elevation.
- **Elevations -** Property line and berm elevations must be above the freeboard elevation.

iii) **Wetlands:**

- **Side slopes** - grading below NWL should be no steeper than 10H:1V. Between NWL and HWL, grading should be no steeper than 5H:1V. Grading above HWL should be no steeper than 4H:1V to 5H:1V; outward facing slopes should be no steeper than 3H:1V. Alternating sections of 7H:1V can be used for terraced grading. Benches are permitted as approved by Water Resources/Services.
  For forebays in wetlands, below NWL a 2.0 m wide, 3H:1V side slope is required, with the remainder being between 5H:1V and 7H:1V.
  Steeper side slopes are allowed above HWL, provided that a 2.0 m wide safety bench is provided above the freeboard elevation.
- **Access road** - The access road to the outlet control structure and the top of the outlet control structure must be above the freeboard elevation.
- **Elevations -** Property line and berm elevations must be above the freeboard elevation.

iv) **General:**

- **Design volume** - As-built volumes must be supplied. The as-built live storage capacity must be no less than 99% of the required 1:100 year storage capacity.
- **Erosion** - Ensure that there are no signs of erosion throughout the pond. The inlet/outlet structure and CBs are the most susceptible to erosion.
- Ensure that the **overland escape route/emergency spillway** has been constructed as per the construction drawing(s). It is important that the spillway be in the proper location and within +/- 50 mm of the design elevation for the overland emergency escape route and within +/- 25 mm for the weir wall in the outlet control structure. The width of the crest of the overland escape route must be within +/- 100 mm of the design width.
- **Sediment areas**, such as forebays, must be properly designed and constructed.

1.2 Inlet/Outlet Control Structures

Inspect inlet/outlet control structures for design as shown on the construction drawing(s) to ensure that:

- The bottom of the structure is benched, so that there is no standing water for dry ponds.
- The invert of grating(s) are checked. Gratings are usually installed at specific elevations to allow stormwater flows into/out of the pond.
- The invert of incoming/outgoing pipe is checked. The invert of the incoming pipe must be at least 300 mm above the top of the erosion protection in the forebay.
- The inlet pipe diameter is 450 mm (dry ponds only).
- Grating(s) are bolted down or secured for safety measures. There should be no gratings on the submerged inlets/outlets.
- There are no signs of erosion around the structure. Usually some type of erosion control protection is in place around the structure (i.e., mats).
- There is little or no build-up of silt or debris.
- There is no damage to structure(s). This includes a check for cracking, honeycombing and spalling.

1.3 Catchbasins (CBs)/Manholes (MHs) - Dry Ponds Only

Inspect all pond CBs and MHs for design as shown on the construction drawing(s) to ensure that:

- All rim and invert elevations are checked.
- All CB gratings are bolted down or secured for safety reasons. Ensure that proper grating has been used.
- The bottom of all MHs are benched so there is no standing water.
- There are no signs of erosion around the CBs.
- There is little or no build-up of silt or debris.
- There is no damage to any of the CBs or MHs. This includes a check for cracking, honeycombing, and spalling.

1.4 Outlet Control Structure

1.4.1 General

Inspect the outlet control structure for design as shown on the construction drawing(s). For wet ponds and wetlands, inspection must be done prior to water being introduced into pond. Ensure that:

- The bottom of the structure is benched toward the orifice. For dry ponds, there should be no standing water in the structure.
- All rim and invert elevations are checked.
- There is little or no build-up of silt or debris.
- There is no damage to structure. This includes a check for cracking, honeycombing and spalling.

1.4.2 Gate valve

Inspect gate valve (if applicable) to ensure that:

- The gate valve works properly. The gate must be easily engaged.
- The valve face is sealed properly and does not leak.
- The approved service provider has made sure that the automatic control gate system (if required) is set up and working properly.

1.4.3 Trash Rack

Inspect trash rack to ensure that:

- Where required, the trash rack is removable and easily cleaned.
- The trash rack is free of debris.

1.4.4 Weir wall

Check the elevation of the top of the weir wall. The size of the opening must also be verified.

1.4.5 Orifice

Inspect orifice to ensure that:

- The centerline or invert elevation of the orifice is checked. It is important that this elevation be as close to the design value as possible.
- The dimensions of the orifice are verified.
- The orifice plate fits snugly to the structure wall to minimize leakage around the plate.

1.5 Storm Pipe System

Inspect the storm pipe system for design as shown on the construction drawing(s) to ensure that:

- All invert elevations are checked. For dry ponds, the piping within the pond bottom usually has a flatter slope, so it is important that elevations are close to design value.
- The upstream storm pipe under pressure (i.e., below 1:100 year hydraulic grade line (HGL) elevation) has been installed with rubber gaskets. Ensure that the drawings are properly labelled.
- Storm MHs designed with bolt-down covers have been properly installed.
- Pipes are free of silt and debris.
- A skimming MH, or equivalent approved by Water Resources, has been constructed upstream of the inlet(s).

1.6 Subdrainage System (Dry Ponds Only)

Inspect the subdrainage system for design as shown on the construction drawing(s) to ensure that:

- Invert elevations are checked. It is important that elevations are close to design value.
- Cleanouts have been installed as indicated. Cleanout tops should be flush with ground surface.
- Drainage blankets have been installed as per design.
- Weeping tile drains/subdrainage system connects downstream of the outlet control structure. If the weeping tile drain connects to the internal CBs or the upstream side of the outlet control structure, some type of backwater valve (i.e., Red Valve) should be incorporated to prevent surcharging. Ensure that these valves have been installed at the location(s) specified in the construction drawing(s).
- System is free of silt and debris.

1.7 Sanitary Pipe System

Inspect the sanitary pipe system for design as shown on the construction drawing(s).

Note: No sanitary sewer MHs are permitted within the pond area.

1.8 Monitoring System

Inspect the monitoring system for design as shown on the construction drawing(s) to ensure that:

- All level/alarm sensors are easily and safely accessible for Maintenance personnel.
- All sensors have been installed at the proper elevations.
- The approved service provider has checked that alarm conditions ring through to the the City's centralized storm pond monitoring systems (SCADA system). This requires that the alarm sensors be programmed to alarm at specified elevations. These elevations should correspond LWL and HWL for dry ponds. For wet ponds and wetlands, the low level alarm should be at (L)NWL+0.10 m. The service provider must also supply a schematic of the inside of the structure (showing alarm set points).
- The doors on the electrical control box close and seal properly.
- The electrical control box is in good condition and does not show signs of rusting or damage.
- Landscaping slopes away from electrical control box.
- All conduit into the electrical outlet control structure has been sealed to prevent infiltration of water and/or humidity.
- All electrical equipment (i.e., fans, heater) works properly and have been properly installed.
- The electrical control box is locked with the Water Services “construction” lock. Locks are available from Water Services.

Note: Water Services is responsible for checking the monitoring system. The RTU must be recording and alarming properly. Phone number(s) must be supplied.

1.9 Signs

Approved signs must be placed at entrances to the pond and at other suitable locations as required. There must not be any damage to signs.

1.10 Miscellaneous

- Inspect the **ramp** to ensure that a clear, 3.50 m wide (minimum) gravelled or paved access (or approved equivalent, capable of supporting a 23 tonne load) is provided from the adjacent street or lane for emergency and maintenance vehicle access. As well, a pathway or gravelled road must extend to the outlet control structure for maintenance purposes, if possible.
- Inspect the **pathway** for signs of cracking or heaving.
- Inspect all **concrete structures** for signs of cracking, honeycombing, and spalling.
- Ensure that the consultant has submitted all final record drawings in mylar material and digital format after a set of print drawings has been checked and approved.

1.11 Landscaping and Irrigation

All landscaping and irrigation will be inspected by Parks and must comply with the Landscape Construction Standard Specification and landscaping/vegetation approved on the construction drawings. It should be noted that ponds require CCC and FAC approval from **both** Parks and Water Resources. All vegetation and landscaping must be established and healthy.

