CITY OF COQUITLAM

STORMWATER MANAGEMENT POLICY AND DESIGN MANUAL

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STORMWATER MANAGEMENT POLICY AND DESIGN MANUAL

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CITY OF COQUITLAM

DRAFTING OF STORMWATER POLICY AND DESIGN MANUAL
AND
UPDATING OF SUBDIVISION SERVICING BYLAW

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- Dayton & Knight Ltd. (lead consultant),
- Barry Lambert Consulting Ltd. (Subdivision Bylaw review),
- Davidson Yuen Simpson Architects (community planning),
- InterCAD Consulting Engineers (traffic issues),
- Phillips Farevaag Smallenberg (landscape architecture), and
- R. Cavanaugh & Associates (environmental issues).

The study team thanks the City of Coquitlam staff who participated in this project through supplying information, attendance at workshops, and review/comments on draft materials.

USE OF THIS MANUAL

This Policy and Design Manual (Manual) contains the stormwater management policies and design criteria for the City of Coquitlam. The policies and criteria are intended to ensure consistency for stormwater management approaches in undertaking new development and redevelopment within the City, and for guiding City improvements to existing stormwater systems.

Adherence to the requirements of this Manual does not imply that the requirement of other bylaws, statutes, regulations and policies have been met; it is the responsibility of the proponent to ensure that all other applicable requirements are met.

This Manual should be used in conjunction with other City policies and bylaws including but not necessarily limited to those listed below:

- Citywide Official Community Plan;
- Strategic Plan;
- Drainage Manual, Operations Department;
- Subdivision Control Bylaw No. 2038, 1989;
- Stream and Drainage System Protection Bylaw No. 4403, 2013;
- Tree Cutting Bylaw No. 2169, 1990;
- Conservation Bylaw No. 2454, 1994;
- Drainage Bylaw No. 3153, 1998; and
- Citywide Stormwater Management Strategy;
- Watershed Studies developed by the City and others for drainage catchments lying wholly or partly within the City.

In addition, this Manual should be used in conjunction with all applicable senior government policies and regulations, including but not necessarily limited to the following:

- Federal Fisheries Act
- Provincial Fish Protection Act, Streamside Protection Regulation
- Greater Vancouver Regional District Liquid Waste Management Plan and Related Documents

Section A – Policies to Understand City Objectives

Section A of this Manual contains the Objectives and the Approach to be used for stormwater management. Stormwater management solutions must satisfy the Objectives when dealing with all aspects of drainage within the City. The Approach provides explanations of responsibility, stormwater management planning, means of settling conflicts, and the analysis needed in support of stormwater management.

Section B – Design Guidelines and Criteria to Understand Process and Criteria

Section B of this Manual contains the technical detail to be used for drainage design within the City, including procedures to be followed, major and minor flow systems, design criteria, computational requirements, and requirements for development proponents to prepare Stormwater Management Plans. Section B is to be used in preparing submissions and for undertaking analysis. Part 1 should be reviewed first to establish overall requirements for submissions, reporting and approvals. Parts 2, 3 and 4 provide hydrologic criteria for planning and detailed design. These criteria should be used when preparing Stormwater Management Plans and detailed calculations. Part 5 should be used to develop the Stormwater Management Plan, and as a checklist to ensure that all reports and data requirements are complete prior to submission. References are included at the end of this manual.

Section C – Stormwater Management Measures to Understand Stormwater Control Measures Suited to Flood Protection, Erosion Prevention and Water Quality Enhancement

Section C of this Manual contains guidelines for selection of appropriate stormwater control measures for mitigating the adverse affects of land use change. Section C provides guidance to screen and select Best Management Practices for meeting the criteria set out in Section B, and for simulating the pre-development conditions or improving hydrologic conditions in the watersheds.

SECTION A - POLICIES

The City stormwater management policies are set out in this section.

Part 1 outlines the objectives in terms of goals.

Part 2 explains the approach to be taken in undertaking stormwater management planning.

PART 1 - OBJECTIVES

Three goals define the City's objectives for stormwater management.

1.1 ***Goal #1*** - Reduce the Potential Risk of Health Hazards, Loss of Life and Property Damage

- provide both major and minor drainage protection for life, livelihood, and property;
- control the incidence of nuisance or damage related surface ponding and flooding to within an acceptable frequency;
- protect municipal infrastructure.

1.2 ***Goal #2*** - Preserve and Improve the Environment for Present and Future Generations

- minimize the potential stormwater impacts of development, such as changes in the groundwater regime, alteration of fish and wildlife habitat, increased pollution, increased erosion and sediment transport, and increased or decreased stream flows;
- where feasible, maintain the shape and composition (geomorphology) of the natural stream channel or ravine geometry, natural biological indicator conditions and the flow conditions (hydrogeometric regime);
- employ stream protection measures, to prevent adverse hydrological and water quality impacts, for all recognized watercourses within the City;
- promote sound development that respects the natural environment;
- where feasible and where opportunities allow, restore watercourses that are currently enclosed to open channels.

1.3 ***Goal #3*** - Conserve Social and Financial Resources

- treat stormwater as a resource rather than a waste product, ensure that stormwater facilities are functional and aesthetically pleasing, and integrate multi-use objectives where possible;
- provide a system of infrastructure and services that enhances general public convenience and safety, enhances aesthetics, and allows development to proceed according to the community plan;
- sustain future development, support orderly and managed development of resources and integration of land uses within the City;
- use best available technologies and management practices where feasible;
- encourage economic design of drainage systems;
- provide consistency and a basis of fairness for balanced and planned development within the community.

This Manual includes descriptions of responsibility levels, planning needs, and required design methods. To meet the stormwater management goals, the City and land development proponents are to follow the approach set out in this Manual, and in supplemental Watershed Studies where such studies have been conducted.

2.0 APPROACH

2.1 Responsibility

Planning for stormwater management shall integrate the needs of the community with due regard for the regulations of the City as well as the Federal and Provincial agencies having jurisdiction. Planning of urban drainage facilities shall incorporate natural watercourses, wetlands and valleys, man-made ponds, channels, streets, storm drainage, greenways and parks into the Neighbourhood Plan. The planning should include attention to watershed management, flood protection, stream protection, stream management area delineation, Federal, Provincial and Municipal regulations, and land ownership.

2.1.1 City of Coquitlam

The City will recognize Integrated Stormwater Management Planning as developed for the GVRD Liquid Waste Management Plan as far as possible within existing City Official Community Plan policies.

The City will be responsible for the preparation of stormwater management guidelines and for approval of drainage design criteria. The stormwater management guidelines and design criteria are contained in this Manual. In conjunction with this Manual, the City is in the process of preparing a Citywide Stormwater Management Strategy for the watersheds lying wholly or partly within the City boundary.

To assist in the planning, the City will over time provide and maintain Watershed Studies encompassing the City. Where storm runoff impacts neighbouring municipalities, the City will pursue agreements, such as Memorandums of Understanding, with those municipalities to determine whether stormwater management criteria additional to or other than those set out in this Manual are needed to protect downstream jurisdictions. The Watershed Studies will be guided by the Citywide Stormwater Management Strategy, by this Manual, and by the existing Official Community Plan, and will be developed in conjunction with the accompanying Neighbourhood Plans. The City will delineate any special requirements needed for protection of designated watersheds and features within watersheds. These special requirements shall be used in conjunction with this Manual by development proponents to prepare Stormwater Management Plans for proposed developments, and by the City for upgrading existing drainage facilities. The City will explore or examine opportunities for community and regional stormwater management facilities in the Watershed Studies. In the absence of specific design criteria developed in a Watershed Study, the criteria set out in this Manual shall be used for stormwater management. The Watershed Studies will include engineering, ecological and planning components integrated to meet community interests.

