SECTION 12 – STORM DRAINAGE SYSTEM

1. GENERAL

The storm sewers shall be designed as a separate system and consider both the minor and major drainage. There shall be of sufficient capacity to carry storm sewer runoff from the ultimate catchment identified in the Stormwater Drainage Master Plan or the Area Basin study if one exists. The design must also account for the interception, conveyance and storage requirements as necessary to accommodate runoff flows from undeveloped contributory areas for the indefinite future or for an interim period until development of those areas occurs.

Control shall be provided to minimize sediment discharge into the storm sewers. This shall be in the form of properly graded and surfaced streets and lanes, landscaping, sediment control structures at pond and pond inlets, or other means where appropriate.

The design of this municipal improvement shall be undertaken in such a manner as to complement with the construction specification in the City Construction Manual.

The storm system must be approved by the Municipal Engineer and Alberta Environment.

As a guideline for raw land a predevelopment flow of 5 l/s per hectare is to be used.

2. MINOR SYSTEM

2.1 COMPOSITION AND CONTROL

The minor system comprises piping, manholes, catchbasins, street gutters and outfall structures that function as a conveyance system to rapidly carry away runoff from snowmelt and rainfall events. The minor system should discharge to an adequate receiving body of water (river, stream, lake or pond) without sustaining any surface ponding, excessive surface flows, downstream erosion, or flooding for events up to and including a 1-in-5-year return period. Where required by the Municipal Engineer, high value commercial areas shall have their minor systems designed to accommodate the 1-in-10-year return period.

Detention facilities shall be designed as part of both the minor and major drainage systems. They must control the peak runoff conditions for events up to the 1-in-100-year return period.

2.2 RAINFALL INTENSITY-DURATION-FREQUENCY

The following formulas define the Intensity-Duration-Frequency Curves (IDF Curves) developed by Atmospheric Environment Services of Environment Canada for the Grande Prairie Regional Airport.

Table 12.1 IDF Formulas

2009 IDF Formulas (1968 – 1993 Data)		
Frequency	**Average Intensity (mm/hr.)**	
	(5 Minute - 2 Hour Time Interval)	**(2 – 24 Hour Time Interval)**
2 year	$352.5 (t + 5.85)^{-0.796}$	$221.4 (t + 3.34)^{-0.676}$
5 year	$519.1 (t + 6.08)^{-0.814}$	$287.5 (t + 2.92)^{-0.661}$
10 year	$616.7 (t + 5.86)^{-0.818}$	$330.1 (t + 2.59)^{-0.655}$
25 year	$733.3 (t + 5.61)^{-0.821}$	$381.5 (t + 2.26)^{-0.648}$
50 year	$820.5 (t + 5.52)^{-0.821}$	$420.9 (t + 2.12)^{-0.644}$
100 year	$904.1 (t + 5.41)^{-0.821}$ **	$460.5 (t - 2.01)^{-0.642}$

t = time (minutes)
** Use with discretion

These IDF formulas shall be used for all new storm basins. For established basins, the design flows shall be based on existing pipe capacities.

2.3 STORM CATCHMENT CALCULATIONS

The following criteria shall be used in the design of the minor storm sewer system:

2.3.1 For areas less than 65 ha:

As an option to computer modelling, the Rational Method of storm sewer system may be used.

$$Q = CiA / 360$$

Where: Q = the design peak flow rate in m^3/s

i = the intensity of rainfall in millimetres per hour corresponding to the time of concentration

A = the contributing area in hectares

C = the runoff coefficient

The five-year and the one-hundred-year rainfall intensities used shall be as calculated using the formulas in Table 12.1. Runoff coefficients shall be according to Table 12.2.

For developed areas, the weighted average of pervious and impervious area runoff coefficients shall be estimated from the following equation:

$$C = \frac{C_p A_p + C_i A_i}{A_p + A_i}$$

where the subscripts ‘p’ and ‘i’ indicate the pervious and impervious surfaces, respectively.

For planning of new areas, the minimum "C" value for various land uses are summarized in the table below.

Table 12.2 Runoff Coefficients

Land Use or Surface Characteristics	Rainfall Event Return Period		
	5 Years	10 Years	100 Years
Residential	0.40	0.40	0.60
Apartments[1]	0.70	0.70	0.80
Downtown Commercial[1]	0.85	0.90	0.90
Neighbourhood Commerical[1]	0.65	0.70	0.80
Light Industrial[2]	0.60	0.70	0.70
Lawns, Parks, Playgrounds	0.20	0.25	0.30
Undeveloped Land (Farmland)	0.10	0.15	0.20
Paved Streets	0.90	0.95	0.95
Gravel Streets	0.25	0.35	0.65

[1] Where specific land surfaces are known for Apartment and Commercial areas, the runoff coefficient may be determined based on the surface characteristics for the ultimate development conditions.

[2] Runoff coefficients for industrial land use must be estimated based on ultimate land use condition.

Note: Values are the recommended minimum for use in the Rational Method.

The duration of rainfall used to determine the intensity is equal to the time of concentration. The time of concentration is comprised of the overland time to the storm sewer inlet and the time of travel in the conduit.

The minimum time of concentration shall be:

15 minutes for large parklands, and

10 minutes for all other lands.

2.3.2 For areas greater than or equal to 65 ha:

Computer models shall be used to determine design flows and the sizing of systems which contain non-pipe stormwater management facilities (e.g. detention ponds) or systems that include a significant amount of undeveloped land.

The selection of an appropriate computer model shall be based on an understanding of the principles, assumptions, and limitations in relation to the system being designed. The City of Grande Prairie encourages the use of XP-SWMM as the preferred model. Other models may be considered on an individual case basis.

Where new developments connect to existing developments, the computer model shall be calibrated utilizing flow monitoring information. In all analyses, the parameters used, the drainage boundaries, the pipe network and its connectivity shall be clearly identified on the overall plan in the Detailed Engineering Drawings, computer printouts and a design summary report.

The design storm hyetograph shall be the four-hour Chicago distribution, see ***Table A.1.***

Design of storm water ponds shall also include the 12 hour AES (Atmospheric Environment Services), see ***Table A.2*** and the 24 hours SCS (Soil Conservation Services) design storms, see ***Table A.3***. The largest storage requirement will determine the pond size.

2.4 SITE DRAINAGE

2.4.1 Release to Storm Drainage System

No Person shall release, or allow to be released, any prohibited material into the storm drainage system. The following may be released into the Storm Drainage System:

a) foundation drainage;
b) water from a portable swimming pool, decorative pond or fountain, having a capacity of three (3) cubic meters (3000 litres) or less;
c) water from irrigating or otherwise watering a lawn, garden and trees or other landscaping; or
d) water from washing of single-family or semi-detached homes with potable water;
e) water resulting from extinguishing fires;
f) water in accordance with a permit or written approval from the Director; and

g) water in accordance with an approval pursuant to Section 12.

All discharges to the City's storm drainage system shall conform to the City's Drainage By-law C-1241 and subsequent amendments.

2.4.2 Roof Drainage

Roof drainage from residential, apartments, commercial and industrial buildings shall discharge to grassed or pervious drainage areas.

Roof drainage from apartment buildings, commercial areas, and industrial areas may discharge to a private storm sewer system that is connected to the City's storm sewer system through an approved storm service connection conforming to the City's Drainage By-law C-1241 and subsequent amendments.

2.4.3 Weeping Tile connections

Weeping tile from residential, apartments, commercial and industrial buildings shall discharge to grassed or pervious drainage areas.

Weeping tile from one family and two family dwellings may discharge to the City's storm sewer system when a storm service connection has been provided to that dwelling and the dwelling has a sump pump system in accordance with the Figure 12.1.

Weeping Tile from apartment buildings, commercial areas, and industrial areas may discharge to a private storm sewer system that is connected to the City's storm sewer system through an approved storm service connection conforming to the City's Drainage By-law C-1241 and subsequent amendments.

2.4.4 Service connections

All developments are required to provide a detailed site grading plan identifying storm drainage patterns, on-site detention, storm sewers, manholes and catchbasins. Calculations for storm sewer and detention sizing must be provided for sites with private storm sewers and detention.

For all new developments a storm sewer and storm service stubs shall be provided to each lot created for multi-family residential, commercial and industrial development.

For all new one family and two family developments a storm sewer and storm service stub shall be provided when the seasonally corrected ground water level is within 3.5m of the centerline of the road design grades.

It is at the Municipal Engineers discretion to waive this requirement.

2.4.5 Service Connection Design Criteria

The storm service stub size is to be determined based on the following, depending on the capacity of the downstream storm sewer system:

Redevelopment Areas

Where the new service is being connected to an existing main in an older area of the City, the allowable capacity for the development will be based on the following formula:

$$\text{Allowable Capacity} = \frac{\text{Development Area x Capacity of}}{\text{Upstream Catchment Area}}$$

New Development Areas

Where the new service is being connected to an existing main in a recently developed area of the City service, the allowable capacity for the development will be determined using the 1:5 year rainfall IDF curve and the appropriate run-off coefficient.