2. FAC Inspection

At the time of FAC Inspection, all items from the CCC Inspection (above) should be **rechecked** as required. In addition, there should be an operations and maintenance (O&M) report/manual (can be as simple as one page) submitted, as well as a list of all maintenance activities performed during the maintenance period.

2.1 Maintenance Requirements

All maintenance activities must be carried out as per ***CHAPTER 10: OPERATING, MAINTENANCE, AND MONITORING REQUIREMENTS*** in this manual.

The FAC maintenance period for pond and wetland construction will be no less than 3 years, unless specified otherwise. For wet ponds, the 3 years of maintenance begins once the last staging of construction is completed. Automatic control gate systems require a 3 year maintenance period, as well. For loaming, seeding and landscaping, the FAC maintenance period will be 3 years from the time of seeding or tree planting, whichever occurs last.

2.2 Accounting Requirements

A copy of the FAC must be submitted to Field Services. At the time the FAC is approved, the Engineer responsible in the Water Services, Business Performance group must make arrangements to have the telephone and utility accounts changed over to Water Services.

APPENDIX J:
Operation And Maintenance Activities for Stormwater Source Control Practices

Table J-1: Typical Maintenance Activities for Dry Swales and/or Bioswales[1]

Required Action	Maintenance Objectives	Frequency
Watering	Irrigation might be required to promote successful germination, establishment and survival of vegetation.	As necessary during first growing season, and as necessary during dry periods after the first growing season.
Mowing	• Occasional mowing of grasses and weed removal to limit unwanted vegetation. Remove and dispose of the clippings. • Maintain irrigated turf grass at 50 to 100 mm tall and non-irrigated native turf grasses at 100 mm to 150 mm tall. • Mowed grass should not be below the design water quality event level. • Mowing the native grasses the first year is critical in order to eliminate competition from annual weeds. • Mowing and other maintenance equipment should not damage or excessively consolidate the surface!	• If native grasses are used, mow only once a year in early spring to remove dead vegetation. Otherwise, routine maintenance frequency, depending on aesthetic requirements. • Do not cut during periods of drought, or when ground conditions or grass are wet, without prior approval.
Vegetative Care	• Maintain a healthy dense grass in channel and side slope. Returf using turf of a quality and appearance to match existing turf, or reseed using seed to match existing tuff in appearance and quality. Supply and fix fully biodegradable coir blanket as supplier's instructions to protect seeded soil. Top-dress and properly tamp with fine-sieved soil matching original landscaping layer to achieve final design levels. • Weeding and removal of invasive species. • Grass in the swales should be fertilized rarely, if at all, to avoid unnecessary export of nutrients. In principle, healthy grass can generally be maintained without using fertilizers because runoff from lawns and other areas contains the needed nutrients. If an application of lime or fertilizer is deemed necessary on the basis of plant vigor and/or soil tests, it should be done only in cool spring or fall weather and only with a no phosphorus fertilizer. • Minimize use of pesticides. • Evaluate trees and shrubs along swale and remove any dead or diseased vegetation. Diseased vegetation should be treated using preventative and low-toxic measures to the extent possible. • Pruning and trimming of trees and shrubs along swale.	• As needed. • As needed. • Avoid, if possible. Use the minimum amount of biodegradable, nontoxic fertilizers and herbicides needed to maintain dense grass cover, free of weeds. • As needed. • As needed.
Debris and litter removal	Remove debris and litter from detention and surrounding area to minimize clogging of the subsoils or filter media and improve appearance of the site. It will also reduce floatables being flushed downstream.	Routine - depending on aesthetic requirements.

1. Source: The City of Calgary. *Stormwater Source Control Practices Handbook*, 2007 (page 5-40).

Required Action	Maintenance Objectives	Frequency
Spiking and scarifying	• Maintain infiltration rate of landscape layer and filter media. • Thatch is a tightly intermingled organic layer of dead and living shoots, stems and roots, developing between the zone of green vegetation and the soil surface. To improve infiltration performance, break up silt deposits. To prevent compaction of the soil surface it should be scarified with self-propelled equipment to a depth of 5 mm to relieve thatch conditions and remove dead grass or other organic matter. • Penetrate the soil surface using self-propelled spiker to penetrate panned layers to a depth of 100 mm and allow water to percolate to the more open soil below. Follow by top dressing with a medium to fine sand. Spiking is particularly effective when the soil is moist.	• Annually or bi-annually, after inlet has been cleaned in spring. • Thatch removal should be carried out in conditions that are dry and free from frost.
Filter media removal and replacement	• The subsoil or filter media layers will clog with time. This layer will need to be removed and replaced, along with all turf and other vegetation (if needed) growing on the surface, to rehabilitate infiltration rates. • Filter media replacement might also be necessary when levels of pollutants reach toxic levels which impair plant growth and the effectiveness of the source control practice. • Replace filter media if cation exchange capacity is significantly reduced.	• Every 5 to 10 years, depending on infiltration rates needed to drain the Water Quality Control Volume in 12 hours or less. Might need to do it more frequently when no sub-drain system is in place and if exfiltration rates are too low to achieve this goal. • As needed. • As needed.
Inspections	• Inspect swale to ensure grass cover is establishing well. If not, reseed or plant an alternative species. • Inspect dry swale or bioswale to determine if the filter media is allowing acceptable infiltration. • Inspect the grass for uniformity of cover, sediment accumulation in the swale, and near culverts. Repair eroded areas (e.g., rills and gullies). • Inspect underdrain and culverts or overflow structures, if present. Clean out underdrain, if required - this might involve replacement of filter media and geofabrics as well.	• Several times during the first few months. • Routine - bi-annual inspection of hydraulic performance, preferably after severe storm event. • Spring and fall. Additional inspection after periods of heavy rainfall is most desirable to check for rills, gullies or water logging. • Annual.

Table J-2: Typical Maintenance Activities for Absorbent Landscape[2]

Required Action	Maintenance Objectives	Frequency
Watering	Irrigation might be required to promote successful germination, establishment and survival of vegetation.	• As necessary during first growing season. • Seeded areas and/or turf sod must be kept consistently and evenly moist for the first three weeks after planting or being put down. • Water, as necessary and depending on amount of hard area draining to absorbent landscape, during dry periods after first growing season. Mulch aids in retaining soil moisture. • When watering, encourage deep-rooting by watering seldom but thoroughly. Grass needs only one inch water per week, or a one hour sprinkling during a week without rainfall. • After establishment, turf sod need not be watered during dry periods. It can be left to go dormant. Gradually stop watering in midsummer, allowing grass to yellow. During severe drought, water dormant grass 1/4 inch to 1/2 inch every two or three weeks to prevent dehydration.
Mowing	• Occasional mowing of grasses and weed removal to limit unwanted vegetation. Maintain irrigated turf grass as 50 to 100 mm (2 to 4 inches) tall and non-irrigated native turf grasses at 100 mm to 150 mm (4 to 6 inches). • Mowing and other maintenance equipment should not damage or excessively consolidate the surface! • Keep mower blades sharp to avoid shredding leaf tissues. • Grass clippings should be left on the lawn where they help retain moisture and provide nutrients or, if too long for this, composted. • Sweep clippings that blow onto pavement.	• Routine - Depending on aesthetic requirements. • Areas seeded in nonnative grasses should be mowed once or twice a year to prevent establishment of woody plants, if not desirable. • Native grass seedings should be mowed two to three times the first year at a height of 150 mm to reduce competition from annual weeds. They should be mowed once the second year, and mowed every other year thereafter. • As needed. • Immediately.
Vegetative Care	• Evaluate trees and shrubs and remove any dead or diseased vegetation. Diseased vegetation should be treated using preventative and low-toxic measures to the extent possible. • Pruning and trimming of trees and shrubs.[3] • Returf using turf of a quality and appearance to match existing turf, or reseed using seed to match existing tuff in appearance and quality. Supply and fix fully biodegradable coir blanket as supplier's instructions to protect seeded soil. Allow to top-dress with fine-sieved soil matching original landscaping layer to achieve final design levels. • Weeding and removal of invasive species. • Dividing and replanting of plants. • Take advantage of any community curbside collection programs. • Individual composting offers a place for debris and results in an excellent source of mulch.	• As needed. • As needed. • As needed. • As needed. • As needed in spring or fall, when plants become overcrowded. • As needed.

2. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 6-37).

Required Action	Maintenance Objectives	Frequency
Fertilization	• For lawns, use no-phosphorus lawn fertilizer. • If fertilizer is spilled on driveway or sidewalk, sweep it up promptly. • Substitute slow-release organic fertilizers for inorganic products.	• Turf sod will likely need to be fertilized once yearly. Apply lawn fertilizer only in cool weather, preferably in fall. • Avoid fertilizer application immediately before rainfall.
Herbicide and Pesticide Use	• In gardens and shrub plantings, apply compost or mulch to reduce weeds and supply nutrients. • Use pesticide alternatives, such as insecticidal soap or natural bacteria. • On lawns, pull weeds by hand when feasible or spot treat with broadleaf herbicide.	It is best to apply broadleaf herbicides in fall.
Debris and litter removal	• Remove debris and litter from the absorbent landscape to minimize clogging of the soils and improve appearance of the site. • Avoid sweeping debris into gutters, where it is easily carried into stormwater systems.	Routine - depending on aesthetic requirements.
Cleaning and inlet	Remove sediment at inlet to absorbent landscaping.	Each spring, after street cleaning has been completed.
Spiking and scarifying	• Maintain infiltration rate of landscape layer and filter media. • Thatch is a tightly intermingled organic layer of dead and living shoots, stems and roots, developing between the zone of green vegetation and the soil surface. To improve infiltration performance, break up silt deposits. To prevent compaction of the soil surface it should be scarified with self-propelled equipment to a depth of 5 mm to relieve thatch conditions and remove dead grass or other organic matter. • Penetrate the soil surface using self-propelled spiker to penetrate panned layers to a depth of 100 mm and allow water to percolate to the more open soil below. Follow by top dressing with a medium to fine sand. Spiking is particularly effective when the soil is moist.	• Annually or bi-annually, after inlet has been cleaned in spring. • Thatch removal should be carried out in conditions that are dry and free from frost.
Remove and/or replace mulch layer	• Where organic mulch is used for metal removal, replace mulch in spring. Remove and dispose off old mulch. • Spot mulch random void areas. • Add additional mulch.	• Annually or bi-annually, after inlet has been cleaned in spring. • As needed. • Once per year, or when erosion is evident, or when the site begins to look unattractive.
Inspections	• Inspect absorbent landscape to determine if the soils are allowing acceptable infiltration. • Inspect and repair eroded areas. • Inspect overflow structures, if present.	• Routine - bi-annual inspection of hydraulic. performance, preferably after severe storm event. • Spring and fall. Additional inspection after periods of heavy rainfall is most desirable to check for rills or water logging. • Annual.

3. Prince George's County (2002) suggests leaving ornamental grasses and perennial seed heads standing to provide winter interest, wildlife forage, and homes for beneficial insects. Plants should not be cut back until spring when new growth commences, and even then it is only done for neatness, it does not impact growth. Plants may be pinched, pruned, sheared or dead-headed during the growing season to encourage more flowering, a bushier plant, or a fresh set of leaves.

Table J-3: Typical Maintenance Activities for Bioretention Areas[4]

Required Action	Maintenance Objectives	Frequency
Watering	Irrigation might be required to promote successful germination, establishment and survival of vegetation.	As necessary during first growing season. Water, as necessary, during dry periods after first growing season.
Mowing	• Occasional mowing of grasses and weed removal to limit unwanted vegetation. Maintain irrigated turf grass as 50 to 100 mm (2 to 4 inches) tall and non-irrigated native turf grasses at 100 mm to 150 mm (4 to 6 inches). • Mowed grass should not be below the design water quality event level. • Mowing and other maintenance equipment should not damage or excessively consolidate the surface!	Routine - Depending on aesthetic requirements.
Vegetative Care	• Evaluate trees and shrubs and remove any dead or diseased vegetation. Diseased vegetation should be treated using preventative and low-toxic measures to the extent possible. • Pruning and trimming of trees and shrubs.[5] • Returf using turf of a quality and appearance to match existing turf, or reseed using seed to match existing tuff in appearance and quality. Supply and fix fully biodegradable coir blanket as supplier's instructions to protect seeded soil. Allow to top-dress with fine-sieved soil matching original landscaping layer to achieve final design levels. • Weeding and removal of invasive species. • Dividing and replanting of plants.	• As needed. • As needed. • As needed. • As needed. • As needed in spring or fall, when plants become overcrowded.
Debris and litter removal	Remove debris and litter from detention and surrounding area to minimize clogging of the filter media and improve appearance of the site.	Routine - depending on aesthetic requirements.
Cleaning of inlet	Remove sediment at inlet to bioretention area	Each spring, after street cleaning has been completed.
Spiking and scarifying	• Maintain infiltration rate of landscape layer and filter media. • Thatch is a tightly intermingled organic layer of dead and living shoots, stems and roots, developing between the zone of green vegetation and the soil surface. To improve infiltration performance, break up silt deposits. To prevent compaction of the soil surface it should be scarified with self-propelled equipment to a depth of 5 mm to relieve thatch conditions and remove dead grass or other organic matter. • Penetrate the soil surface using self-propelled spiker to penetrate panned layers to a depth of 100 mm and allow water to percolate to the more open soil below. Follow by top dressing with a medium to fine sand. Spiking is particularly effective when the soil is moist.	• Annually or bi-annually, after inlet has been cleaned in spring. • Thatch removal should be carried out in conditions that are dry and free from frost.

4. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 7-37).

Remove and/or replace mulch layer	• Where organic mulch is used for metal removal, replace mulch in spring. Remove and dispose off old mulch. • Spot mulch random void areas • Add additional mulch	• Annually or bi-annually, after inlet has been cleaned in spring. • As needed. • Once per year, or when erosion is evident, or when the site begins to look unattractive.
Filter media removal and replacement	• The filter media and landscaping layer will clog with time. This layer will need to be removed and replaced, along with all turf and other vegetation (if needed) growing on the surface, to rehabilitate infiltration rates. • Filter media replacement might also be necessary when levels of pollutants reach toxic levels which impair plant growth and the effectiveness of the source control practice. • Replace filter media if cation exchange capacity is significantly reduced.	Every 5 to 10 years, depending on infiltration rates needed to drain the Water Quality Control Volume in 12 hours or less. Might need to do it more frequently when no sub-drain system is in place and if exfiltration rates are too low to achieve this goal. • As needed • As needed
Inspections	• Inspect detention area to determine if the filter media is allowing acceptable infiltration. • Inspect and repair eroded areas. • Inspect underdrain and overflow structures, if present. Clean out underdrain, if required - this might involve replacement of filter media and geofabrics as well.	• Routine - bi-annual inspection of hydraulic performance, preferably after severe storm event. • Spring and fall. Additional inspection after periods of heavy rainfall is most desirable to check for rills or water logging. • Annual.

5. Prince George's County (2002) suggests leaving ornamental grasses and perennial seed heads standing to provide winter interest, wildlife forage, and homes for beneficial insects. Plants should not be cut back until spring when new growth commences, and even then it is only done for neatness, it does not impact growth. Plants could be pinched, pruned, sheared or dead-headed during the growing season to encourage more flowering, a bushier plant, or a fresh set of leaves.