2.1.1 City of Coquitlam cont'd/

The Citywide Stormwater Management Strategy will be reviewed and updated every two years to incorporate new information and experience gained by City staff. This Manual will be updated at 5-year intervals, or more frequently if needed, to include more current information, or to reflect changes in land use and development policy. The Watershed Studies will be updated every 12 years, as required by the GVRD Liquid Waste Management Plan.

The Watershed Studies will include the following elements:

- develop general stormwater management goals and objectives for the individual watershed and establish the terms of reference, scope and level of effort for the Watershed Study;
- review data relevant to City of Coquitlam drainage;
- identify known drainage problems;
- advise on rainfall, stream and groundwater monitoring facilities;
- develop hydrologic and hydraulic models and management strategies;
- establish the roles and level of public involvement in Watershed Study development, implementation, and ongoing monitoring; and
- implementation plan including a financing strategy to support the stormwater management measures.

2.1.2 Development Proponents

Development proponents include applicants for approval for rezoning, subdivision and building permits. Development proponents shall be responsible for drainage designs and for preventing or mitigating impacts on any downstream drainage facilities and watercourses. Development proponents shall prepare a Stormwater Management Plan as described in Section B of this Manual. The Stormwater Management Plan shall be developed in two phases as follows:

- *Preliminary Planning* - undertaken in support of rezoning and/or subdivision applications; and
- *Detailed Design* - undertaken following preliminary review of subdivision and building permit applications.

The City may require development proponents to include detention storage or other stormwater control measures in Stormwater Management Plans on a case-by-case basis to protect downstream properties and resources, including watercourses. Where open drainage courses receive flows from detention facilities, the facilities are to be designed to ensure that discharge controls for frequent storms will minimize stream peak flow and erosion processes as described in Section B of this Manual.

2.1.2 Development Proponents cont'd/

The Stormwater Management Plan prepared by development proponents shall include the following elements when dealing with all open and closed watercourses.

(1) Stormwater release rates and storage must be designed to ensure related flows do not increase the frequency and magnitude of erosion events in natural watercourses compared to the predevelopment condition. When stormwater management requires flow attenuation by storage ponds, adverse effects on fish, fish habitat or other resources must not be created. Stormwater detention facilities should be designed as wet ponds or engineered wetlands where possible.

(2) Where required, streams are to be protected and stabilized to control erosion and downstream sedimentation. Bio-engineering techniques should be used, where possible. For upstream development, the City requires the developer or builder to submit a lot grading plan that specifies permanent lot drainage, and a sediment control plan that specifies how construction activities will be managed to minimize soil loss from site drainage, both during construction and after development. Requirements for lot drainage and soil erosion protection are described in Section B of this Manual and in City bylaws.

(3) Stormwater management facilities should be designed as multi-use facilities that include recreational, environmental and aesthetic aspects as well as flow control and water quality control where possible.

(4) All filling or soil removal activities in or around watercourses must first be approved by the City as well as by other applicable regulatory agencies, and must be undertaken in accordance with City bylaws.

(5) Stream crossing type, sizing, location and installation plans as well as bridge locations shall be approved by the City and by regulatory agencies. Consideration shall be given to backwater issues, protection of fisheries resources, and trash accumulation. Of particular importance are flood protection and the preservation of existing fish passage in streams.

(6) Drainage service connections are to be provided in accordance with City bylaws, including cross connection control, waste discharge, flood protection and quality control.

(7) All discharges to the City drainage system or sensitive soils must be controlled to ensure erosion and downstream deposition in watercourses will not occur.

2.1.2 Development Proponents cont'd/

(8) Sources of pollution shall be excluded from all drainage systems in accordance with City bylaws and senior government regulations and policies. In particular, attention shall be paid to temperature, organic matter, toxic matter and sediment.

(9) Particular consideration shall be given to sustaining adequate base flows in streams and to the protection of fish habitat.

(10) No changes shall be made in or about a stream unless permission is first received from the Ministry of Water, Land and Air Protection and Fisheries and Oceans Canada.

(11) Removal of trees is controlled under City bylaws. Removal of trees in riparian areas may also be controlled under the Federal Fisheries Act and/or by restrictive covenant which may be made out in the name of the City or the Province.

2.2 Ownership

Stream corridors may remain within private property, with provision for easements or rights-of-way except at utility crossings or under special circumstances, such as where the City or Regional District retains or acquires ownership for park or buffer use. Fence construction may be necessary to protect stream corridors, but should be restricted as far as possible to minimize interference with maintenance work in the stream. Changes to existing developments, subdivisions and buildings shall be subject to the requirements of this Manual, City bylaws, and other relevant policies and regulations.

2.3 Analytical Methods

Hydrologic modelling techniques (whether by desktop computation or by computer modelling) shall be used to design urban drainage facilities. The modelling technique for the analysis shall be determined by the complexity of the watershed or development under consideration, as required by the City. Criteria for analytical methods are presented in Section B of this Manual.

SECTION B - DESIGN GUIDELINES AND CRITERIA

Section B is set out in five parts, and contains the detailed methods and criteria to be used in preparing Stormwater Management Plans. The intent of Section B is to provide a framework for consistent drainage analysis throughout the City, and to provide development proponents with procedures for preparing submissions. Section B does not provide material specifications. Refer to the City Subdivision and Development Servicing Bylaw for material specifications.

The drainage design objectives are as follows:

- to safely convey the 1:100-year storm event with overland and piped flows to a suitable receiving water body;
- to safely contain the 1:10 year storm event within the minor system without surcharge;
- to convey storm flows such that downstream capacity is not exceeded for the 1:10 year storm event, and that the major system is not adversely affected; and
- to ensure that the quantity and quality of flows do not adversely affect the receiving waters.

Runoff after completion of development must not exceed the criteria specified in this Manual. To meet the flow criteria specified in this Manual, the use of detention-retention methods or other Best Management Practices may be required. Engineering techniques which identify and incorporate natural processes can be used to preserve and enhance natural features as well as improve the effectiveness of natural systems. A wide range of methods are feasible for the control of stormwater (see Section C of this Manual).

Section B includes the following subsections:

- *Part 1* – Stormwater Management Procedure - identifies overall City requirements in terms of preliminary studies, detailed submissions, and scheduling.

- *Part 2* - Major System - identifies the design criteria associated with major flows, flood routes, structures, containment and erosion – to be used in conjunction with relevant bylaws.

- *Part 3* - Minor System - identifies criteria associated with minor flows, hydraulic design levels, street and gutter flow, storm sewer design, lot grading, groundwater recharge, water quality, erosion, and structures – to be used in conjunction with relevant bylaws.

- *Part 4* - Analytical Criteria - provides a general reference for design method, flow and runoff formulas, rainfall criteria, and runoff coefficients. The analytical criteria are to be used in conjunction with the City Watershed Management Strategy, individual Watershed Studies, and relevant policies and bylaws.

- *Part 5* – Stormwater Management Plan - provides a reference for the scope of design details to be used in submissions, as well as procedures for preparing submissions.

1.0 STORMWATER MANAGEMENT PROCEDURE

The responsibilities and procedures to be followed by the City and by development proponents are described in this section.