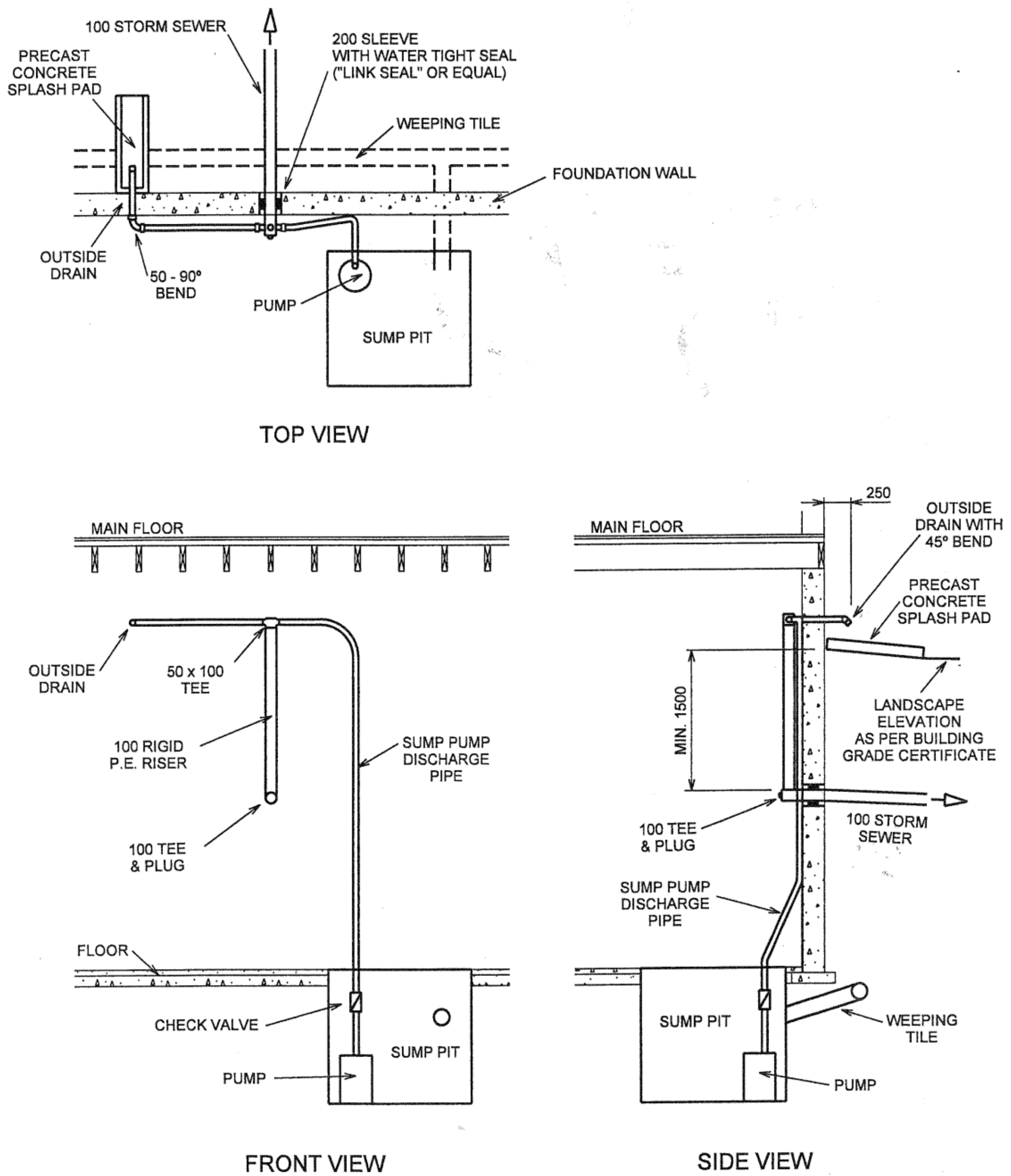
2.4.6 Service Connection Installation

Residential lots

Storm services shall be an 150mm in diameter with a 150 mm – 100 mm reducer at the property / easement line to allow for 100mm connections. The storm service shall have a plug in it and be insulated if less than 1.8 m cover.

Storm services shall be installed at the same location as the sanitary services at the property / easement line as per the typical service detail.

Figure 12.1 Residential Lot Storm Service Connections



Multi-Family Residential, Commercial and Industrial Lots

Storm services shall be based on allowable capacity for the development determined by downstream capacity.

Where the development is located in an area that does not have offsite detention facilities to provide flood control for events up to the 1:100 year storm event or downstream capacity constraints exist, the site should be designed with onsite detention to accommodate storage volumes for events up to the 1:100 year event. The maximum allowable discharge from the site shall be limited to a predevelopment flow of 5 l/s per hectare.

If a large portion of the site is landscaped or ponding volumes are not feasible due to small lot sizes than larger release rates may be permitted at the discretion of the Engineering Services Department.

Calculations for storm sewer and detention sizing must be provided for these sites. Ponding of runoff on roofs, parking lots or landscaped areas to reduce runoff rates must be approved by the Municipal Engineer.

2.5 MINIMUM PIPE SLOPES / VELOCITIES

The minimum velocity shall be 0.6 m/s. Where velocities in excess of 3 m/s are attained, special provisions shall be made to protect against displacement by erosion or impact.

Table 12.3 Pipe Minimum Slope

Pipe size	Min. Slope
200 mm	0.40%
300 mm	0.22 %
375 mm	0.15 %
450 mm	0.12 %
525 mm	0.10 %
600 mm	0.10 %

2.6 "N" VALUES

Pipe sizing shall be determined by utilizing the Manning's Formula, using an "n" value of 0.013 for concrete and plastic pipes.

2.7 HYDRAULIC GRADELINE

Storm sewer pipe shall be designed to convey the design flow when all pipes are flowing full, with the hydraulic gradeline occurring at the pipe obvert / crown.

All pipe obvert elevations must match at manhole junctions to carry the hydraulic gradient.

2.8 MAXIMUM SURFACE DRAINAGE

Surface water shall not be permitted to run a distance greater than the following, without provision for interception by the first catchbasin or catchbasin manhole, as the case may be:

Paved Lanes as measured in the center line of the lane:

- 300 metres or the intersection of the curb/gutter of a road, whichever is shorter, for longitudinal grades greater than 1 %,
- 200 metres or the intersection of the curb/gutter of a road, whichever is shorter, for longitudinal grades between 0.8% and 1 %.

Local Roads as measured in a continuous concrete gutter:

- 200 metres with longitudinal grades greater than 1%,
- 150 metres with longitudinal grades between 0.6% and 1%.

Collectors or Arterial road, as measured in a continuous concrete gutter, shall not exceed 120 metres.

On new PUL lots or parks providing overland drainage for adjacent parcels, as measured in the grass swale, the maximum distance shall be 120 metres at a minimum longitudinal grade of 0.8%. Grades <0.8% are acceptable in older subdivisions where a grade ≥0.8% cannot be established due to adjacent development restrictions (e.g. existing concrete or paved driveways, garages, etc.).

The above requirements are a maximum for straight portions of road or utility lot. When the drainage is proposed to be directed around a significant curve or bend the Municipal Engineer may request catchbasins to be placed at a closer spacing to allow for sufficient drainage interception during high runoff or spring thaw events.

In the design of drainage inlets along walkways and utility rights-of-way, the designer must consider the total area that may drain to them and space catch basins and inlets accordingly.

2.9 DRAINAGE INTERCEPTION

Surface water shall be intercepted with an adequate number of catchbasins such that the inlet capacity is sufficient to receive the design stormwater flow. In all cases an analysis of catchbasin grate capability will be required to determine if the system requires a double set of catchbasins to accommodate the volume of water carried over that distance. Catchbasin capacity shall be considered as shown in the Table below, where values are given for sag conditions and on slope conditions based upon inlet grate type.

Table 12.4 Catchbasin Capacities (L/s)

Catchbasin	Flow Condition	
	Continuous Slope	Sump Condition
F33	11	20
F36	10	23
F38, F39	20	38
F51	40	80
K2	25	45

Notes:

Capacities for F33 and F36 are based on hydraulic studies conducted by the City of Edmonton (Townsend and Moss, 1980). Continuous slope capacity based on gutter flow of 40 L/s (1.4 cfs). Sump capacity is based on 5 cm (2 in) in head.

Capacities for others are based on the work of Wilson (1983). Continuous slope capacity based on ratios for F33 and F36 tests. Sump capacity based on 65% of theoretical capacity for 5 cm (2 in) head.

Capacities can be considered to be double those shown in the table when assessing the 1-in-100-year event.

The following should be consider when choosing locations for sewer inlets

- Drainage should not pass through intersections, but rather, sufficient inlet capacity is to be provided to intercept all flow at the uphill side.
- Inlets required at sags and/or at intersections should be located at the EC or BC of the curb return.
- Where there is a continuous grade through the curb return at an intersection, stormwater catch basins and catch basin manholes shall be located at the uphill side of the curb return (BC).

- Design locations for catch basins on residential or other roadways shall be chosen to avoid conflict with driveway crossings wherever possible. Subject to roadway design, drainage locations at property lines are preferred in these instances.
- Minor runoff event flows from swales or other flow channels draining significant areas of residential development, parks, school sites, municipal reserve, public utility lots, or walkway lots shall not cross sidewalks or walkways. To avoid excessive drainage of water across walks, or ponding of water where flow is obstructed by walks, drainage inlets shall be provided at strategic locations on the upstream side of walks to intercept concentrated drainage flows. Catch basin inlets are to be installed for this purpose and shall be located a minimum of 600 mm from the edge of the walk.
- Catch basins and catch basin manholes used to intercept drainage in lanes are to be located generally at the longitudinal centre line of the lane and so as not to be within the typical wheel track area.