Table J-4: Typical Maintenance Activities for all Porous Pavement Types[6]

Required Action	Maintenance Objectives	Frequency
Post-construction erosion and sediment control	• Amend exposed soil with compost and mulch, plant exposed areas as soon as possible, armour areas where flows are concentrated. • Surrounding landscaped areas should be inspected regularly and possible sediment sources controlled immediately.	As needed.
Surface cleaning	Clean permeable paving surfaces to maintain infiltration capacity once or twice annually following maintenance recommendations under the specific section for each paving type.	Once or twice annually.
Debris and litter removal	Accumulated material should be removed from pavement and surrounding areas as a source control measure.	As needed.
Maintain adjacent planted areas	Planted areas adjacent to permeable pavement should be well maintained to prevent soil washout onto the pavement. If any washout does occur it should be cleaned off the pavement immediately to prevent further clogging of the pores. Furthermore, if any bare spots or eroded areas are observed within the planted areas, they should be replanted and/or stabilized at once.	Twice annually.
Winter maintenance	• Do not overuse abrasives such as sand or cinders on or adjacent to permeable pavement. • Salt is acceptable for use as a deicer on the permeable pavements, though non-toxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable. Salt will allow surface layer to drain reducing possibility of icing up of this layer.	As needed.
Replacing utility cuts	Utility cuts should be backfilled with the same aggregate base used under the permeable paving to allow continued conveyance of stormwater through the base, and to prevent migration of fines from the standard base aggregate to the more open graded permeable base material.	As needed.
Inspection	Inspect for accumulation of fine sediments or poor infiltration.	Routine and during a storm event to ensure that water is not bypassing these surfaces or taking too long to drain out.

6. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 8-70).

Table J-5: Maintenance Considerations for Permeable Asphalt and Permeable Concrete[7]

Required Action	Maintenance Objectives	Frequency
Surface cleaning	Clean surfaces using suction, sweeping with suction or high-pressure wash and suction (sweeping alone is minimally effective for permeable asphalt and concrete).	Once or twice annually.
Repair utility cuts	Small utility cuts can be repaired with conventional asphalt or concrete if small batches of permeable material are not available or are too expensive.	As needed.
Repair damaged areas	Small damaged areas can be patched with permeable or standard asphalt. Larger areas should be patched with an approved permeable asphalt. Under no circumstance is the pavement surface to ever be seal coated!	As needed.

Table J-6: Maintenance Considerations for Permeable Unit Pavers[8]

Required Action	Maintenance Objectives	Frequency
Surface cleaning	Washing with water should not be used to remove debris and sediment in the openings between the pavers. Sweeping with suction can be applied to paver openings when surface and debris are dry. Vacuum settings might have to be adjusted to prevent excess uptake of aggregate from paver openings or joints (Smith, 2000). Joints might have to be refilled with appropriate aggregate.	Once or twice annually.
Remove surface debris and sediment	Accumulated material should be removed as a source control measure.	As needed.
Replace pavers for utility work	Pavers can be removed individually and replaced when utility work is complete. Geotextile (ensuring appropriate 0.30 m overlap) and sand bedding course will need to be replaced as well.	As needed.
Replace broken pavers	Replace broken pavers as necessary to prevent structural instability in the surface.	As needed.
Snowplowing	The structure of the top edge of the paver blocks reduces chipping from snowplows. For additional protection, skids on the corner of plow blades are recommended. Blade might have to be slightly raised to prevent blocks from being picked up.	As needed.

7. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 8-71).
8. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 8-71).

Table J-7: Typical Maintenance Activities for Rainwater Harvesting Systems[9]

Required Action	Maintenance Objectives	Frequency
Debris removal	Debris should be removed from the roof as it accumulates	As needed.
Clean gutters	Gutters should be cleaned as necessary, especially in fall after leaves have dropped and in mid to late-spring to flush the pollen deposits from surrounding trees	As needed.
Maintain screens	Screens at the top of the down spout should be maintained in good condition.	As needed.
Clean pre-filters	Pre-filters should be cleaned, and debris removed	Monthly.
Change filters	Filters should be changed when they become clogged or when a pressure drop is noticed	Every six months.
UV unit maintenance	UV units should be cleaned and the bulb should be replaced according to manufacturer's recommendations.	As needed.
Chlorinate storage tanks	Storage tanks should be chlorinated quarterly to 0.20 ppm to 0.50 ppm at a rate of 60 mL (¼ cup) of household bleach (5.25% solution) to 3.80 m^3 (1,000 gallons) of stored water	Every three months.
Inspect/Clean storage tanks	Periodically inspect storage tanks to check for debris, and remove any accumulated debris. When storage tanks are cleaned, the inside surface should be rinsed with a chlorine solution of 240 mL (1 cup) bleach to 38 L (10 gallons) water. The carbon filter, if there is one, should be removed and all household taps flushed until chlorine odor is noticed. Chlorinated water should be left standing in the piping for 30 minutes. Replace the carbon filter and resume use of the system.	As needed.

9. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 9-32).

Table J-8: Typical Maintenance Activities for Green Roof Systems[10]

Required Action	Maintenance Objectives	Frequency
Weeding	Pull any plants taller than a foot, typically tree seedlings.	Twice annually.
Verify waterproofing	Conduct surveys of green roof to verify that the waterproofing system remains watertight below the vegetated cover.	Once annually.
Complete membrane replacement	Eventually the membrane will have to be replaced. Depending on roof size, building height, type of planting, and depth of growing medium, the system will either be removed and reinstalled over the new membrane, or replaced entirely. If the green roof can be removed and stored on the roof while the membrane is being replaced in sections, then additional cost is "labour" only, and comparable to original installation cost; if green roof has to be moved off the roof, and then brought back up, costs will increase accordingly, and the arguments for starting fresh, with new growing medium and plants, become more convincing.	Every 30-50 years.
Regular overall inspections	All facility components, including structural components, waterproofing, drainage layers, soil substrate, vegetation, and drains should be inspected for proper operation throughout the life of the roof garden.	• Twice annually (extensive systems). • Four times annually (intensive systems).
Drainage maintenance	• Clear the pipe inlet of soil substrate, vegetation or other debris that could obstruct free drainage of the pipe. Sources of sediment or debris should be identified and corrected. • Inspect drain pipe inlet for cracks, settling and proper alignment, and correct and re-compact soils or fill material surrounding pipe if necessary.	As needed.
Replanting	During regularly scheduled inspections and maintenance, bare areas should be filled in with designer recommended plant species to maintain the required plant coverage.	As needed.
Removal of dead/nuisance plants	• Normally, dead plant material will be recycled (i.e., composted) on the roof; however specific plants or aesthetic considerations might warrant removing and replacing dead material (following designer's recommendations). • Invasive or nuisance plants should be removed regularly and not allowed to accumulate and exclude planted species.	As needed.
Fertilization (Intensive systems only)	While extensive systems should not require fertilizing, intensive systems should be fertilized at regular intervals.	Follow manufacturer and designer recommendations.

10. Source: The City of Calgary. *Stormwater Source Control Practices Handbook,* 2007 (page 10-42).

Required Action	Maintenance Objectives	Frequency
Watering/ irrigation	• Surface irrigation systems on extensive roof gardens can promote weed establishment and root development near the drier surface layer of the soil substrate, and increase plant dependence on irrigation. Accordingly, subsurface irrigation methods are preferred. If surface irrigation is the only method available, use drip irrigation to deliver water to the base of the plant. • Extensive roof gardens should be watered only when absolutely necessary for plant survival. When watering is necessary (i.e., during early plant establishment and drought periods), provide water based on (recorded) soil moisture within the growing medium. Do not saturate growing medium so that water retention capacity is not jeopardized.	• As needed (extensive systems) • As recommended by designer and installer (intensive systems)

APPENDIX K:
Calgary Design Storm Tables

Table K-1: Calgary 1-Hour Design Storm

Time (min)	Intensity (mm/hr) for Return Period								
	2	5	10	25	50	100	200	500	1000
0	5.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	5.589	7.622	8.972	10.716	12.024	13.283	17.012	19.293	20.945
10	7.955	10.866	12.807	15.283	17.168	18.961	26.367	30.021	32.689
15	16.695	23.029	27.274	32.555	36.673	40.516	62.055	70.930	77.487
20	58.763	87.477	106.693	132.056	150.050	168.138	188.467	214.112	233.236
25	22.201	30.772	36.520	43.630	49.196	54.372	84.106	96.165	105.099
30	13.232	18.142	21.432	25.552	28.750	31.748	48.307	55.207	60.288
35	9.731	13.306	15.694	18.719	21.040	23.236	33.654	38.386	41.854
40	7.831	10.695	12.604	15.041	16.895	18.660	25.829	29.402	32.010
45	6.624	9.040	10.647	12.711	14.271	15.763	21.000	23.862	25.943
50	5.782	7.887	9.284	11.088	12.444	13.746	17.735	20.119	21.849
55	5.158	7.032	8.275	9.885	11.090	12.251	15.383	17.427	18.905
60	4.675	6.371	7.493	8.953	10.041	11.093	13.609	15.398	16.690