1.1 Approach

A Stormwater Management Plan is required for all rezoning, development permit, subdivision and building permit applications except for the following, unless otherwise included in a Watershed Study or integrated stormwater management plan adopted by Council:

(a) all single and two family subdivisions and rezonings that do not require new storm drainage systems other than storm service connections and are adjacent to and utilize existing storm drainage systems with adequate capacity for both minor and major storm events; or

(b) building permits for single or two family dwellings; or

(c) developments, other than single or two family dwellings, with a total area of building footprint plus parking or other impermeable surface cover of less than $500m^2$. The total area is to include any existing impermeable surface cover which is to be retained after redevelopment. Parking areas include both mandatory parking areas plus any additional proposed parking area.

It is the responsibility of the development proponent to ensure that all applicable guidelines, bylaws, standards and other regulations and policies are strictly followed. The City may, at its discretion, require the preparation of Stormwater Management Plans for projects exempted by the criteria listed in Items (a), (b) and (c) above, where such projects are deemed to have potential adverse impacts on Development Permit Areas, and/or downstream stormwater management systems.

A Stormwater Management Plan of the planned project is to be developed in two phases at the expense of the development proponent; the City may determine whether the Stormwater Management Plan will be prepared by the proponents or by the City. The Stormwater Management Plan must be developed or overseen by a Professional Engineer who is registered in the Province of British Columbia and is experienced in hydrologic analysis. The Stormwater Management Plan should be conservative in calculation, coupled with sound engineering judgment, but the economic aspects of the design should not be overlooked. Low maintenance and operational simplicity are preferred. Criteria and proposed solutions will be reviewed by the City.

The development proponent shall provide the City with the technical information, and the City may at its discretion undertake the hydrologic analyses by computer model to determine the suitability of the proponent's development design.

Phase 1 of the Stormwater Management Plan is to be completed in support of an application for rezoning, subdivision, or building permit, and Phase 2 is to be completed as a condition of subdivision approval or the issue of a building permit. Phases 1 and 2 are described in detail in Section B, Part 5 of this Manual.

1.1.1 Phase 1: Preliminary Planning

Preliminary planning in a watershed is required to define the development drainage, to examine and assess different stormwater management alternatives, and to recommend a Stormwater Management Plan that is economically and environmentally justifiable for the development. The Stormwater Management Plan is to be prepared according to the requirements of this Manual and the individual Watershed Studies as undertaken by the City.

1.1.2 Phase 2: Detailed Design

Detailed design needed to implement the Stormwater Management Plan may be preceded by a pre-design report if requested by the City, but in any case shall include final sizing, grading, determination of hydraulic grade lines, location, lot grading plans, sediment control plans, water quality control plans (where requested), cost estimates, operation and maintenance responsibility for stormwater drainage facilities, and the schedule for implementation. Summary reports of studies carried out in Phase 2 may be required with the submission of detailed engineering plans.

1.2 Stormwater Management Plan

A Stormwater Management Plan is required for all submissions other than the exceptions listed in Section 1.1. Also, in the absence of a Watershed Study, Stormwater Management Plans must be developed that are self-sufficient and can be demonstrated to meet the constraints and goals of this Manual.

1.2.1 Formal Report

A report will be required by the City upon the completion of each of the two phases of the study. Report detail will reflect the complexity and size of the development. The required detail will be determined by the City at the outset of the study. As a guideline, Section B, Part 5 provides normal requirements to be included in the reports.

1.2.2 Approvals

The minor and major drainage systems must be designed to meet the requirements of the City as described in Section B, Parts 2, 3 and 4 of this Manual.

2.0 MAJOR SYSTEM

The major system includes all drainage pathways that convey, detain, divert and intercept the major design (100-year return) storm runoff. This section contains the major system scope, provisions, and technical requirements for use in Phase 1 (Planning) and Phase 2 (Detailed Design), as described in Part 5 of Section B.

2.1 General Criteria

The major system design must meet the following criteria:

1) The combined capacity of the major (overland) and minor (piped) systems must be able to safely contain storm flows resulting from the 1:100-year design storm;

2) Major flows shall be contained within public road allowances and rights-of-way, and shall discharge off-site to public road allowances and rights-of-way capable of accepting the design flows;

3) Major flow channels shall be designed to resist erosion or other detrimental effects at design flows; and

4) Overland flow channel capacities shall be calculated using the Manning formula at critical design sections.

2.2 Floodplain

The floodplain hydraulic gradeline elevation for a 1:200-year storm shall be defined for pre-development and post-development conditions in the area to be developed and along the affected watercourses downstream of the development.

2.3 Acceptable Levels of Flooding

Regional flood protection is assumed by the Ministry of Water, Land and Air Protection, Water Management Branch.

The depth of flooding permitted is specified below.

(1) No building shall have a flood water rise above the lowest elevation of the ground line, unless the building has been floodproofed. Basements, including underground parking garages, shall be floodproofed where groundwater rises above the basement floor.

(2) For all classes of roads, the product of depth of water (m) at the gutter and the velocity of flow (m/s) shall not exceed $0.65m^2/s$. The velocity shall not exceed 4.5m/s (see Figure 1).

(3) For arterial roads not requiring emergency access, the depth of water at the crown shall not exceed 50mm (see Figure 2 for depth calculations).

(4) For arterial, collector, or local roads requiring emergency access, one lane or a 3m width at the crown shall be free from flooding.

To meet the criteria for major storm runoff, sags or low points in roads or subdivisions are not permitted unless adequate provision is made for safe overland flow from the low points.

2.4 Peak Flow and Runoff Volume Control

Peak flow and runoff volume control for both major and minor storms will be required to protect downstream properties, infrastructure, natural streams and other resources.

In general, stormwater management measures shall include both flood prevention and erosion control measures for natural watercourses for both large, infrequent storms and smaller, more frequent storms. Stormwater management measures suitable for flood protection and erosion control are described in Section C of this Manual. Controls to prevent erosive flows in watercourses shall recognize both peak flow rates and the duration of peak flows. The objective is to limit both the magnitude and the duration of post-development peak flows to that of the pre-development peak flows as far as possible.

In the absence of specific requirements or other measures developed in the Watershed Studies and/or agreements with other jurisdictions approved by Council, the following criteria shall be used to limit flows in natural watercourses except for discharge directly to the Fraser River, the Coquitlam River, the Pitt River and DeBoville Slough:

- limit the post-development peak rate of runoff from the development site from the two-year design storm to 50 percent of the pre-development peak runoff flow from the two-year design storm.

2.4.1 General

(a) Downstream detrimental impacts shall not be increased. Where peak flow rates or volumes are increased and will cause detrimental impacts, provisions for downstream improvements must be provided.

(b) Increases in peak storm flows and volumes to the major watercourses and receiving waters shall be minimized. Consideration shall be given to fish bearing streams and to streams presently at capacity. Limits on major flood routes will be required up to the 1:100-year storm; this may be varied on a case-specific basis where justified by the Watershed Studies.