2.10 MINIMUM GUTTER GRADE

The minimum gutter grade shall be 0.60%, and 0.80% on curves with radii less than or equal to 20m, refer to Section 14 – Roadway Design Standards for more information.

2.11 MAIN DETAIL AND LOCATION

a) The minimum size of storm sewer mains shall be 300mm in diameter.

b) Mains installed for residential lot service connections <u>only</u> may be 200mm in diameter with a minimum grade of 0.40%.

c) Pipe classes shall be determined to withstand subsequent superimposed loading. Approved Class B sand bedding shall be used with all size pipes having water tight joints. CSP pipe is not considered as having water tight joints, and will require Class B crushed gravel bedding.

d) Various factors affecting the pipe class shall be taken into account, and pipe class shall be evaluated as per standard engineering practice, and clearly identified on the Detailed Engineering Drawings.

e) Mains shall be installed to provide a minimum cover to top of pipe of 1.80 m from the final finished surface grade.

f) Mains shall be located within the right-of-way (ROW) in accordance with Section 20, Cross Sections.

g) Storm main(s) shall be separated by a minimum horizontal distance from the water main(s) by

h) 2.50 metres measured from the center of each pipe, for pipe diameters of 300 mm or less,

i) 2.20 meters measured from outside walls of pipes, for pipe diameter greater than 300 mm.

j) At crossings, storm main(s) shall be separated by a minimum vertical distance from the water main(s) by 500 mm measured from the outside walls of the pipes.

k) At crossings, storm main(s) shall be separated by a minimum vertical distance from the sanitary main(s) by 500 mm measured from the outside walls of the pipes.

2.12 MANHOLE DETAIL AND LOCATION

Manholes shall require:

a) Safety platforms at intermediate levels greater than 6.5m in depth. All barrels and cones shall be provided with bar ladder rungs spaced at 400mm O.C.

b) Manholes shall be located at the upstream end of each line, at all changes in pipe size, grade, material and alignment. Under no circumstances will manholes be permitted in driveways or private property. Due consideration should be given to access by a flusher truck.

c) Storm sewers for weeping tile connections are to be extended 1.5 m past the last house service lead, with the exception of storm mains in cul-de-sacs where service leads may be connected directly to the end of the line manhole provided that the lead enters the manhole less than 0.60 m above the invert of the main.

d) Benching in manholes shall be provided to minimize hydraulic losses. The downstream invert in a manhole shall be a minimum of 30mm lower than the lowest upstream invert. At a change in direction, the drop shall be a least 60mm. If an influent pipe diameter is greater than 525 mm and the bend is greater than 45 degrees or if the outflow pipe velocity exceeds 1.5 m/s, then minor losses shall be considered.

e) Tee riser manholes may be utilized on lines 900 mm in diameter and larger. Tee riser manholes must be bedded in concrete to the springline of the pipe.

f) Manhole spacing on storm sewers may not exceed 120 m.

g) Manhole spacing on curved sewers shall not exceed 90 m along the curve. Manholes shall be located at the beginning and end of curve.

h) Manhole bases should be reinforced concrete poured-in place, precast slabs, vaults, or precast tees as per the City Construction Manual.

i) Where drops of 1.0 m or less occur at manholes, the designer is to ensure that free outflow and low backwater conditions will exist in the downstream sewer so that hydraulic jump formation and associated concentrated scouring effects are avoided. For drops of greater than 1.0 m, a specifically designed drop manhole may be required to address the hydraulic requirements of the change of elevation.

j) Manhole frames and covers are not to be located within a sidewalk.

2.13 CURVED SEWERS

Curved sewers will be permitted with the following restrictions:

a) Only to follow curved right-of-ways

b) The sewer shall be laid as a simple curve with a radius equal to or greater than 90 m or the manufacturer's minimum recommended radius, whichever is larger.

c) Manholes shall be located at the beginning and end of the curve.

d) Manholes shall be located at intervals not greater than 90 m along the curve.

e) The main shall run parallel to property line.

f) The minimum grade for sewers on a curve shall be 50% greater than the minimum grade required for straight runs of sewers.

2.14 CATCHBASIN LEAD DETAIL AND LOCATION

Catchbasin leads shall:

a) Be installed only into manholes or catchbasin manholes, as the case may be.

b) Catch basin leads shall be installed to maintain designed hydraulic gradient within the system, and shall be installed matching the obvert of the senior pipe.

c) Have a minimum lead size of 300mm in diameter with a minimum grade of 2.0%.

d) The maximum length of a catchbasin lead shall be 30m.

e) If a lead of over 30m in length is required, a catchbasin manhole shall be installed at the upper end.

f) Catchbasin leads shall have a minimum cover of 1.20 m from the finished road surface to the top of pipe.

2.15 OUTFALL DETAIL AT CREEKS

a) Obverts of outfall pipes shall have at least 150 mm above the 1-in-5-year flood level in the receiving stream.

Inverts of outfall pipes shall be above the winter ice level. Otherwise, outfall pipes shall be located to avoid damage from moving ice during breakup.

b) Drop structures and energy dissipaters shall be used where necessary to prevent erosion. For all outfalls, it is required that a hydraulic analysis be completed, to ensure that the exit velocities will not damage natural watercourses. The final exit velocities, where the flow passes from an apron or erosion control medium to the natural channel, shall not exceed 1.0 m/s and may be further limited depending on site specific soil and flow conditions.

c) Facilities shall be provided which will prevent entry or access by children or other unauthorized persons. A grate with vertical bars spaced at no more than 150 mm shall be installed with adequate means for locking in a closed position. Provide for opening or removal of the gate for cleaning or replacing the bars.

d) Outfalls, which are often located in parks, ravines, or on river banks should be made as safe and attractive as is reasonably possible. The appearance of these structures is important and cosmetic treatment or concealment is to be considered as part of the design. Concrete surface treatment is recommended to present a pleasing appearance.

e) The outfall shall require the approval of the Municipal Engineer.

2.16 RURAL RUNOFF INLETS

a. Each inlet may be unique and appropriate consideration must be given to provisions for grates, safety, debris interception, sediment catchment and storage and maintenance. Normally a road right-of-way or a public utility lot will be required to permit access to inlets for maintenance purposes.

b. Gratings installed over the ends of rural runoff inlets shall be sized with hydraulic capacity of 200% of the design flow rate to allow for the effects of blockage or fouling of the grate by debris carried by the flow.

3. MAJOR SYSTEM

3.1 COMPOSITION AND CONTROL

The major system comprises the street system, detention facilities, parkland and any other land required to convey runoff from events up to and including a 1-in-100-year return period to the receiving water. The major system shall be evaluated in a manner sufficient to ensure that no flooding that may cause significant property damage (e.g. flooding of buildings) occurs during the 1-in-100-year event.

Detention facilities shall be designed as part of both the minor and major drainage systems. They must control the peak run-off condition for events up to the 1-in-100-year return period.

3.2 RETURN PERIOD EVENT

The major drainage system shall be assessed with respect to the 1-in-100-year return period event. New developments must also accommodate the major flows from adjacent developments.

3.3 ON-STREET STORAGE AND FLOW-ACROSS CONSIDERATIONS

The grading of streets and the layout of the major drainage system shall be assessed, relative to the following guidelines, during the 1-in-100-year event:

a) Storm water will be contained within City property.

b) No building shall be inundated at its ground line.

c) Continuity of the overland flow routes between adjacent developments shall be maintained.

d) The depth of water for all roads should be less than the following:

- Local / Collector Roads - 350mm
- Arterial Roadways - 150mm

e) All ponding areas are to be denoted on the detailed engineering drawings and to adhere to Alberta Environment's standards regarding depth.

f) The major overland route and calculated depth of ponding shall be clearly identified on the overall lot grading plan of development.

g) The velocities and depths of flow in the major drainage system shall not exceed the values outlined in the table below:

Table 12.5 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 a 20 kg child and a concrete lined channel. Larger persons may be able to withstand deeper flows.

3.4 INLET/OUTLET CONTROL DEVICES

The outlet from an onsite stormwater management storage system must incorporate appropriate means for the control of outflow and to limit the rate of discharge. The proposed release rates are to be confirmed by detailed modelling of the existing storm sewer system and are to be based on any proposed changes in the release rate to the receiving water body and revisions to the basin boundaries.

Orifice plates or "hydrobrakes" shall be employed as outlet control devices with by-pass system. Controlling flow by restricting pipe diameter and slope should not be approved. Inlet control, utilizing different styles of catchbasin grates is also recommended.

4. STORMWATER MANAGEMENT FACILITY DESIGN

4.1 OVERVIEW

Detention facilities and the entire area that would be submerged by the 1-in-100-year event shall be contained on City property. The need for a specific detention facility shall require the approval of the Municipal Engineer. In assessing the need for specific detention facilities, the Developer’s Engineer must consider the impacts of uncontrolled drainage as well as the capital and operating costs of providing control.