Table K-2: Calgary 24-Hour Design Storm

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0	5	0.481	0.642	0.747	0.890	0.992	1.094	0.926	1.025	1.093
10	0	10	0.485	0.648	0.753	0.898	1.001	1.103	0.934	1.035	1.104
15	0	15	0.489	0.653	0.760	0.906	1.009	1.113	0.943	1.045	1.114
20	0	20	0.493	0.659	0.766	0.914	1.018	1.122	0.953	1.055	1.125
25	0	25	0.497	0.665	0.773	0.922	1.027	1.132	0.962	1.065	1.136
30	0	30	0.501	0.670	0.780	0.930	1.036	1.143	0.971	1.076	1.148
35	0	35	0.506	0.676	0.787	0.938	1.045	1.153	0.981	1.087	1.159
40	0	40	0.510	0.682	0.794	0.947	1.055	1.163	0.991	1.098	1.171
45	0	45	0.515	0.689	0.801	0.955	1.065	1.174	1.002	1.109	1.183
50	0	50	0.520	0.695	0.809	0.964	1.075	1.185	1.012	1.121	1.196
55	0	55	0.525	0.702	0.817	0.974	1.085	1.197	1.023	1.133	1.209
60	1	0	0.530	0.708	0.824	0.983	1.096	1.208	1.034	1.145	1.222
65	1	5	0.535	0.715	0.832	0.992	1.106	1.220	1.045	1.158	1.235
70	1	10	0.540	0.722	0.841	1.002	1.117	1.232	1.057	1.171	1.249
75	1	15	0.545	0.729	0.849	1.012	1.128	1.245	1.068	1.184	1.263
80	1	20	0.551	0.737	0.858	1.023	1.140	1.257	1.081	1.197	1.278
85	1	25	0.556	0.744	0.867	1.033	1.152	1.270	1.093	1.211	1.293
90	1	30	0.562	0.752	0.876	1.044	1.164	1.284	1.106	1.226	1.308
95	1	35	0.568	0.760	0.885	1.055	1.176	1.297	1.119	1.240	1.324
100	1	40	0.574	0.768	0.894	1.067	1.189	1.311	1.133	1.255	1.340
105	1	45	0.580	0.777	0.904	1.078	1.202	1.326	1.146	1.271	1.357
110	1	50	0.586	0.785	0.914	1.090	1.216	1.341	1.161	1.287	1.374
115	1	55	0.593	0.794	0.925	1.103	1.229	1.356	1.175	1.303	1.391
120	2	0	0.599	0.803	0.935	1.115	1.243	1.372	1.191	1.320	1.410
125	2	5	0.606	0.812	0.946	1.128	1.258	1.388	1.206	1.337	1.428
130	2	10	0.613	0.822	0.957	1.142	1.273	1.404	1.222	1.355	1.447
135	2	15	0.621	0.832	0.969	1.156	1.288	1.421	1.239	1.374	1.467

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
140	2	20	0.628	0.842	0.981	1.170	1.304	1.439	1.256	1.393	1.488
145	2	25	0.636	0.852	0.993	1.184	1.321	1.457	1.274	1.413	1.509
150	2	30	0.644	0.863	1.006	1.199	1.338	1.476	1.292	1.433	1.531
155	2	35	0.652	0.874	1.019	1.215	1.355	1.495	1.311	1.454	1.553
160	2	40	0.661	0.886	1.032	1.231	1.373	1.515	1.330	1.476	1.576
165	2	45	0.669	0.898	1.046	1.248	1.392	1.535	1.350	1.498	1.600
170	2	50	0.678	0.910	1.060	1.265	1.411	1.556	1.371	1.521	1.625
175	2	55	0.688	0.922	1.075	1.282	1.430	1.578	1.392	1.545	1.651
180	3	0	0.697	0.935	1.090	1.301	1.451	1.601	1.415	1.570	1.678
185	3	5	0.707	0.949	1.106	1.320	1.472	1.624	1.438	1.596	1.706
190	3	10	0.718	0.963	1.123	1.339	1.494	1.648	1.462	1.623	1.735
195	3	15	0.728	0.978	1.140	1.360	1.517	1.674	1.487	1.651	1.765
200	3	20	0.739	0.993	1.157	1.381	1.540	1.700	1.513	1.680	1.796
205	3	25	0.751	1.008	1.176	1.403	1.565	1.727	1.540	1.710	1.828
210	3	30	0.763	1.024	1.195	1.426	1.591	1.755	1.568	1.742	1.862
215	3	35	0.775	1.041	1.214	1.449	1.617	1.784	1.598	1.775	1.898
220	3	40	0.788	1.059	1.235	1.474	1.645	1.815	1.628	1.809	1.934
225	3	45	0.802	1.077	1.257	1.500	1.673	1.846	1.660	1.845	1.973
230	3	50	0.816	1.096	1.279	1.526	1.703	1.880	1.694	1.882	2.013
235	3	55	0.831	1.116	1.302	1.554	1.735	1.914	1.729	1.922	2.055
240	4	0	0.846	1.137	1.327	1.584	1.767	1.950	1.766	1.963	2.100
245	4	5	0.862	1.159	1.352	1.614	1.802	1.988	1.804	2.006	2.146
250	4	10	0.879	1.182	1.379	1.646	1.838	2.028	1.845	2.051	2.195
255	4	15	0.896	1.206	1.407	1.680	1.875	2.070	1.888	2.099	2.246
260	4	20	0.915	1.231	1.437	1.715	1.915	2.113	1.933	2.150	2.301
265	4	25	0.934	1.258	1.468	1.753	1.957	2.159	1.980	2.203	2.358
270	4	30	0.955	1.286	1.501	1.792	2.001	2.208	2.031	2.259	2.419
275	4	35	0.977	1.315	1.536	1.833	2.047	2.259	2.084	2.319	2.483
280	4	40	1.000	1.346	1.572	1.877	2.096	2.313	2.141	2.383	2.551
285	4	45	1.024	1.379	1.611	1.924	2.148	2.371	2.201	2.450	2.624
290	4	50	1.050	1.414	1.652	1.973	2.203	2.432	2.265	2.522	2.702
295	4	55	1.077	1.452	1.696	2.025	2.262	2.497	2.334	2.599	2.784
300	5	0	1.106	1.492	1.743	2.081	2.325	2.566	2.408	2.682	2.873
305	5	5	1.138	1.534	1.793	2.141	2.392	2.640	2.487	2.771	2.969
310	5	10	1.171	1.580	1.847	2.205	2.464	2.719	2.572	2.866	3.072
315	5	15	1.207	1.629	1.904	2.274	2.541	2.805	2.664	2.970	3.184
320	5	20	1.246	1.682	1.966	2.349	2.624	2.897	2.764	3.082	3.305
325	5	25	1.288	1.739	2.034	2.429	2.715	2.997	2.873	3.205	3.437
330	5	30	1.334	1.801	2.107	2.517	2.813	3.105	2.993	3.339	3.582
335	5	35	1.384	1.869	2.187	2.613	2.920	3.224	3.124	3.486	3.741
340	5	40	1.438	1.944	2.275	2.717	3.037	3.354	3.269	3.650	3.917
345	5	45	1.499	2.026	2.371	2.833	3.167	3.497	3.430	3.831	4.113
350	5	50	1.565	2.117	2.478	2.961	3.311	3.656	3.611	4.034	4.332
355	5	55	1.640	2.219	2.598	3.104	3.471	3.833	3.814	4.263	4.580
360	6	0	1.724	2.333	2.733	3.266	3.652	4.033	4.045	4.524	4.862
365	6	5	1.819	2.463	2.885	3.448	3.857	4.259	4.311	4.824	5.186
370	6	10	1.928	2.612	3.061	3.658	4.092	4.519	4.619	5.172	5.563
375	6	15	2.054	2.785	3.264	3.901	4.365	4.821	4.983	5.583	6.007
380	6	20	2.203	2.988	3.503	4.187	4.686	5.176	5.417	6.074	6.540
385	6	25	2.380	3.231	3.790	4.530	5.071	5.601	5.947	6.674	7.190
390	6	30	2.598	3.528	4.140	4.949	5.541	6.120	6.609	7.424	8.004
395	6	35	2.871	3.901	4.580	5.475	6.132	6.773	7.462	8.392	9.056
400	6	40	3.226	4.387	5.153	6.160	6.901	7.624	8.606	9.692	10.469
405	6	45	3.711	5.051	5.936	7.095	7.952	8.785	10.225	11.536	12.477
410	6	50	4.422	6.025	7.085	8.466	9.494	10.488	12.707	14.367	15.565