(c) The number of stormwater control facilities (if required) shall be minimized. Stormwater control facilities are described in Section C of this Manual. In general, where detention is used, off-stream storage is preferred rather than on-stream storage within a watercourse, in keeping with the policies of Fisheries and Oceans Canada. Detention facilities designed for flow control shall account for the effects of multiple storms that do not allow the detention facility to empty completely between storms. As a guideline, where single-event models are used to determine the volume of detention facilities designed for flow control, a factor of safety can be used to account for the effects of sequential storms. The factor of safety shall be 1.1 for development sites with a post-development impervious cover of 20 percent, and shall increase linearly to a factor of safety of 1.5 for development sites with a post-development impervious cover of 100 percent. Alternatively, continuous models may be used to check for the effects of multiple storms. (The design governing storm must be comparable to the probability of the design event. For example, a required 1:25 protection can be simulated by a 1:25-year and an annual storm combined event, or a 1:10 year and 1:25 year combined event. Various combinations and storm durations shall be used to determine the governing design).

(d) Groundwater infiltration is to be encouraged only where the Watershed Studies determine that this practice is appropriate. Allowance shall be made for infiltration in hydraulic design only if specified in the Watershed Studies, or if approved by the City.

2.4.2 Single and Two Family Residential Subdivisions

(a) Permanent storage facilities provided as a condition of subdivision under the Land Title Act are to be owned and maintained by the City. Permanent storage facilities provided in Bare Land Strata subdivisions will be owned and maintained by the Strata Corporation, or as specified by the City.

(b) Where land developments occur in advance of completed detention facilities or major flow routes, the City may consider temporary storage facilities on an individual basis.

2.4.3 Commercial, Industrial, Institutional and Multi-Family Residential

(a) Storage facilities (if required) may be at surface or underground, and may be either privately or City owned, as specified by the City. Rooftop or parking lot storage may be considered, where appropriate. B.C. Building Code and City bylaw restrictions shall be met when designing rooftop storage.

(b) The owner shall be responsible for the maintenance of private systems. The City may require an enforcement agreement (penalties, bonding, additional fee for periodic inspections) to allow the City to do regular inspections, carry out maintenance, and to charge back cost, if facilities are not being maintained.

2.4 Peak Flow and Runoff Volume Control cont'd/

2.4.4 Structural Considerations

(a) If a detention basin is to be constructed on-stream within a watercourse, to reduce cost it may be constructed upstream of a road crossing of the watercourse, as long as geotechnical evaluations conclude that the design is appropriate. All detention or retention facilities must be constructed to allow an overtopping release to a major floodway, without causing undue erosion or damage. All facilities on fish-bearing streams shall be designed to pass fish.

(b) All stormwater control facilities are to be designed with due concern for environmental needs, safety and aesthetics (see Section C of this Manual).

(c) Section C of this Manual and Figures 3 and 4 illustrate typical detention basin design. Appendix A provides additional criteria to be used when designing detention facilities.

(d) A pre-design engineering report is to be completed prior to design of detention facilities, and is to include geotechnical assessments of the site and structure, and the location, number, size and release rate of the proposed detention facilities.

2.5 Outlet Structures from Stormwater Control Facilities

Where a dry or wet retention or detention basin is proposed for flow control on a major system watercourse, the outlet structure must be designed for ease of operation and for hydraulic efficiency. All operational structures are to be of a free-flow, ungated type. Manual controls such as gates, valves, or stop log structures are unacceptable, although a valve for an emergency drain is required and sluice gates shall be provided for emergency releases.

Multi-inlet control structures shall be used rather than culvert restrictions. Multi-inlet structures provide consistent control for design storm flows of different return periods, and they also improve sediment capture for initial runoff. For example, three orifices located vertically on a control structure are normally designed such that the lower smaller orifice restricts smaller frequent storms, and the larger upper orifices control larger, less frequent storms.

2.5 Outlet Structures from Stormwater Control Facilities cont'd/

Consideration shall be given to the design of smaller sediment trap basins at the points of discharge into detention/retention facilities. Normally, basin inlets shall be designed to provide sediment containment in forebays. Accumulation of sediment shall not restrict inflows, and suitable designs shall be provided to allow ease of sediment removal (see Section C of this Manual).

Where storm drains or culverts exceed 150 m in length, inlets and outlets are to be protected from child entry. All inlets are to be protected from debris build-up. Downstream channels are to be protected from erosion by channel lining and/or energy dissipation.

The dam creating the basin must be designed to safely pass extreme flow events by overtopping or otherwise safely conveying excess storm flows.

2.6 Culvert and Bridge Design

Only arterial and collector roads will normally be allowed to cross major system watercourses and their crossings must normally be designed for a 1:100-year storm, unless specified otherwise in a Watershed Study.

Bridges and bottomless culverts shall be selected over conventional culverts to satisfy fisheries concerns. Where approved, culverts shall be constructed with headwalls and endwalls. Where necessary these structures shall be designed to restrict entry by small animals, such as beavers, and to allow fish passage.

2.7 Diversion Channels

Diversion channels direct runoff from undersized natural channels or storm facilities into adequate receiving channels, detention facilities or natural lakes. Roadways, stormwater interceptor sewers, or open ditches are acceptable means of diverting water. Weirs, multiple outlets or other structures at the point of diversion shall ensure low flows maintain base flows into creeks while diverting high flows into the diversion.

Roadways may convey the flow providing the flooding criteria of Section 2.3 are not exceeded. Considerations to the curb, gutter, crown and intersection grading design and construction are necessary. Inlets restricted to the capacity of the downstream drainage facilities will keep flow above the ground and on the roadway as planned during major runoff events, while allowing controlled levels of flow to enter the downstream system during minor events.

2.7 Diversion Channels cont’d/

Stormwater interceptor sewers are designed to convey major flows. Typically splitter manholes with multiple outlets are used to divert major flows and allow minor flows to continue downstream.

Alternatively, engineered ditches with a narrow invert cross section and a wide upper flood plain section may convey diversion flows. The narrow invert cross-section carries low flows with minimum risk of siltation, while the wide upper section is sized to convey major flows safely and store water restricted at culverts.

All designs of diversion channels shall follow the hydraulic criteria of this Manual.

2.8 Down Slope Cul-de-Sacs

Unless suitable major flood routes are provided, down slope cul-de-sacs from streets shall be avoided and not form part of the major system.

2.9 Watercourse Erosion and Bank Stability

Unless determined otherwise in a Watershed Study, a normal low water channel shall retain a capacity for at least a 1:5 year flood within the natural channel. Erosion protection to this level at least must be undertaken. Protection shall be designed to prevent undermining from higher floodwater stages if the channel is also used for major flows. Erosion protection may be required up to the 1:200 year floodwater elevation.

2.10 Groundwater Recharge Systems

Groundwater recharge shall not normally be considered for major flood routing. Special cases may include subdivisions where infiltration is shown in a Watershed Study to be adequate for a major storm flow and where a surface outlet is not practical. For further criteria on hydrogeologic investigation and design, see Section B, Part 3, Section 3.10 (Groundwater Recharge Systems).

3.0 MINOR SYSTEM

The minor system includes all drainage works that convey, detain, divert and intercept minor design storm runoff. The minor design storm shall be the 1:10 year storm, except the 1:25 year storm shall be used for high value commercial or industrial development and for downtown business areas, as required by the City. The determination of the minor runoff depends on the design storm, building code requirements, private lot drainage, road drainage, and storm drain hydraulics. Should downstream capacity be insufficient, the City may require some additional internal control in the form of storage on flat roofs, temporary ponding on parking areas furthest away from the building, or underground storage.

This section is to be used to determine minor flows, and for sizing drainage collectors for containment and conveyance of minor flows. Part 2, Section 2.4 of Section B should be reviewed for peak flow control design, and Section 2.5 should be reviewed for outlet structure design for minor flows.