Where a detention facility is to have multiple functions, its design shall consider the aesthetic implications of shape, grading and landscape features. Municipal Engineer should be contacted to provide input during the conceptual stages.

An emergency overflow system shall drain to a receiving stream, if possible, for storms greater than the 1-in-100-year event.

The effects of the maximum pond water levels shall be considered in the design of the minor system and lot grading. The hydraulic gradeline elevations for the minor system piping shall be calculated starting from the maximum ponding level during the 1-in-5-year storm event.

Proposals that rely on third party implementation shall not be accepted.

4.2 BASIS FOR DETAILED DESIGN

4.2.1 Level of Service

Stormwater management facilities shall be designed to satisfy the level of service requirements for major system storage elements as stated above. The requirements for hydraulic performance for stormwater management facilities including storage capacity, outlet restrictions, bypass and drawdown rates and other basic design parameters such as elevations and design water levels are required to be specifically defined and documents in the Storm Design Report for the respective development area.

4.2.2 Geotechnical Considerations

Special geotechnical investigations to address issues related to the design of all constructed wetlands, stormwater management ponds and dry ponds are to be undertaken as a part of the planning and design studies and are a prerequisite to the final design of such facilities.

4.2.3 Aesthetic Considerations

Where a detention facility is to have multiple functions, its design shall consider the aesthetic implications of shape, grading and landscape features. Municipal Engineer should be contacted to provide input during the conceptual stages.

4.2.4 Staged Construction – Standards for Interim Facilities

When stormwater management storage facilities are to be implemented in stages, the standards applicable to the design and construction of the interim facilities are to be generally in accordance with the standards set out herein for permanent facilities of that type. For example, where an interim dry pond facility is proposed as a preliminary stage in the implementation of a stormwater pond system, it shall be designed and constructed in accordance with the criteria and standards applicable to a permanent pond. Any proposal for application of alternative standards will require special approval.

4.2.5 Storage Alternatives

The review of stormwater management facility alternatives should include the storage methods described in this subsection. The optimum number and location of stormwater management facilities must be determined bearing in mind the major/minor system concept. A combination of the various types of facilities should be considered to select a cost-effective drainage system that minimizes flooding and erosion and maximizes water quality improvement. Constructed wetlands or wet ponds should be used as the final treatment process prior to discharging to the receiving watercourse.

.1 Wet Pond - Retention Storage

Retention Storage collects and stores storm runoff for a significant period and releases it after the storm runoff has ended. Retention storage is often associated with “wet reservoirs,” more commonly referred to as “stormwater management lakes” or “wet ponds”. These may accommodate special recreational or aesthetic uses centered on a minimum number of permanent pools.

.2 Wetland Pond – Retention Storage

Constructed stormwater wetlands are human-made systems, designed, constructed and operated to emulate natural wetlands or many of their biological processes. They are generally shallow impoundments, planted with emergent rooted vegetation or colonized naturally by volunteer plan species. Water is the primary factor controlling the environment and associated plant and animal life. The water storage, filtering capacity and biological processes in wetlands can improve the quality of stormwater discharge. They may be designed as single or multiple cell compartments to allow redistribution of flows, maintenance of plant communities and flexibility in operation. Multiple cell wetlands may be designed as a series of cells or as parallel cells.

.3 Dry Pond - Detention Storage

Detention storage or “dry ponds” have been commonly used for storage in urban drainage works but their use is actively discouraged by the City because of their shortcomings for stormwater quality enhancement. When the inflow is large enough, the proper functioning of flow controls on the outlet from the system restricts the outflow to a rate much less than the inflow and causes the excess to be temporarily detained in the storage element. Dry ponds should only be used at the discretion of the City when constructed wetlands and or wet ponds are not practical, such as under the airport flight paths.

.4 Upstream Storage

The storage of water close to the points of rainfall occurrence is referred to as upstream storage. This may be retention or detention storage and usually consists of rooftop ponding, parking lot ponding, property line swale ponding and small ponds in green areas. Although this method lends itself well to planned unit development, it may only be applicable when suitable and effective means are established to ensure that both implementation and long-term operating and maintenance responsibilities are met by property owners.

.5 Downstream Storage

Water stored downstream of the area where the rainfall occurs is downstream storage. It may be of either the retention or detention types.

.6 Offstream Storage

A minor conveyance system may conduct low flows directly to an outlet, but have restricted outlet capacity or flow control elements that allow only peak flows to be routed to a storm water management facility for storage. This form of storage is usually termed “offstream” or “off-line” storage. The storage may incorporate depressed open areas, reservoirs and low lying recreation fields.

.7 Channel Storage (Drainage Parkway)

Slow-flow channels with wide bottoms provide channel storage as an inherent part of their hydraulic characteristics. As the channel fills to transport water it is also storing water.

.8 Onstream Storage (Drainage Parkway)

Onstream storage is achieved through the construction of an embankment across a channel so that a storage pond is formed. Spillway considerations are important to pass large floods exceeding the design runoff.

4.3 ENGINEERING DRAWING REQUIREMENTS

The engineering drawings for any SWM facility are to include the following information, in addition to the physical dimensions:

- The High Water Level (HWL) design event.
- Elevations at Normal Water Level (NWL), 5 Year Level and HWL.
- Volumes at NWL, 5 Year Level and HWL.
- Freeboard elevation.
- Notation including the lowest allowable building opening elevation for lots abutting the pond.
- Contributing basin size in ha.
- Measurements to located submerged inlet(s), outlet(s) and sediment traps referenced to identifiable, permanent features which are not submerged at NWL.

4.4 DESIGN DETAILS FOR WET PONDS

4.4.1 Land Dedication

a) The requirement for dedication of land on which a stormwater management pond is to situated will be in accordance with the City’s current practices.

b) The area of land covered by water, subject to flooding to HWL and freeboard will be designated as a “Public Utility Lot.” This designation will also apply to all rights-of-way for access to and protection of inlets, outlets and flow control facilities, and maintenance access routes to the pond.

4.4.2 Minimum Size

The minimum surface area shall be 2 hectares at normal water level. This is to discourage proliferation of large numbers of small ponds with higher maintenance costs and to achieve maintain water quality and treatment.

4.4.3 Side Slopes

a) Side slope requirements are to be generally as shown Figure 12.1.

b) Areas normally or infrequently covered by water, from the design high water level down to a point 1.0 m below the normal water level, shall have a maximum slope of 7 horizontal and 1 vertical. This is to include all overflow areas.

c) A slope of 3 horizontal to 1 vertical shall be used from the 1.0 m depth point (below normal water level) to the pond bottom.

d) Where confined space or extremes of topography dictate, limited areas within overflow areas located on Public Utility proposals to amend the slope requirements will be approved by the Municipal Engineer on a site specific basis.

4.4.4 Depth

The minimum depth from normal water level to pond bottom (beyond the side slope area) shall be 2.0 m and the maximum 2.5 m. Refer to Figure 12.1.

4.4.5 Fluctuation

The maximum water level fluctuation in residential areas during the 1-in-100-year storm event shall 2.0 m. Refer to Figure 12.1.

4.4.6 Freeboard

The minimum freeboard required is 1.0 m. At the Municipal Engineers discretion in consultation with the Developers Engineer, ponds with surface areas exceeding 2.0 hectares and with less than 1.0 meter water fluctuation during a 1:100, the Municipal Engineer can reduce the required freeboard. Refer to Figure 12.1.

4.4.7 Pond Bottom Material

a) For areas where the ground water table is below NWL, the pond bottom and side slopes are to be composed of impervious material with a suitably low permeability (e.g. with a permeability coefficient in the order of $1x10^{-6}$ cm/s). Intruding silt or sand seams shall be sealed off.

b) For areas where the ground water table is expected to be near or above the NWL, the pond bottom may be of a pervious material as dictated by geotechnical considerations.

4.4.8 Circulation Requirements

Narrow and/or dead bay areas where floating debris may accumulate are to be avoided. Inlets and outlets should be located to maximize detention time and circulation within the pond water body.

4.4.9 Inlet and Outlet Requirements

.1 Submergence of Inlets and Outlets

Inlets and outlets are to be fully submerged, with the crown of the pipe at least 1.0 m below normal water level with less than 25 meters of pipe allowed to flooded.

.2 Provision for Free Outfall from Inlets to Wet Pond

The invert elevation of the inlet pipe(s) to the first manhole upstream from the wet pond shall be at or above the normal water level of the pond to avoid deposition of sediments in the inlet to the pond. To avoid backwater effects in the upstream sewers the obvert of the inlet sewer at the first manhole upstream from the pond shall be at or above the pond level for the 1 in 5 year storm. A drop structure upstream from the pond will generally be required to achieve this. Inlet and outlet control calculations are required to verify the mode of operation of the inlets.

.3 Separation of Inlets and Outlets

Whenever feasible and at the discretion of the City, the inlet and outlet should be physically separated and be located at the perimeter of the facility. The inlet and outlet should be distanced as far as possible from each other to avoid hydraulic short-circuiting.

.4 Sediment Removal Provisions

a) The pond design shall include an approved sedimentation removal process for control of heavy solids that may be washed to the pond during the development of the contributing basin.
b) Sediment basins shall be provided at all inlet locations for use after completion of the subdivision development.