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
415	6	55	5.589	7.622	8.972	10.716	12.024	13.283	17.012	19.293	20.945
420	7	0	7.955	10.866	12.807	15.283	17.168	18.961	26.367	30.021	32.689
425	7	5	16.695	23.029	27.274	32.555	36.673	40.516	62.055	70.930	77.487
430	7	10	58.763	87.477	106.693	132.056	150.050	168.138	188.467	214.112	233.236
435	7	15	22.201	30.772	36.520	43.630	49.196	54.372	84.106	96.165	105.099
440	7	20	13.232	18.142	21.432	25.552	28.750	31.748	48.307	55.207	60.288
445	7	25	9.731	13.306	15.694	18.719	21.040	23.236	33.654	38.386	41.854
450	7	30	7.831	10.695	12.604	15.041	16.895	18.660	25.829	29.402	32.010
455	7	35	6.624	9.040	10.647	12.711	14.271	15.763	21.000	23.862	25.943
460	7	40	5.782	7.887	9.284	11.088	12.444	13.746	17.735	20.119	21.849
465	7	45	5.158	7.032	8.275	9.885	11.090	12.251	15.383	17.427	18.905
470	7	50	4.675	6.371	7.493	8.953	10.041	11.093	13.609	15.398	16.690
475	7	55	4.288	5.841	6.868	8.207	9.202	10.166	12.223	13.815	14.962
480	8	0	3.970	5.406	6.355	7.595	8.514	9.405	11.111	12.546	13.577
485	8	5	3.704	5.041	5.925	7.081	7.936	8.768	10.197	11.504	12.442
490	8	10	3.477	4.731	5.559	6.644	7.445	8.225	9.434	10.634	11.494
495	8	15	3.281	4.463	5.242	6.266	7.021	7.756	8.785	9.896	10.691
500	8	20	3.110	4.229	4.966	5.936	6.650	7.346	8.227	9.262	10.001
505	8	25	2.959	4.023	4.723	5.646	6.323	6.985	7.742	8.710	9.401
510	8	30	2.825	3.839	4.506	5.387	6.033	6.664	7.316	8.227	8.876
515	8	35	2.705	3.674	4.312	5.155	5.772	6.376	6.939	7.799	8.411
520	8	40	2.596	3.526	4.137	4.945	5.537	6.116	6.603	7.417	7.996
525	8	45	2.497	3.391	3.978	4.755	5.323	5.880	6.301	7.075	7.625
530	8	50	2.407	3.268	3.833	4.582	5.129	5.665	6.028	6.765	7.289
535	8	55	2.325	3.155	3.700	4.423	4.950	5.468	5.780	6.485	6.985
540	9	0	2.249	3.051	3.578	4.277	4.786	5.287	5.554	6.229	6.707
545	9	5	2.179	2.955	3.465	4.141	4.635	5.119	5.347	5.994	6.453
550	9	10	2.114	2.866	3.360	4.016	4.494	4.964	5.156	5.779	6.220
555	9	15	2.053	2.783	3.263	3.900	4.363	4.819	4.980	5.580	6.004
560	9	20	1.997	2.706	3.172	3.791	4.241	4.684	4.817	5.396	5.805
565	9	25	1.944	2.634	3.087	3.689	4.127	4.558	4.666	5.224	5.619
570	9	30	1.894	2.566	3.007	3.594	4.020	4.440	4.525	5.065	5.447
575	9	35	1.848	2.503	2.932	3.504	3.920	4.329	4.393	4.916	5.286
580	9	40	1.804	2.443	2.862	3.420	3.825	4.224	4.269	4.777	5.135
585	9	45	1.763	2.386	2.795	3.340	3.736	4.125	4.153	4.646	4.993
590	9	50	1.723	2.333	2.732	3.265	3.651	4.032	4.044	4.523	4.860
595	9	55	1.686	2.282	2.672	3.193	3.571	3.943	3.941	4.407	4.735
600	10	0	1.651	2.234	2.616	3.126	3.495	3.859	3.844	4.297	4.617
605	10	5	1.617	2.188	2.562	3.061	3.423	3.780	3.752	4.194	4.505
610	10	10	1.586	2.145	2.511	3.000	3.354	3.704	3.665	4.096	4.399
615	10	15	1.555	2.103	2.462	2.942	3.289	3.631	3.583	4.003	4.298
620	10	20	1.526	2.064	2.415	2.886	3.226	3.562	3.504	3.914	4.203
625	10	25	1.498	2.026	2.371	2.833	3.167	3.496	3.430	3.830	4.112
630	10	30	1.472	1.990	2.328	2.782	3.109	3.433	3.358	3.750	4.026
635	10	35	1.446	1.955	2.287	2.733	3.055	3.373	3.290	3.674	3.943
640	10	40	1.422	1.922	2.248	2.686	3.002	3.315	3.225	3.601	3.864
645	10	45	1.399	1.890	2.211	2.641	2.952	3.259	3.163	3.531	3.789
650	10	50	1.376	1.859	2.175	2.598	2.904	3.206	3.104	3.464	3.717
655	10	55	1.355	1.830	2.140	2.557	2.857	3.154	3.047	3.400	3.648
660	11	0	1.334	1.801	2.107	2.517	2.812	3.105	2.992	3.338	3.581
665	11	5	1.314	1.774	2.075	2.478	2.769	3.057	2.940	3.279	3.518
670	11	10	1.294	1.747	2.044	2.441	2.728	3.011	2.889	3.223	3.457
675	11	15	1.276	1.722	2.014	2.405	2.688	2.967	2.841	3.168	3.398
680	11	20	1.258	1.698	1.985	2.371	2.649	2.924	2.794	3.116	3.341
685	11	25	1.240	1.674	1.957	2.338	2.612	2.883	2.749	3.065	3.287
690	11	30	1.223	1.651	1.930	2.305	2.576	2.843	2.706	3.017	3.234
695	11	35	1.207	1.629	1.904	2.274	2.541	2.805	2.664	2.970	3.183