3.1 Pipe Design

3.1.1 Pipe Capacity

The Manning formula shall be used for calculating flow using a roughness coefficient of 0.012 for PVC pipe and 0.013 for concrete pipe. Storm sewers shall not to be designed to surcharge.

3.1.2 Velocities

1. The minimum velocity in storm sewers shall be 0.75m/s flowing full.
2. If design velocity is supercritical or exceeds 3m/s, appropriate analysis and justification shall be provided and provisions made to ensure that structural stability and durability concerns are addressed and the sewers protected from displacement by erosion or thrust.

3.1.3 Minimum Pipe Diameter

1. The minimum storm sewer diameter shall be 250mm except that 200mm may be used for the upstream end of a storm sewer that cannot be extended and has no catch basins connected.
2. Downstream storm sewers shall not have a smaller diameter than those upstream regardless of grade.

3.1 **Pipe Design** cont'd/

3.1.4 Curvilinear Storm Sewers

Curvilinear sewers may only be used as approved by the Manager for special conditions and conflicts. If approved, the following criteria apply:

1. Curvilinear storm sewers shall be on a constant simple curve and only one horizontal or vertical curve is allowed between manholes.
2. Horizontal curves shall parallel the street centre line. The mid-point and quarter points of a curve shall be located by survey and the offset shown on record plans. Elevations shall be shown at 5.0m stations for vertical curves.
3. Minimum grades shall be 50 percent greater than for straight runs of storm sewer.

3.1.5 Depth of Storm Sewer

Storm sewers shall have a minimum 1.0m cover. The depth shall be sufficient to allow gravity connections from 0.6m below the existing or proposed basement floor elevation on lots abutting the storm sewer, and potentially on upstream lands in the catchment area, at a two percent grade to the crown of the storm sewer. Where it is not practical to service lots by gravity from a street storm sewer, statutory rights-of-way shall be provided. Sewer depths are generally not to exceed 3.5m. Sewers in excess of 3.5m will require site-specific review including operational, access and maintenance requirements, and subject to approval of the Manager

3.1.6 Storm Sewer Location

1. Storm sewers shall extend across the full width of each lot and extend to the boundaries of the subdivision plan to provide for further extension and connection beyond the subdivision where such extension is feasible.
2. Storm sewers within public streets or lanes shall be located in accordance with the Supplementary Detail Drawings for each classification and section of road. The minimum right-of-way width is 3.0m with the storm sewer centered within the right-of-way unless the storm sewer depth exceeds 3.0m, in which case a greater width must be provided. Sanitary and storm sewers located 1.0m apart, centered within the right-of-way may share a 3.0m right-of-way if no deeper then 2.0m but otherwise requires a 4.5m right-of-way.

3.1 Pipe Design cont'd/

3.1.6 Storm Sewer Location cont'd/

3 If a storm sewer is located within a statutory right-of-way, the property owner may be required to provide access for maintenance vehicles and equipment. The maintenance access shall be constructed to support a minimum 9.0 tonne loading.

4 A storm sewer crossing under a watercourse or under a structure shall be encased in concrete. A storm sewer under an arterial road or railway may be required to be installed inside an encasing pipe.

3.2 Manholes

Manholes shall be provided at all changes in grade, pipe size and horizontal alignment on non-curvilinear storm sewers and at existing, and planned, intersecting storm sewers. The maximum distance between manholes shall be as follows:

Pipe Size (mm diameter)	Maximum Distance (m)
375 and smaller	125
450 to 750	155
900 and larger	185

Cleanouts with diameter of 200mm may be used as an alternative to a manhole at the upper end of a storm sewer where it is within 45m of an existing manhole and the depth of the storm sewer is less than 2.0m.

Manhole and cleanout locations shall not conflict with curbs, gutters or sidewalks, and, where possible, shall be located outside of the wheel path of normal traffic flow.

Manhole rim elevations in off-road areas shall be set below adjacent sanitary manhole rim elevations.

The crown of the inlet pipe must not be lower than the crown of the outlet pipe.

3.2 Manholes cont'd/

For storm sewers 600mm diameter or less, the minimum drop in invert levels to compensate for changes in flow direction through manholes is:

- deflections up to 22 ½° — no drop required
- deflections up to 45° — 25mm
- deflections up to 90° — 50mm

Detailed engineering calculation is required for head losses for sewers greater than 600mm diameter.

Horizontal changes of direction greater than 90° are not permitted in a manhole.

Where a future storm sewer will be extended from a manhole, a capped stub shall be placed with the grade, size and location suitable for future extension. Where required, a temporary inlet shall be placed with its invert less than 900mm below the road surface and connected to the stub with a manufactured wye.

3.3 Service Connections

Service connections of an adequate size, but not less than 150mm diameter shall be provided from the storm sewer within the property to 2.0m beyond the property line for each new lot or to the property line for each existing lot. For existing lots with more than one storm service, additional service connections shall be provided to match the existing service diameter but shall not be less than 150mm. In industrial areas, service connections shall be placed to serve each side of the road at 45m intervals. Where possible service connections shall be located adjacent to sanitary sewer service connections. The cover from finished surface at the property line or edge of right-of-way must be a minimum of 1.0m.

Service connections not connected shall be capped and marked with a post. Curb saw cuts shall be provided to locate all service connection alignments and the cuts shall be painted green.

Service connections from industrial properties and from other properties requiring a connection greater than two pipe sizes smaller than the storm sewer must enter the storm sewer at a manhole.

3.3 Service Connections cont'd/

When a half or partial road is constructed, service connections may need to be extended toward the opposite side of the road such that completion of servicing will not involve trenching in the completed portion of the road. Extensions of service connections will require ultimate lot patterns of opposite lands to be established and subject to direction and approval of the Manager.

Inspection chambers shall be provided for each connection, with the inlet side either connected to an existing building storm sewer or land drain, or extending 2m beyond the inspection chamber, capped and marked with a green painted post (90mm x 40mm). Inspection chambers must be centered precisely at a 300mm offset from property line to allow gas mains to be laid between the inspection chamber and sidewalk without damage to either.

3.4 Connection of Foundation Perimeter Drains and Services

Unless otherwise authorized by the City, foundation perimeter drains shall be connected by gravity to the storm sewer system, provided that the elevation of the basement floor is at least 600mm above the elevation of the building service connection at property line or 150mm above the major hydraulic gradeline at that point, whichever is higher.

For buildings located close to a storm sewer outfall or watercourse, there is the additional requirement that the basement floor elevation shall also be set at the floodplain elevation of the receiving water as defined by the Ministry, or the major hydraulic gradeline at the point of discharge.

3.5 Lot Grading, Swales and Driveways

Lots over 0.5 ha shall be graded to drain away from building foundations and to a drainage system or natural drainage path. Lawn drains, swales and, if necessary, French drains shall be installed to prevent surface water run-off flowing onto adjacent lots and connected to the storm drainage system. If lots must drain towards other parcels, swales shall be provided and protected by easements.

A Minimum Building Elevation (MBE) for each lot and/or building site shall be established and recorded on the lot grading plans by the consulting engineer. The MBE is the lowest elevation permitted for a floor slab or underside of joists above a crawl space and shall be at least 600mm above the building service connection invert at the property line plus an allowance for the installation of a service connection from the building, or 150mm above the 100-year hydraulic grade line whichever is higher.