.5 Wet Pond Edge Treatment

a) Edge treatment or shore protection is required and shall be compatible with the adjacent land use. The treatment used shall meet the criteria for low maintenance, safety and ease of access to the water’s edge.

b) The edge treatment is to cover 1.5 m below and 3.0 m horizontally above the normal water level and shall be adequate to prevent erosion of the pond edge due to wave action.

c) The designer is encouraged to propose alternate edge treatments that exceed this minimum standard. The final selection of edge treatment is subject to the approval of the Municipal Engineer.

.6 Landscaping Requirements

Landscaping of areas bounding the pond is to be part of the pond construction requirement, and plans shall be submitted as part of the engineering drawings. This shall include all proposed public lands comprising the pond and all easement areas on private property, including areas from the pond edge treatment to the limit of inundation when the pond is filled to the design high water level. The minimum requirement for landscaping shall be the establishment of grass cover. Refer to Figure 12.2.

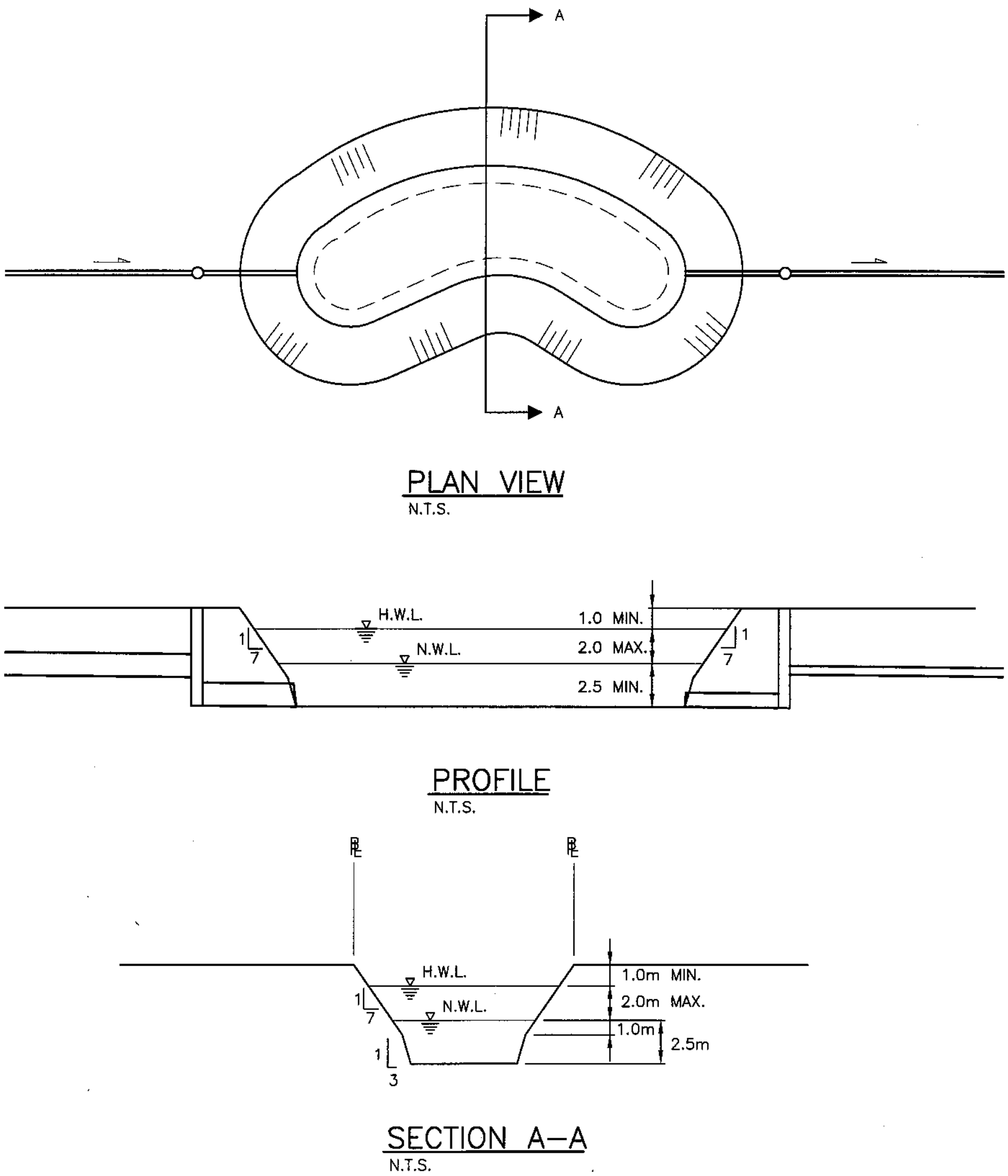
.7 Best Management Practices for Design

a) **Pond Shape**: To avoid reducing the pollutant removal capability and to maximize travel distance, the inflow points of the wet pond should be as far from the outlet as possible. To maximize stormwater contact and residence time in the pool, a length to width ration of 3:1 to 5:1 is recommended.

b) **Avoidance of Short-Circuiting and the Promotion of Plug Flow**: To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding “dead zones” and maximizing the time water stays in the pond during the active part of a storm. Design features that encourage plug flow and avoid dead zones are:

- Providing a broad surface for water exchange across cells rather than a constricted area.
- Maximize the flow path between inlet and outlet, including the vertical path; also, enhance treatment by increasing residence time. Bafflers or islands can be added within the permanent pool to increase the flow path.
- The ratio of flow path length to width from the inlet to the outlet should be at least 3:1. The flow path length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2.
- If there are multiple inlets, the length-to-width should be based on the average flow path length for all inlets

Figure 12.2



CITY OF GRAND PRAIRIE
MASTER DRAINAGE PLAN (2001)
PROPOSED WET POND CONCEPT

4.5 DESIGN DETAILS FOR CONSTRUCTED WETLAND

4.5.1 Land Dedication Requirements for Constructed Wetlands

a) The land requirement for dedication of land on which a storm water management pond is situated will be in accordance with the City's current practices.

b) The area of covered by the wetlands, subject to flooding to the HWL and freeboard will be designated as a "Public Utility Lot." This designation will also apply to all rights-of-way for access to and protection of inlets, outlets and flow control facilities, and maintenance access routes to the pond.

4.5.2 Suspended Solids Removal

The minimum design requirements for total suspended solids removal is 85% of particle size 75um or greater, as recommended by Alberta Environment, April 2001. Constructed wetlands are considered to be the most efficient treatment for sediment control and it is expected that this recommended criteria for reduction of total suspended solids will be achieved.

4.5.3 Wetland Drainage Area

a) A minimum drainage area of 5 ha is required to generate constant or periodic flow to the constructed wetland.

b) The smallest practical drainage area is considered to be 20 ha. For drainage areas between 5 and 20 ha in size, the City may approve the use of constructed wetlands on a site-specific basis.

c) To determine that a permanent pool can be maintained in a constructed wetland, hydrological studies are to be conducted using the size and characteristic of the drainage area.

d) The City prefers that fewer, larger wetlands be constructed rather than a series of smaller constructed wetlands.

e) The Developer is required to implement appropriate sediment controls during development in the drainage area to minimize sediment loading to the forebay and wetland during construction phase of the project and during the staged construction of the stormwater management facility.

4.5.4 Wetland Soil Characteristics

a) For wetland deep water areas, low soil permeability of 10^{-7} m/s is recommended to maintain a permanent pool of water and minimize exfiltration. Compacted sandy clays and silty clay loams may be suitable provided that documented geotechnical testing demonstrates low soil permeability.

b) Wetland vegetative zones can be constructed using soils from recently displaced wetlands, sterilized topsoil, or peat from within the drainage basin or region. A layer of 10 cm to 30 cm soil shall be spread over the vegetation zones of the constructed wetland. Planting will be done in this soil over the 2 years following construction.

c) One year after completion of construction a stable mixture of water tolerant grasses shall be in place.

d) In the spring of the second year following construction of the non-surviving woods plants shall be replaced and the remaining 50% of the woody plants should be planted.

e) Two years after completion of the construction a diverse population of water tolerant grasses, native grasses, wild flowers, and water tolerant woody plants should have taken root.

f) Manipulation of water levels may be used to control plant species and maintain plant diversity.

g) Harvesting emergent vegetation is not recommended.

4.5.5 Upland Vegetation in the Extended Detention Storage Area around the Wetland

a) Requirements for screening the constructed wetlands, between NWL and HWL, from adjacent land uses and for visual aesthetics shall be agreed by the Developer and the City.

b) A mow strip of a minimum of 2 m shall extend from the public utility lot boundary towards the constructed wetland NWL. This is to act as a safety bench and weed barrier to prevent root invasion of adjacent properties by Poplar and Aspen species.

4.5.6 Wetland Water Depth

a) Use a variety of water depths, 0.1 m to 0.6 m with an average permanent water depth of 0.3 m to encourage emergent vegetation.

b) Deep water areas, i.e. greater than 2 m are to be limited to less than 25% of the wetland surface area.

c) Water fluctuation in excess of 1 m above NWL should be infrequent to prevent killing of the vegetation.