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
700	11	40	1.191	1.607	1.879	2.244	2.507	2.767	2.624	2.924	3.135
705	11	45	1.176	1.586	1.854	2.215	2.474	2.731	2.585	2.880	3.087
710	11	50	1.161	1.566	1.831	2.186	2.442	2.696	2.547	2.838	3.042
715	11	55	1.147	1.547	1.808	2.159	2.412	2.662	2.510	2.797	2.997
720	12	0	1.133	1.528	1.785	2.132	2.382	2.629	2.475	2.757	2.955
725	12	5	1.120	1.509	1.764	2.106	2.353	2.597	2.441	2.719	2.913
730	12	10	1.106	1.491	1.743	2.081	2.325	2.566	2.407	2.682	2.873
735	12	15	1.094	1.474	1.722	2.057	2.297	2.536	2.375	2.645	2.834
740	12	20	1.081	1.457	1.703	2.033	2.271	2.506	2.344	2.610	2.797
745	12	25	1.069	1.441	1.683	2.010	2.245	2.478	2.314	2.576	2.760
750	12	30	1.057	1.425	1.664	1.987	2.220	2.450	2.284	2.543	2.724
755	12	35	1.046	1.409	1.646	1.966	2.195	2.423	2.256	2.511	2.690
760	12	40	1.035	1.394	1.628	1.944	2.171	2.396	2.228	2.480	2.656
765	12	45	1.024	1.379	1.611	1.924	2.148	2.371	2.201	2.450	2.624
770	12	50	1.013	1.365	1.594	1.903	2.125	2.346	2.175	2.420	2.592
775	12	55	1.003	1.351	1.578	1.884	2.103	2.321	2.149	2.392	2.561
780	13	0	0.993	1.337	1.561	1.864	2.082	2.297	2.124	2.364	2.531
785	13	5	0.983	1.324	1.546	1.846	2.061	2.274	2.100	2.337	2.502
790	13	10	0.974	1.311	1.530	1.827	2.040	2.252	2.076	2.310	2.473
795	13	15	0.964	1.298	1.516	1.809	2.020	2.229	2.053	2.284	2.446
800	13	20	0.955	1.285	1.501	1.792	2.000	2.208	2.031	2.259	2.419
805	13	25	0.946	1.273	1.487	1.775	1.981	2.187	2.009	2.235	2.392
810	13	30	0.937	1.261	1.473	1.758	1.963	2.166	1.987	2.211	2.366
815	13	35	0.929	1.250	1.459	1.742	1.944	2.146	1.966	2.187	2.341
820	13	40	0.920	1.238	1.446	1.726	1.927	2.126	1.946	2.164	2.317
825	13	45	0.912	1.227	1.433	1.710	1.909	2.107	1.926	2.142	2.293
830	13	50	0.904	1.216	1.420	1.695	1.892	2.088	1.907	2.120	2.269
835	13	55	0.896	1.206	1.407	1.680	1.875	2.069	1.888	2.099	2.246
840	14	0	0.889	1.195	1.395	1.665	1.859	2.051	1.869	2.078	2.224
845	14	5	0.881	1.185	1.383	1.651	1.843	2.034	1.851	2.058	2.202
850	14	10	0.874	1.175	1.371	1.637	1.827	2.016	1.833	2.038	2.181
855	14	15	0.867	1.165	1.360	1.623	1.812	1.999	1.816	2.019	2.160
860	14	20	0.860	1.156	1.349	1.610	1.797	1.983	1.799	2.000	2.139
865	14	25	0.853	1.146	1.338	1.597	1.782	1.966	1.782	1.981	2.119
870	14	30	0.846	1.137	1.327	1.584	1.767	1.950	1.766	1.963	2.100
875	14	35	0.839	1.128	1.316	1.571	1.753	1.935	1.750	1.945	2.080
880	14	40	0.833	1.119	1.306	1.558	1.739	1.919	1.734	1.927	2.061
885	14	45	0.826	1.111	1.296	1.546	1.726	1.904	1.719	1.910	2.043
890	14	50	0.820	1.102	1.286	1.534	1.712	1.889	1.704	1.893	2.025
895	14	55	0.814	1.094	1.276	1.522	1.699	1.875	1.689	1.877	2.007
900	15	0	0.808	1.085	1.266	1.511	1.686	1.860	1.675	1.861	1.990
905	15	5	0.802	1.077	1.257	1.500	1.673	1.846	1.660	1.845	1.973
910	15	10	0.796	1.069	1.247	1.488	1.661	1.833	1.646	1.829	1.956
915	15	15	0.790	1.061	1.238	1.477	1.649	1.819	1.633	1.814	1.940
920	15	20	0.784	1.054	1.229	1.467	1.637	1.806	1.619	1.799	1.924
925	15	25	0.779	1.046	1.220	1.456	1.625	1.793	1.606	1.784	1.908
930	15	30	0.773	1.039	1.212	1.446	1.613	1.780	1.593	1.770	1.892
935	15	35	0.768	1.032	1.203	1.436	1.602	1.767	1.581	1.756	1.877
940	15	40	0.763	1.024	1.195	1.426	1.590	1.755	1.568	1.742	1.862
945	15	45	0.758	1.017	1.186	1.416	1.579	1.743	1.556	1.728	1.848
950	15	50	0.753	1.010	1.178	1.406	1.569	1.731	1.544	1.715	1.833
955	15	55	0.748	1.004	1.170	1.396	1.558	1.719	1.532	1.702	1.819
960	16	0	0.743	0.997	1.162	1.387	1.547	1.707	1.521	1.689	1.805
965	16	5	0.738	0.990	1.155	1.378	1.537	1.696	1.509	1.676	1.791
970	16	10	0.733	0.984	1.147	1.369	1.527	1.685	1.498	1.663	1.778
975	16	15	0.728	0.977	1.140	1.360	1.517	1.673	1.487	1.651	1.765

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
980	16	20	0.724	0.971	1.132	1.351	1.507	1.663	1.476	1.639	1.752
985	16	25	0.719	0.965	1.125	1.342	1.497	1.652	1.466	1.627	1.739
990	16	30	0.715	0.959	1.118	1.334	1.488	1.641	1.455	1.615	1.726
995	16	35	0.710	0.953	1.111	1.325	1.478	1.631	1.445	1.604	1.714
1000	16	40	0.706	0.947	1.104	1.317	1.469	1.621	1.435	1.592	1.702
1005	16	45	0.701	0.941	1.097	1.309	1.460	1.611	1.425	1.581	1.690
1010	16	50	0.697	0.935	1.090	1.301	1.451	1.601	1.415	1.570	1.678
1015	16	55	0.693	0.930	1.084	1.293	1.442	1.591	1.405	1.559	1.666
1020	17	0	0.689	0.924	1.077	1.285	1.433	1.581	1.396	1.549	1.655
1025	17	5	0.685	0.919	1.071	1.277	1.425	1.572	1.386	1.538	1.644
1030	17	10	0.681	0.913	1.064	1.270	1.416	1.562	1.377	1.528	1.633
1035	17	15	0.677	0.908	1.058	1.262	1.408	1.553	1.368	1.518	1.622
1040	17	20	0.673	0.903	1.052	1.255	1.400	1.544	1.359	1.508	1.611
1045	17	25	0.669	0.898	1.046	1.248	1.391	1.535	1.350	1.498	1.600
1050	17	30	0.665	0.892	1.040	1.240	1.383	1.526	1.341	1.488	1.590
1055	17	35	0.662	0.887	1.034	1.233	1.376	1.517	1.333	1.479	1.580
1060	17	40	0.658	0.882	1.028	1.226	1.368	1.509	1.324	1.469	1.570
1065	17	45	0.654	0.877	1.022	1.220	1.360	1.500	1.316	1.460	1.560
1070	17	50	0.651	0.873	1.017	1.213	1.352	1.492	1.308	1.451	1.550
1075	17	55	0.647	0.868	1.011	1.206	1.345	1.484	1.300	1.442	1.540
1080	18	0	0.644	0.863	1.006	1.199	1.338	1.476	1.292	1.433	1.531
1085	18	5	0.640	0.858	1.000	1.193	1.330	1.467	1.284	1.424	1.521
1090	18	10	0.637	0.854	0.995	1.186	1.323	1.460	1.276	1.415	1.512
1095	18	15	0.634	0.849	0.989	1.180	1.316	1.452	1.268	1.407	1.503
1100	18	20	0.630	0.845	0.984	1.174	1.309	1.444	1.261	1.398	1.494
1105	18	25	0.627	0.840	0.979	1.168	1.302	1.436	1.253	1.390	1.485
1110	18	30	0.624	0.836	0.974	1.162	1.295	1.429	1.246	1.382	1.476
1115	18	35	0.621	0.832	0.969	1.156	1.288	1.421	1.239	1.374	1.467
1120	18	40	0.618	0.827	0.964	1.150	1.282	1.414	1.232	1.366	1.459
1125	18	45	0.614	0.823	0.959	1.144	1.275	1.407	1.225	1.358	1.450
1130	18	50	0.611	0.819	0.954	1.138	1.269	1.399	1.218	1.350	1.442
1135	18	55	0.608	0.815	0.949	1.132	1.262	1.392	1.211	1.342	1.434
1140	19	0	0.605	0.811	0.945	1.126	1.256	1.385	1.204	1.335	1.425
1145	19	5	0.602	0.807	0.940	1.121	1.250	1.378	1.197	1.327	1.417
1150	19	10	0.599	0.803	0.935	1.115	1.243	1.372	1.191	1.320	1.409
1155	19	15	0.597	0.799	0.931	1.110	1.237	1.365	1.184	1.313	1.402
1160	19	20	0.594	0.795	0.926	1.104	1.231	1.358	1.178	1.306	1.394
1165	19	25	0.591	0.791	0.922	1.099	1.225	1.352	1.171	1.298	1.386
1170	19	30	0.588	0.788	0.917	1.094	1.219	1.345	1.165	1.291	1.379
1175	19	35	0.585	0.784	0.913	1.089	1.214	1.339	1.159	1.284	1.371
1180	19	40	0.583	0.780	0.908	1.083	1.208	1.332	1.153	1.278	1.364
1185	19	45	0.580	0.777	0.904	1.078	1.202	1.326	1.146	1.271	1.357
1190	19	50	0.577	0.773	0.900	1.073	1.196	1.320	1.140	1.264	1.349
1195	19	55	0.575	0.769	0.896	1.068	1.191	1.313	1.134	1.257	1.342
1200	20	0	0.572	0.766	0.892	1.063	1.185	1.307	1.129	1.251	1.335
1205	20	5	0.569	0.762	0.888	1.058	1.180	1.301	1.123	1.244	1.328
1210	20	10	0.567	0.759	0.884	1.054	1.174	1.295	1.117	1.238	1.322
1215	20	15	0.564	0.755	0.880	1.049	1.169	1.289	1.111	1.232	1.315
1220	20	20	0.562	0.752	0.876	1.044	1.164	1.284	1.106	1.226	1.308
1225	20	25	0.559	0.749	0.872	1.039	1.159	1.278	1.100	1.219	1.302
1230	20	30	0.557	0.745	0.868	1.035	1.153	1.272	1.095	1.213	1.295
1235	20	35	0.555	0.742	0.864	1.030	1.148	1.266	1.089	1.207	1.289
1240	20	40	0.552	0.739	0.860	1.026	1.143	1.261	1.084	1.201	1.282
1245	20	45	0.550	0.736	0.856	1.021	1.138	1.255	1.079	1.195	1.276
1250	20	50	0.547	0.733	0.853	1.017	1.133	1.250	1.074	1.190	1.270
1255	20	55	0.545	0.729	0.849	1.012	1.128	1.244	1.068	1.184	1.263