3.5 Lot Grading, Swales and Driveways cont'd/

Swales along rear, front and side yards may be used in conjunction with lot grading to protect property from overland sheet flow from adjacent uphill properties. A lot grading swale shall be protected by a registered easement in favour of all upstream properties. Easements shall be 1.8m wide, unless also occupied by drainage pipes, in which case they must be 3.0m wide. Lot grading swales shall have 150mm minimum depth, 1.5m width, one percent minimum grade, velocity limited to 1m/s and be lined with turf on a minimum of 100mm of topsoil or some other protection from erosion (see Section C for additional design guidance). Maintenance of the swale will be the responsibility of the property owner.

To facilitate surface drainage, and unless otherwise approved by the City, the guidelines listed below shall be followed for lot grading and swales.

(1) For single-direction drainage, there shall be a two percent minimum grade away from the building location.

(2) For double-direction drainage, there shall be a one percent minimum grade away from the building location.

(3) Semi-detached units shall be treated as a single lot. However, the City encourages two-direction drainage systems for such units.

(4) Strata title complexes shall incorporate internal drainage systems by catch basins and storm sewers in accordance with City standards.

(5) Link (duplex to triplex) units shall be treated as one single lot. However, on one-direction drainage systems, the apron swale shall be two percent minimum.

(6) Various house styles (i.e. back-splits, walkouts, side-splits and front-splits) shall be encouraged to suit the lot grading.

(7) Lawns and swales shall have a minimum slope of 1 percent. Swales along rear lot lines shall be two percent minimum, to a maximum length of 60m before interception.

(8) Retaining walls with adequate drainage systems shall be used where deemed necessary.

(9) Minimum driveway slope shall be 0.50 percent. A driveway sloping down towards a building shall be designed so that runoff water cannot accumulate and/or enter any building.

3.5 Lot Grading, Swales and Driveways cont'd/

Additionally, to ensure driveway flooding is avoided, carports or garages attached to residential buildings shall not be constructed with the floor level below the adjacent curb of the City street or crown of pavement of the City street unless:

(a) the drainage of the driveway serving the carport or garage is connected by gravity to a City storm sewer and above the 100-year hydraulic gradeline of the drainage system; or

(b) the runoff water from the driveway can flow through or past the carport without accumulating and entering into the residence; or

(c) where a storm sewer connection is not available, the drainage of the driveway serving the carport or garage shall be designed by a Professional Engineer registered in the Province of British Columbia.

3.6 Catch Basins and Subgrade Drains

Catch basins shall be provided as required to collect from a maximum area of 400m^2 of road, at the beginning of curb returns to which water flows and at low points. Leads shall be a minimum 150mm diameter except where one lead services a double catch basin in which case the lead shall be 200mm in diameter. Double catch basins shall not be directly connected to each other but by a wye in the leads. The minimum grade for leads shall be one percent and the maximum length of catch basin leads shall be 30m. Rim elevations shall be 30mm below finished pavement grade.

Side inlet catch basins shall be used on arterial and collector roads, low points of local roads and cul-de-sacs and on all roads with grades greater than five percent.

Road subgrade drains shall be provided in accordance with the Supplementary Specifications for Contract Documents, Drawing No. COQ-SW1.

Lawn basin leads shall be a minimum of 150mm with a minimum grade of one percent and connect directly to a manhole or be provided with an inspection chamber at the property line.

3.7 Inlet Structures

Storm sewer inlet structures shall be provided as follows:

- Supplementary Detail Drawing COQ-S13A shall be used where a ditch conveys storm water into the storm system of the proposed development and the inlet pipe is not greater than 450mm diameter;
- MMCD Drawing S13 shall be used where the inlet pipe is greater than 450mm diameter;
- Lawn basin MMCD Drawing S12 shall be used in local low spots where storm water is unable to reach the storm system by a ditch.

3.8 Culverts

1. Driveway culverts shall be designed to convey the minor flow with the headwater not backed up above the crown of the culvert.
2. Culverts located on natural watercourses and culverts under roadways shall be designed to convey the major flow.
3. Inlet and outlet structures with energy dissipation, scour protection, overflow protection and erosion control are required on all culverts designed to convey the major flow.
4. Surcharging at an inlet under major flow is acceptable provided that the headwater profile does not rise above the MBE of adjacent properties. The maximum elevation of standing water above existing finished ground surfaces, parking lots, street surfaces, etc. caused by any surcharging shall not be greater than 300mm. Adequate erosion protection shall be required where surcharging is evident.

3.9 Outfall Structures

Minor system outfalls into watercourses shall be designed recognizing aesthetics and erosion control. End walls shall be designed in accordance with MMCD Drawing S14. When culverts or storm sewers are greater than 600mm, the outfall pipe or structure shall be protected against entry by a free swinging, weighted grating, which will allow passage of materials on discharge. To protect against entry, the City may require a locking mechanism that limits the arc of the grating.

Outlets having discharge velocities greater than 1m/s shall require evaluation of the downstream channel and rip-rap or an approved energy dissipating structure may be required to control erosion. Energy dissipation shall be provided on outfalls to watercourses to reduce maximum outlet flow velocity to 1m/s.

Structures exceeding 1m in height and/or 2m in width shall require individual structural design and shall include safety railing, where specified by the City.

3.10 Groundwater Recharge Systems

To promote a reduction in storm flows and maintenance of stream base flows, groundwater recharge systems shall be investigated and used where shown to be appropriate and technically feasible and as recommended in the Watershed Studies, or as otherwise approved by the City. Roof downspout systems that discharge to the ground may be required for new building construction of single-family homes and duplexes where it has been shown within the watershed study that local conditions are suitable for these systems. All roof downspout systems shall include an overflow bypass to the minor drainage system. Roof downspout systems shall be designed to infiltrate roof runoff only, and shall be sized for the two-year design storm (see Section C of this Manual for design guidance). The minor and major drainage systems shall not be downsized to account for stormwater infiltration from roof downspout systems. However, infiltration may be used to achieve the post-development peak runoff rate from the two-year return storm as specified in Section 2.4 of this Manual.

Only infiltration of uncontaminated runoff will be considered. Recharge facilities are to be installed in accordance with standards established by good engineering practice. Stilling ponds, sumps or filtration beds are to be used for protection of groundwater recharge systems. Facilities for infiltration of stormwater are described in Section C of this Manual.

3.10.1 Hydrogeologic Investigation

As a minimum, the following hydrogeological determinations shall be undertaken by a qualified hydrogeologist when proving out a groundwater infiltration system for an individual development:

(1) area availability and integration with land use plans;
(2) review soil permeability and infiltration rates;
(3) groundwater levels (may require piezometers to evaluate levels over seasonal groundwater highs);
(4) accessibility of high permeability soil units capable of accepting a high flow with minimum affect on groundwater table (determine transmissibility and storage coefficients – a test well or wells may be required);
(5) confirmation that no groundwater discharge areas will substantially decrease or increase in flow as a result of the infiltration system;
(6) effect of sediment loads on infiltration structures and the consequences of plugging of the water-soil interface;
(7) impact on groundwater quality;
(8) maintenance of structures and costs;
(9) design simplicity;
(10) provision for overflow;
(11) provisions for system failure (1.5 times design or 50 percent standby areas minimum);
(12) performance assessments from records of other systems of similar design for the area.