4.5.7 Wetland Surface Area

a) The surface area of the constructed wetland shall be a minimum of one hectare at the NWL.

b) The wetland surface area is typically about 3% to 5% of the drainage area.

4.5.8 Wetland Volume

To achieve suspended solids removal for the highest level of protection, it is required to provide 80 m^3 of dead storage volume per hectare for a drainage area 35% impervious. For an area 85% impervious, a dead storage volume of $140m^3$ per hectare of drainage is required.

4.5.9 Length to Width Ratio

a) The minimum ratio should provide an effective flow path length at low flow that is three times the relative wetland width in order to increase the residence time.

b) Incoming water should be well distributed throughout the land and be conveyed as sheet flow to optimize treatment.

4.5.10 Forebay

a) A forebay is required at each major inlet to trap suspended solids before stormwater enters the constructed wetland.

b) A major inlet is one that provides greater than 10% of the total storm inflow to the wetland.

c) A forebay is to be between 2.4 m to 3.0 m deep for major inlets.

d) Provide maintenance access at forebays to permit removal of sediments.

e) Runoff leaving the forebay should pass through shallow areas of emergent vegetation.

f) Side slopes shall be a maximum of 7 horizontal and 1 vertical (7H:1V) along accessible areas around open and deep water areas at the forebay.

4.5.11 Permanent Pool at the Outlet

a) The permanent pool requires a depth of 2.4 m to 3.0 m. Size can be variable depending on the wetland’s configuration.

b) Side slopes shall be a maximum of 7H:1V along accessible areas around open and deep water areas at the permanent pool.

4.5.12 Inlet and Outlet

a) Inlets are to discharge to a forebay.

b) A variable water level control structure is required on the outlets for maintenance and water management purposes and to assist with the establishment and management of vegetation. The control structure should be capable of maintaining water levels between 0.5 m below NWL and 0.5 m about NWL. Variable water level control should be obtained through the manipulation of stop logs or similar overflow devices.

c) Inlets and outlets should be located to avoid short-circuiting and maximize the flow path.

d) The maximum depth in the inlet and outlet areas is restricted to 3.0 m.

e) Inlets and outlets are to be fully submerged, with the crown of the pipe at least 1.0 m below NWL. Inlet and outlet pipe inverts are to be a minimum of 100 mm above the bottom.

f) Provide maintenance access to forebay and permanent pool to allow for sediment removal.

g) An emergency overflow system shall drain to an overland route away from private property where possible.

4.5.13 Grading

a) Slopes shall be 5H:1V or flatter to support larger areas of wetland vegetation. Terraced slopes are acceptable.

b) A 2 m wide shallow marsh bench around the wetlands at NWL with a 10H:1V slope and the use of terraced grading is recommended to improve public safety.

c) Side slopes around the accessible deep areas in sediment forebay and permanent pool areas shall be a maximum of 7H:1V.

d) The 2 m wide mow strip shall have a side slope of either 7H:1V at accessible deep water areas or 5H:1V in other areas around the wetland.

4.5.14 Floatables, Oil and Grease

To trap floatable materials, oil and grease, inlets and outlets are to be below normal water level.

4.5.15 Maintenance

a) The Developer is required to provide an operations and maintenance manual.

b) Maintenance and warranty period shall be two years from construction completion certificate (CCC) issuance.

c) Removal of accumulated sediment during construction from forebays will be required prior to issuance of the final acceptance certificate (FAC).

d) Sediment traps are to be cleaned during the maintenance period.

e) Sediment removal is required when forebay and permanent pool volumes are reduced by greater than 25%.

f) Replace or adjust plantings and manage nuisance species during maintenance period.

g) During the maintenance period, the facility shall be inspected at least twice each year to determine vegetation distribution and the preservation of design depth. These inspection reports shall be submitted when applying for the FAC.

h) In future years, wetland vegetation regeneration should be possible by lowering the water level in the fall season using the control structure.

4.5.16 Monitoring

a) The Developer shall monitor stormwater quality. If required by the City, effluent from the permanent pool shall be sampled and tested for the following parameters: TSS, TP, NH_3, BOD and faecal coliforms each during the maintenance period and the date provided to the City.

b) The Developer shall also monitor wetland and upland vegetation and take any corrective action required during the maintenance period.

c) At the end of the maintenance period, before the issuance of the FAC, the Developer shall ensure that at least 75% of the grass cover and 30% of the non grass emergent vegetation around the wetland's edge has established given normal season conditions. A vegetation survey by a qualified professional shall be submitted to the City.

4.5.17 Access

Access is required to all inlets and outlets for maintenance, operation of water control structures, removal of debris and litter and vegetation management.

4.5.18 Fencing

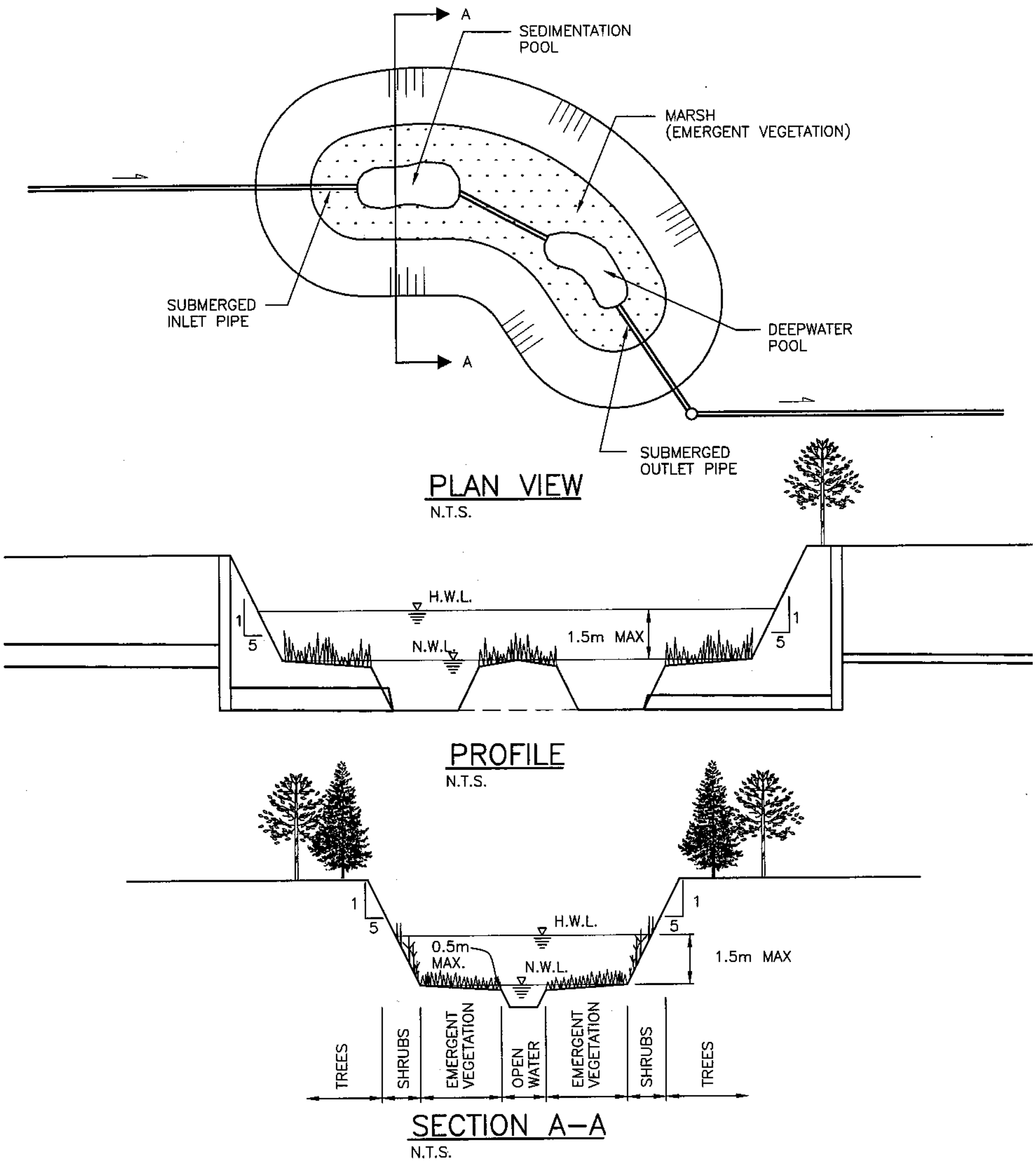
a) The Developer is required to use natural solutions such as grading and planting strategies to provide safety features for the wetland, inlets and outlets.

b) The Developer shall provide a fence at the public utility lot boundary with openings for maintenance and public access to trails.

4.5.19 Mosquito Control

The Developer shall include design features that minimize mosquitoes in a constructed wetlands facility. Features can include system design and vegetation management that would preclude stagnant backwaters and shading of the water surface, providing habitat for purple martin, swallows, batfish, dragon flies, bats and other predators.

Figure 12.3



CITY OF GRAND PRAIRIE
MASTER DRAINAGE PLAN (2001)
PROPOSED WETLAND CONCEPT

4.6 DESIGN DETAILS FOR DRY PONDS

4.6.1 Land Dedication for Dry Ponds

Dry ponds are to be located within public utility lots that encompass all lands subject to inundation at the HWL and freeboard.