Time (min)	Hours	Minutes	Intensity (mm/hr) for Return Period								
			2	5	10	25	50	100	200	500	1000
1260	21	0	0.543	0.726	0.845	1.008	1.124	1.239	1.063	1.178	1.257
1265	21	5	0.541	0.723	0.842	1.004	1.119	1.234	1.058	1.172	1.251
1270	21	10	0.538	0.720	0.838	0.999	1.114	1.229	1.053	1.167	1.245
1275	21	15	0.536	0.717	0.835	0.995	1.109	1.223	1.048	1.161	1.239
1280	21	20	0.534	0.714	0.831	0.991	1.105	1.218	1.043	1.156	1.233
1285	21	25	0.532	0.711	0.828	0.987	1.100	1.213	1.038	1.150	1.228
1290	21	30	0.530	0.708	0.824	0.983	1.096	1.208	1.034	1.145	1.222
1295	21	35	0.527	0.706	0.821	0.979	1.091	1.203	1.029	1.140	1.216
1300	21	40	0.525	0.703	0.818	0.975	1.087	1.198	1.024	1.135	1.211
1305	21	45	0.523	0.700	0.814	0.971	1.082	1.193	1.020	1.129	1.205
1310	21	50	0.521	0.697	0.811	0.967	1.078	1.188	1.015	1.124	1.200
1315	21	55	0.519	0.694	0.808	0.963	1.073	1.184	1.010	1.119	1.194
1320	22	0	0.517	0.691	0.805	0.959	1.069	1.179	1.006	1.114	1.189
1325	22	5	0.515	0.689	0.801	0.955	1.065	1.174	1.002	1.109	1.183
1330	22	10	0.513	0.686	0.798	0.952	1.061	1.170	0.997	1.104	1.178
1335	22	15	0.511	0.683	0.795	0.948	1.056	1.165	0.993	1.099	1.173
1340	22	20	0.509	0.681	0.792	0.944	1.052	1.160	0.988	1.095	1.168
1345	22	25	0.507	0.678	0.789	0.941	1.048	1.156	0.984	1.090	1.163
1350	22	30	0.505	0.676	0.786	0.937	1.044	1.151	0.980	1.085	1.158
1355	22	35	0.503	0.673	0.783	0.933	1.040	1.147	0.976	1.080	1.153
1360	22	40	0.501	0.670	0.780	0.930	1.036	1.143	0.971	1.076	1.148
1365	22	45	0.500	0.668	0.777	0.926	1.032	1.138	0.967	1.071	1.143
1370	22	50	0.498	0.665	0.774	0.923	1.028	1.134	0.963	1.067	1.138
1375	22	55	0.496	0.663	0.771	0.919	1.024	1.130	0.959	1.062	1.133
1380	23	0	0.494	0.660	0.768	0.916	1.020	1.125	0.955	1.058	1.128
1385	23	5	0.492	0.658	0.765	0.912	1.017	1.121	0.951	1.053	1.124
1390	23	10	0.490	0.656	0.763	0.909	1.013	1.117	0.947	1.049	1.119
1395	23	15	0.489	0.653	0.760	0.906	1.009	1.113	0.943	1.045	1.114
1400	23	20	0.487	0.651	0.757	0.902	1.005	1.109	0.940	1.040	1.110
1405	23	25	0.485	0.648	0.754	0.899	1.002	1.105	0.936	1.036	1.105
1410	23	30	0.483	0.646	0.752	0.896	0.998	1.101	0.932	1.032	1.101
1415	23	35	0.482	0.644	0.749	0.892	0.995	1.097	0.928	1.028	1.096
1420	23	40	0.480	0.641	0.746	0.889	0.991	1.093	0.924	1.023	1.092
1425	23	45	0.478	0.639	0.743	0.886	0.987	1.089	0.921	1.019	1.087
1430	23	50	0.477	0.637	0.741	0.883	0.984	1.085	0.917	1.015	1.083
1435	23	55	0.475	0.635	0.738	0.880	0.980	1.081	0.914	1.011	1.079
1440	24	0	0.473	0.632	0.736	0.877	0.977	1.077	0.910	1.007	1.074

Table K-3: Environment Canada - 1-30 day Precipitation Depths for Calgary International Airport

Return Period	Number of Days													
	1	2	3	4	5	6	7	8	9	10	15	20	25	30
	Precipitation Depth (mm)													
2	40.93	48.33	52.78	57.04	60.33	63.76	67.06	71.34	73.64	76.65	91.95	103.70	114.85	126.04
5	57.98	66.56	72.65	79.31	83.58	87.51	92.38	97.87	101.16	105.02	125.89	141.42	155.36	169.66
10	69.30	78.66	85.83	94.08	99.01	103.28	109.18	115.48	119.42	123.85	148.42	166.46	182.24	198.61
25	83.57	93.92	102.46	112.71	118.47	123.16	130.37	137.68	142.44	147.60	176.83	198.03	216.13	235.12
50	94.15	105.24	114.79	126.53	132.89	137.90	146.09	154.15	159.52	165.21	197.90	221.44	241.27	262.19
100	104.68	116.49	127.06	140.27	147.24	152.56	161.72	170.52	176.50	182.73	218.85	244.72	266.27	289.12
Probable Maximum Rainfall	378.10	414.60	455.60	511.20	535.50	550.90	586.70	616.30	639.40	660.90	790.30	881.10	950.20	1026.40

Table K-4: Water Quality Design Event

Time (min)	Intensity (mm/hr)
0	0.000
5	14.540
10	47.795
15	61.507
20	30.228
25	13.974
30	6.460
35	2.986
40	1.380
45	0.638
50	0.295
55	0.136
60	0.063