3.10 Groundwater Recharge Systems cont'd/

3.10.2 Methods and General Suitability

The following methods should be considered where shown to be suitable:

1.	exfiltration (retention) basins and drainfields (areas underlain with perforated pipe networks)		not suited for fill areas or areas with high groundwater tables
2.	trenches or drainfields		suitable only for undisturbed ground where water can move horizontally out of trenching and where drainage water is free from silts – this is especially a concern in areas with new development where filtration or stilling basins will be required
3.	dry wells or sumps		suitable for areas with low groundwater tables or suitable as part of a storm sewer network in conjunction with outfall – where used independently, an accessible filtration bed shall be included

3.11 Water Quality Protection and Enhancement

3.11.1 Water Quality Control

A water quality control plan may be required as part of the Stormwater Management Plan at the discretion of the City where there are reasonable grounds to anticipate discharge of prohibited materials to the drainage system as defined in City bylaws.

A Water Quality Inlet or Coalescing Plate Separator shall be required to treat the runoff from all impervious surfaces at fuel transfer stations and other operations where there is a risk of spills of petroleum hydrocarbons (see Section C for design guidance).

Bio-retention or dry swale with under-drain systems or equivalent shall be provided to treat the runoff from all uncovered paved parking areas capable of containing ten or more vehicles. Parking areas surfaced with (porous) concrete grid or modular pavers shall be exempt from providing bio-retention or dry swale systems (see Section C for design guidance).

3.11 Water Quality Protection and Enhancement cont'd/

3.11.2 Water Quality Design Volume

Where structural facilities for contaminant removal are required and single event runoff models are used, facilities shall be designed to treat the runoff volume resulting from the 24-hour storm with a six-month return frequency, unless specified otherwise in a Watershed Study. The six-month, 24-hour storm can be estimated as 70 percent of the two-year, 24 hour storm. Where continuous runoff modelling is used, contaminant removal facilities shall be designed to treat 90 percent of the runoff volume in an average year.

3.11.3 Sediment Capture and Treatment

Criteria for sediment control plans and for the allowable concentration of suspended solids in stormwater discharged to the downstream receiving environment are given in City bylaws. If runoff water is contaminated, it must be treated prior to infiltration. Where heavy silt laden water is anticipated on a temporary basis (during a subdivision development including the period of building erection up until all open areas are grassed or stabilized), sediment traps or temporary filtration devices shall be used to offload any permanent facilities. The development proponent is required to submit to the City a Sediment Control Plan in accordance with the requirements of city bylaws as part of the Phase 2 – Stormwater Management Plan submission. An example site layout is shown on Figure 5. Use of synthetic erosion mats, natural erosion control blankets and hydroseeding are encouraged. A reference for detailed guidance for erosion and sediment control at construction sites is provided in Section C, Part 1.1 of this Manual.

4.0 ANALYTICAL CRITERIA

In this section hydraulic and hydrologic criteria to be used for estimating runoff flows and volume are described.

4.1 Hydraulic Criteria

Hydraulic criteria are used for four aspects of drainage design as follows:

(1) to route storm flows through natural and man-made channels, and to allow estimation of travel times, (steady, uniform flow);

(2) to route storm flows through special structures such as culverts, weirs or flow control devices (steady, gradually and rapidly varied flow);

(3) to control flow rates and minimize erosion in natural channels; and

(4) to ensure scour velocities for sediment transport in pipes to downstream silt traps or other capture/treatment facilities.

4.1.1 Steady, Uniform Flow Criteria

Open channel design flows shall be as specified in this Manual and in the Watershed Studies. The design criteria and procedures contained in this Manual shall be used for both desktop calculations and computer model flow routing, unless specified otherwise in a Watershed Study.

4.1.2 Steady, Varied Flow Criteria

Varied flow conditions through culverts and detention basin flow control devices such as weirs or restrictions may be analyzed by published nomographs for culvert inlet and outlet analysis. Control orifices and weirs should be analyzed from first principles. Hydraulic software may be used within the limitations of the flow analysis of the software.

Inlet control nomographs or charts are made available from American Concrete Pipe Institute (1990), and American Iron and Steel Institute (1995). These can be used with appropriate inlet contraction coefficients when inlet conditions are shown to govern. Pipe or uniform flow design criteria are assumed when inlet conditions do not govern. The type of flow condition shall be confirmed.

4.1 Hydraulic Criteria cont'd/

4.1.2 Steady, Varied Flow Criteria cont'd/

Detention basin gravity release designs shall be based on stage-discharge curves for orifice plates and overflow weirs. For orifices or weirs, stage-discharge (water elevation head for corresponding flow) curves are developed from appropriate contraction losses or weir formulas. Multiple control orifices shall be used for detention control structures. Orifices shall be sized to provide control for a series of design storm frequencies starting with the two-year return storm as specified in Section 2.4 up to the detention design flood storm.

Backwater curves, when required, shall be prepared by appropriate hand or computer techniques for Manning's formula open channel flow hydraulics. Stream channels and pipe lengths may be considered as uniform shapes.

Inlet control depths at culverts for major floodways may be used as starting points for determination of backwater curves in the upstream channel. This may be performed manually or by an appropriate computer model; recommended roughness coefficients are shown in Section B, Part 4.2.2 (f).

4.1.3 Reservoir Routing

For detention storage, routing procedures for determining control orifice sizing may follow the conservation of mass approach. Average inflow minus average outflow equals the rate of change in storage, as shown in Equation 1.

$$\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} = \frac{S_2 - S_1}{60(t_2 + t_1)} \qquad (1)$$

Equation 1 can be re-arranged as shown in Equation 2:

$$\frac{I_1 + I_2}{2} + \frac{S_1}{60(t_2 - t_1)} - \frac{Q_1}{2} = \frac{S_2}{60(t_2 - t_1)} + \frac{O_2}{2} \qquad (2)$$

where: I_1 and I_2 are known inflows at time t_1 and t_2 from inflow, m^3/s

S_1 and S_2 are hydrograph storage volumes at time t_1 and t_2, m^3

O_1 and O_2 are outflows at t_1 and t_2, m^3/s

Initial outflow O_1 is known, m^3/s

(t_2-t_1) is the time increment, minutes

4.1 Hydraulic Criteria cont'd/

4.1.3 Reservoir Routing cont'd/

$$\frac{S_2}{60(t_2 - t_1)} + \frac{O_2}{2}$$

is plotted against O_2 from the known head-storage relationship for the detention basin and outflow structure.

Predetermined values for the storage and respective outflow discharge relationships may be determined by the criteria described in Section 4.1.2.

The known quantities on the left hand side of Equation 2 allow determination of the right hand side. Values of O_2 can then be estimated from the above noted plot, tabulated and used to calculate the next step until an outflow hydrograph is produced. Alternatively, computer software may be used to perform the calculations once the stage-storage and head-discharge data are prepared.

4.1.4 Erosion Guidelines

Velocity in water courses is not to exceed critical velocity (i.e. should remain subcritical) unless control structures are provided. Generally maximum velocities allowable unless specified otherwise by the City are as follows:

Lining Materials	Maximum Permissible Velocity m/s
Fine sand	0.45
Sandy loam	0.5
Silt loam	0.6
Ordinary firm loam	0.75
Stiff clay	1.1
Shales and hardpans	1.8
Fine gravel	0.75
Graded silt to cobbles	1.2
Coarse gravel	1.2
Cobbles	1.5
CMP channels, sewers and culverts (concrete and asphalt)	7.3

Guidance for erosion protection and sediment control on construction sites can be found in Section C of this Manual. Grass seeding is generally required on cut banks to provide slope stabilization. Table 4-1 provides a general summary of information provided by USEPA (1972), and presents gradient maximums to minimize erosion.