4.6.2 Frequency of Operation

a) All dry ponds shall be off-line storage areas designed to temporarily detain excess runoff and reduce the peak outflow rates to the downstream system.

b) Designs that propose containment of runoff due to events more frequent than 1 in 2 years are to include special provisions to facilitate clean up, i.e. paved bottom areas.

4.6.3 Depth of Ponding

The maximum live storage limit in a dry pond is 1.5 m measured from the invert elevation of the outlet pipe. Refer to Figure 12.3.

4.6.4 Dry Pond Bottom Grading and Drainage

The dry pond shall be graded to properly drain all areas after its operation. The pond bottom shall have a minimum slope of 1%, greater is recommended where feasible. Lateral slopes shall be 2% or greater. French drains or similar may be required where it is anticipated that these slopes will not properly drain the pond bottom, or where dictated by multiple use or special considerations.

4.6.5 Side Slopes

Side slopes subject to inundation upon filling of the dry pond shall have a maximum slope of 5 horizontal to 1 vertical within public property. Where possible, reduced slopes should be used.

4.6.6 Landscaping

Landscaping of dry ponds will be considered part of the construction and plans shall be submitted with the engineering drawings. The minimum requirement for landscaping of dry ponds shall be the establishment of grass cover. See Section 16 – Landscaping.

4.6.7 Inlets and Outlets

a) All inlet and outlet structures associated with dry ponds shall have grates provided over their openings to restrict access and prevent entry into sewers by children or other persons. A maximum clear bar spacing of 150 mm shall be used for gratings.

b) Grated outlet structures are to be designed with a hydraulic capacity of at least twice the required capacity to allow for possible plugging. Further, the arrangement of the structures and the location of the grating shall be such that the velocity of the flow passing through the grating will not exceed 1.0 m/s. Appropriate fencing and guard-rails are to be provided to restrict access and reduce the hazard presented by headwalls and wingwalls.

c) Whenever feasible at the discretion of the City, the inlet and outlet should be physically separated from the perimeter of the dry pond. The inlet and outlet should be distanced as far as possible from each other to avoid hydraulic short-circuiting.

d) An emergency overflow system shall drain to an overland route away from private property where possible.

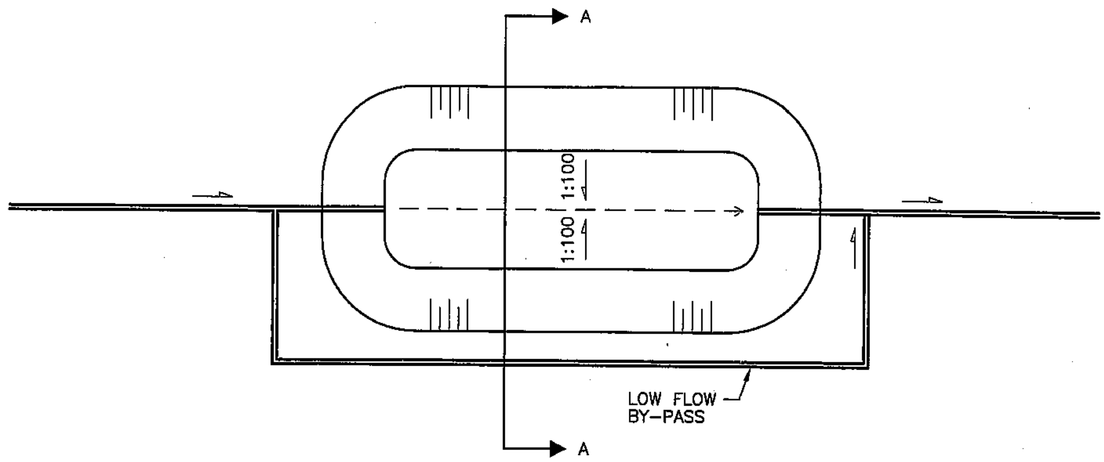
4.6.8 **Best Management Practices for Dry Ponds**

a) Pond shape: To maximize the treatment potential of the pond, the inlet and outlet should be positioned in such a way that short circuiting in the basin is minimized. Ponds that are considerably longer than wide (e.g. length equal to three times width) will likely provide additional detention time for settling and biological treatment.

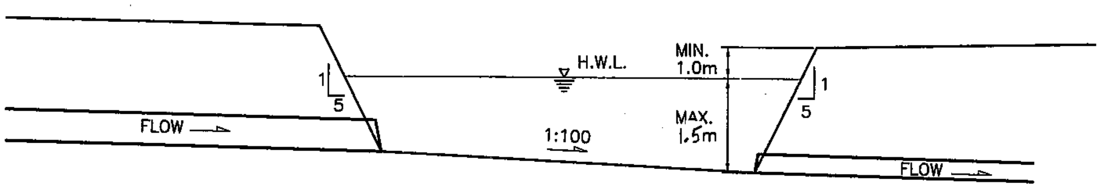
b) Pond Inlet/Outlet Structures and Pipes: The pond should be designed in such a way that turbulence in the main treatment areas is minimized. For example, inflow points should be designed with energy dissipaters to reduce inflow velocity.

c) Scour Control: Flow-diffusion devices, including plunge pools, directional berms or other specially created dissipation structures, are recommended to reduce the scouring of pond bottom.

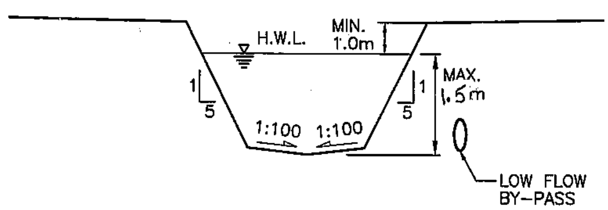
Figure 12.3



PLAN VIEW
N.T.S.



PROFILE
N.T.S.



SECTION A–A
N.T.S.

4.7 DESIGN DETAIL FOR DRAINAGE PARKWAYS

4.7.1 Land Dedication for Drainage Parkways

Drainage Parkways are to be located within public utility lots that encompass all lands subject to inundation at the HWL and freeboard. Adjacent land provided for maintenance access may be Municipal Reserve if providing a recreation use.

4.7.2 Depth of Ponding

The maximum live storage limit is 1.0 m measured from the NWL. Refer to Figure 12.3.

4.7.3 Base Width and Slope

The minimum base width is 5.0 m and a low-flow channel to carry the base flow shall be provided. The minimum longitudinal slope is 0.5% and 1.0 % is preferred.

4.7.4 Side Slopes

Side slopes subject to inundation shall have a maximum slope of 5 horizontal to 1 vertical.

4.7.5 Access

A minimum setback of 5 m on one side to construct walkways and provide access for maintenance shall be provided.

4.7.6 Landscaping

Wetland areas shall contain emergent vegetation to enhance water quality, adjacent to the channel. Landscaping will be considered as part of the construction and plans shall be submitted with the engineering drawings. The minimum requirement for landscaping shall be the establishment of grass cover. See Section 16 – Landscaping.

4.7.7 Inlets and Outlets

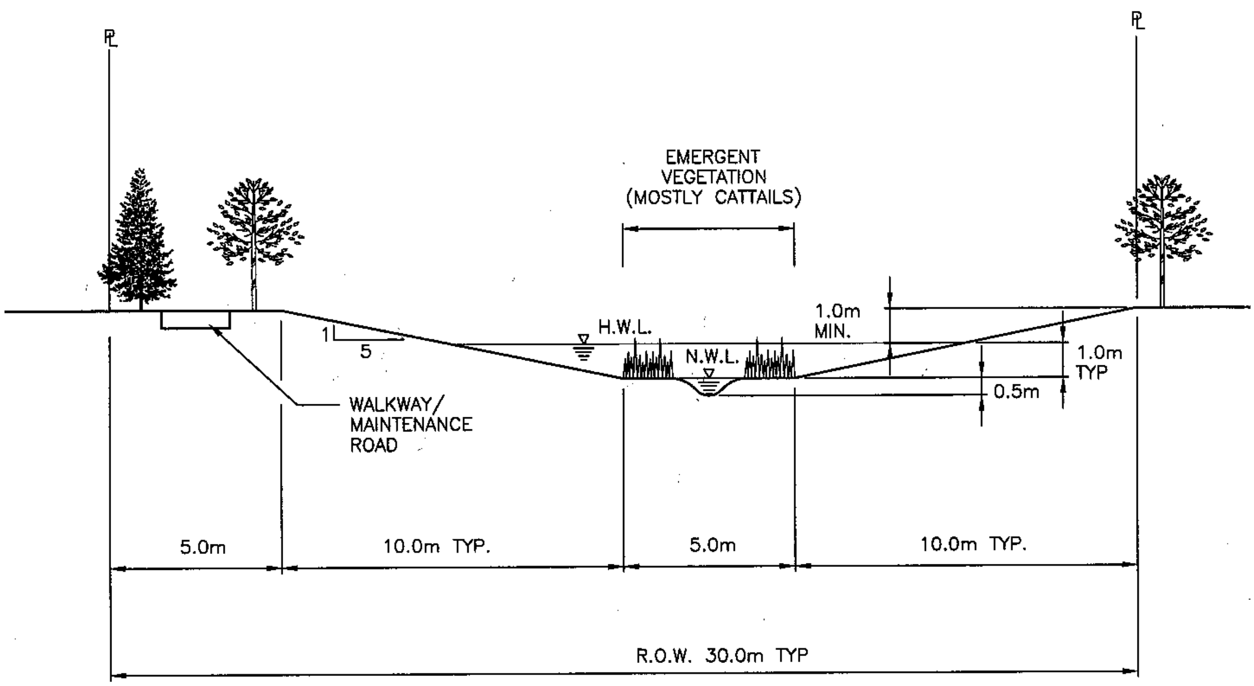
a) All inlet and outlet structures associated with dry ponds shall have grates provided over their openings to restrict access and prevent entry into sewers by children or other persons. A maximum clear bar spacing of 150 mm shall be used for gratings.

b) Grated outlet structures are to be designed with a hydraulic capacity of at least twice the required capacity to allow for possible plugging. Further, the arrangement of the structures and the location of the grating shall be such that the velocity of the flow passing through the grating will not exceed 1.0 m/s. Appropriate fencing and guard-rails are to be provided to restrict access and reduce the hazard presented by headwalls and wingwalls.

c) Whenever feasible at the discretion of the City, the inlet and outlet should be physically separated from the perimeter of the dry pond. The inlet and outlet should be distanced as far as possible from each other to avoid hydraulic short-circuiting.

d) An emergency overflow system shall drain to an overland route away from private property where possible.

Figure 12.4



CITY OF GRAND PRAIRIE
MASTER DRAINAGE PLAN (2001)
PROPOSED DRAINAGE PARKWAY CONCEPT

4.8 RECEIVING WATERS

Measures should be incorporated in new development to prevent any increase in the amount of downstream erosion.

If a development will cause downstream erosion despite the use of on-site peak runoff rate controls, appropriate measures should be constructed in the downstream areas.

Preservation of watercourse aesthetics and wildlife habitat should be considered in erosion and bank stability work.

4.9 CULVERTS AND BRIDGES

Culvert and bridge design should consider backwater effects over a range of flows. The design of a hydraulic structure requires assessment of both its nominal design "capacity" and its performance during the 1-in-100-year event.

4.10 TESTING

The design must be conducive to achieving appropriate construction results as detailed in the Construction Manual.

APPENDIX A

Table A.1
City of Grande Prairie Design Storm Hyetographs
Based on Chicago Distribution
4 Hour Design Storms
Rainfall Intensity in mm/hr

Time (min.)	1-in-5 Year Storm	1-in-10 Year Storm	1-in-25 Year Storm	1-in-100 Year Storm
5	1.9	1.9	2.2	3.6
10	2.0	2.1	2.4	3.8
15	2.1	2.2	2.5	4.1
20	2.4	2.4	2.7	4.3
25	2.6	2.5	2.9	4.6
30	2.8	2.8	3.2	5.2
35	3.1	3.0	3.5	5.7
40	3.5	3.3	3.9	6.3
45	3.9	3.7	4.4	7.7
50	4.5	4.2	5.1	8.9
55	5.3	5.0	6.0	10.6
60	6.5	6.2	7.4	13.9
65	8.3	8.1	9.9	18.2
70	12.4	12.2	15.2	26.2
75	27.0	26.9	34.0	41.0
80	69.8	83.2	100.2	125.2
85	33.1	33.8	43.3	60.6
90	19.7	19.7	23.7	43.1
95	13.8	13.8	15.2	32.1
100	10.8	10.7	13.2	23.3
105	9.0	8.8	10.7	19.5
110	7.7	7.5	9.1	16.4
115	6.8	6.5	7.9	13.6
120	6.0	5.8	7.0	12.0
125	5.4	5.2	6.3	10.6
130	4.8	4.8	5.7	9.5
135	4.5	4.4	5.2	8.4
140	4.2	4.1	4.8	7.8
145	3.9	3.8	4.6	7.3
150	3.7	3.6	4.3	6.9
155	3.5	3.4	4.0	6.5
160	3.3	3.2	3.8	6.1
165	3.2	3.1	3.6	5.8
170	3.0	2.9	3.4	5.4
175	2.9	2.8	3.3	5.2
180	2.8	2.7	3.1	5.0
185	2.7	2.6	3.0	4.8
190	2.6	2.5	2.9	4.6
195	2.4	2.4	2.8	4.4
200	2.2	2.3	2.7	4.3
205	2.1	2.2	2.6	4.1
210	2.1	2.2	2.5	4.0
215	2.0	2.1	2.4	3.9
220	2.0	2.1	2.4	3.7
225	1.9	2.0	2.3	3.7
230	1.9	1.9	2.2	3.5
235	1.8	1.9	2.1	3.5
240	1.8	1.8	2.1	3.4
TOTAL ppt	28.0	28.9	34.8	53.5

Table A.2
City of Grande Prairie
Design Storm Hyetographs
Based on Atmospheric
Environment Services (AES)
12 Hour Design Storm

Time (hours)	Discrete Rainfall (%)	Rainfall (mm/hr)
0	0	0.0
1	1	0.8
2	5	3.8
3	18	13.8
4	33	25.3
5	16	12.3
0	11	8.4
6	7	5.4
7	4	3.1
8	2	1.5
9	1	0.8
10	1	0.8
11	1	0.8
Total Precipitation (mm)		76.6

Table A.3
City of Grande Prairie
Design Storm Hyetographs
Based on SCS Type II 24 Hour Design Storm

Time (hours)	Increase Curve Value	Rainfall (mm/hr)	Time (hours)	Increase Curve Value	Rainfall (mm/hr)
0.0	0.000	0.0	12.0	0.230	115.2
0.2	0.002	1.0	12.2	0.040	20.0
0.4	0.002	1.0	12.4	0.025	12.5
0.6	0.002	1.0	12.6	0.018	9.0
0.8	0.002	1.0	12.8	0.017	8.5
1.0	0.002	1.0	13.0	0.012	6.0
1.2	0.002	1.0	13.2	0.010	5.0
1.4	0.002	1.0	13.4	0.010	5.0
1.6	0.002	1.0	13.6	0.010	5.0
1.8	0.002	1.0	13.8	0.010	5.0
2.0	0.002	1.0	14.0	0.010	5.0
2.2	0.002	1.0	14.2	0.006	3.0
2.4	0.002	1.0	14.4	0.006	3.0
2.6	0.002	1.0	14.6	0.006	3.0
2.8	0.002	1.0	14.8	0.006	3.0
3.0	0.002	1.0	15.0	0.006	3.0
3.2	0.002	1.0	15.2	0.006	3.0
3.4	0.002	1.0	15.4	0.006	3.0
3.6	0.002	1.0	15.6	0.006	3.0
3.8	0.002	1.0	15.8	0.006	3.0
4.0	0.002	1.0	16.0	0.006	3.0
4.2	0.004	2.0	16.2	0.004	2.0
4.4	0.004	2.0	16.4	0.004	2.0
4.6	0.004	2.0	16.6	0.004	2.0
4.8	0.004	2.0	16.8	0.004	2.0
5.0	0.004	2.0	17.0	0.004	2.0
5.2	0.004	2.0	17.2	0.004	2.0
5.4	0.004	2.0	17.4	0.004	2.0
5.6	0.004	2.0	17.6	0.004	2.0
5.8	0.004	2.0	17.8	0.004	2.0
6.0	0.004	2.0	18.0	0.004	2.0
6.2	0.004	2.0	18.2	0.004	2.0
6.4	0.004	2.0	18.4	0.004	2.0
6.6	0.004	2.0	18.6	0.004	2.0
6.8	0.004	2.0	18.8	0.004	2.0
7.0	0.004	2.0	19.0	0.004	2.0
7.2	0.004	2.0	19.2	0.003	1.5
7.4	0.004	2.0	19.4	0.003	1.5
7.6	0.004	2.0	19.6	0.003	1.5
7.8	0.004	2.0	19.8	0.003	1.5
8.0	0.004	2.0	20.0	0.003	1.5
8.2	0.006	3.0	20.2	0.003	1.5
8.4	0.006	3.0	20.4	0.003	1.5
8.6	0.006	3.0	20.6	0.003	1.5
8.8	0.006	3.0	20.8	0.003	1.5
9.0	0.006	3.0	21.0	0.003	1.5
9.2	0.006	3.0	21.2	0.002	1.0
9.4	0.006	3.0	21.4	0.002	1.0
9.6	0.006	3.0	21.6	0.002	1.0
9.8	0.006	3.0	21.8	0.002	1.0
10.0	0.006	3.0	22.0	0.002	1.0
10.2	0.011	5.5	22.2	0.002	1.0
10.4	0.011	5.5	22.4	0.002	1.0
10.6	0.011	5.5	22.6	0.002	1.0
10.8	0.011	5.5	22.8	0.002	1.0
11.0	0.011	5.5	23.0	0.002	1.0
11.2	0.015	7.5	23.2	0.002	1.0
11.4	0.022	11.0	23.4	0.002	1.0
11.6	0.050	25.1	23.6	0.002	1.0
11.8	0.110	55.1	23.8	0.002	1.0
			24.0	0.002	1.0
			Total Precipitation (mm)		**100.6**