4.1 Hydraulic Criteria cont'd/

4.1.4 Erosion Guidelines cont'd/

TABLE 4-1

GENERAL EROSION PROTECTION CRITERIA (summarized from USEPA, 1972)*

Method	Drainage Area	Depth	Height	Duration of normal use	Maximum side slopes	Stabilization
Sodded channels	No size limit	0.1-0.9m parabolic; 0.15-1.8m trapezoidal	--	permanent	3:1	Sod; stone bottom for base flows. Slope: <1 percent
Asphalt or stone channels	No size limit	0.3m min.	--	permanent	2:1	Slope: 1 percent or greater
Berms	Less than 2.0 ha	--	450mm max.	temporary	3:1	Slope of channel: grass or erosion protection blanket; slope < 1 percent asphalt or stone slope > 1 percent to 5 percent
Culverts and sewers	No size limit	--	--	permanent	--	Gravel bedding with compacted fill, stone, asphalt or concrete apron at outfall or velocity breaker if velocity > 3.1m/s.

* Guidelines for Erosion and Sediment Control: Planning and Implementation, U.S. Environmental Protection Agency, 1972.

4.1 Hydraulic Criteria cont'd/

4.1.5 Control of Gullying and Incision

Where existing gullies or earthen channels are used for discharge and if slopes are required to be steeper than those allowed for in Table 4-1, or if velocities exceed recommended maximums, boulder or concrete block control steps shall be provided such that the length between steps and pools is found by Equation 3.

$$L = 0.3113 / S^{1.188} \quad (3)$$

where: L = length between steps, m

S = slope, m/m

at 5 percent slope, L = 11m

at 20 percent slope, L = 2m

The drainage channel shall be constructed at the natural slope using the step - pool design. The pool shall be sized to provide energy dissipation and the control step shall be designed to avoid toe erosion. The steps shall be keyed into the banks on either side of the gulley.

4.2 Hydrologic Criteria

This section describes the hydrologic methods to obtain design storm flows for the City to be used in the preparation of Stormwater Management Plans. Precipitation and physical data to conduct hydrologic analysis to obtain the design storm flows are also given. Discharge estimates from the Rational method, or computer rainfall-runoff simulation models where approved by the City, shall determine sizes for drainage conveyance facilities as appropriate and as approved by the City. To size drainage storage facilities, approved computer rainfall-runoff simulation models is the preferred method.

4.2.1 Rational Method

The Rational Method requires calculation of concentration times and establishment of ground surface conditions. Normally, the method should be restricted to design of drainage systems for areas less than 10 ha (25 acres). The Rational Method formula and variables are shown in Equation 4.

4.2 Hydrologic Criteria cont'd/

4.2.1 Rational Method cont'd/

$$Q = KCIA \quad (4)$$

where: Q = Flow in m^3/s

K = Dimensionless constant to establish units of compatibility (= .00278)

C = Runoff coefficient (dimensionless)

I = Rainfall intensity in mm/hr

A = Runoff area in hectares

In the case of applying the Rational Method to mixed land use in a drainage area, a weighted average C value should be used as calculated from Equation 5.

$$C_{avg} = \Sigma \frac{A_i C_i}{A} \quad (5)$$

where: A_i is the area with the same type of land use correlated to runoff coefficient C_i, and A is the sum total of all areas, A_i.

The estimated rainfall intensity for the Rational Method is equal to the Time of Concentration as calculated in Section 4.2.3. A minimum inlet time of ten minutes shall be used when calculating peak flows with the Rational method. Runoff coefficients for various land uses developed by the City of Coquitlam are shown in Table 4-2.

TABLE 4-2

RUNOFF COEFFICIENTS © FOR RATIONAL METHOD

Description of Area	Runoff Coefficient
Downtown Commercial Area	0.80
Highway Commercial and Light Industrial Areas	0.80
Apartment and Other High Density Multiple Family Areas	0.80
Single Family Residential, Duplex and Low Density Multiple Family Areas	0.67
Open Areas, Parks, and Playgrounds	0.30

4.2 Hydrologic Criteria cont'd/

4.2.2 Computer Rainfall/Runoff Simulation Models

For areas larger than 10 hectares, or with complicated land use patterns, or where hydrograph volumes for determining storage purposes are required or where required by a Watershed Study, computer rainfall/runoff simulation models shall be used. Computer models as approved by the City may be used to determine peak flows and hydrograph volumes.

The simulation model shall be validated and properly calibrated under local conditions before its actual application. Calibration data may be available from Watershed Studies or other sources.

The precipitation and physical criteria as described below shall be used for the estimation of runoff by the Rational method and computer simulation models.

4.2.2(a) Design Rainfall

Figure 6 shows the four rainfall zones identified for use in the City of Coquitlam: Zone 3, 4, 5 and 6. Where a parcel crosses two rainfall zones, the higher rainfall zone shall be used.

Design IDF Curves. Two sets of IDF curves are provided:

- 2021 IDF Curves: Shall be used to evaluate the capacity of existing infrastructure.
- 2050 IDF Curves: Shall be used for sizing proposed new or replacement infrastructure (to accommodate new development, to address existing system capacity or condition deficiencies, to upgrade existing infrastructure as part of the frontage works program, etc..).

Figures 7 through 10 show the 2021 rainfall intensity-duration-frequency curves developed for each of the rainfall zones. Figures 11 through 14 show the 2050 rainfall intensity-duration-frequency curves developed for each rainfall zone for 2050.

Alternatively, the rainfall IDF curves for a particular return period can be mathematically represented in the form of Equation 6.

$$I = Ac \times T^{B} \qquad (6)$$

where: I = rainfall intensity, mm/hr
T = storm duration, hours (greater than five minutes)
Ac, B = constants used to develop Figures 7 through 10 are shown in Table 4-3.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(a) Design Rainfall cont'd/

TABLE 4-3

MATHEMATICAL CONSTANTS FOR DERIVING 2021 IDF CURVES

Rainfall Station	Storm Return Frequency					
	2-year	5-year	10-year	25-year	50-year	100-year
Zone 3						
• Coefficient Ac	12.208	16.033	18.764	22.559	25.467	28.529
• Coefficient B	-0.460	-0.476	-0.483	-0.491	-0.494	-0.496
Zone 4						
• Coefficient Ac	11.834	15.304	17.701	20.822	23.204	25.640
• Coefficient B	-0.444	-0.458	-0.466	-0.475	-0.480	-0.485
Zone 5						
• Coefficient Ac	12.933	17.225	20.334	24.506	27.828	31.332
• Coefficient B	-0.447	-0.470	-0.486	-0.506	-0.521	-0.536
Zone 6						
• Coefficient Ac	14.672	18.873	21.606	25.134	27.662	30.233
• Coefficient B	-0.408	-0.421	-0.429	-0.440	-0.447	-0.455

TABLE 4-4
MATHEMATICAL CONSTANTS FOR DERIVING 2050 IDF CURVES

Rainfall Station	Storm Return Frequency					
	2-year	5-year	10-year	25-year	50-year	100-year
Zone 3						
• Coefficient Ac	16.439	22.821	27.470	34.017	39.002	44.272
• Coefficient B	-0.458	-0.475	-0.483	-0.492	-0.494	-0.496
Zone 4						
• Coefficient Ac	15.928	21.862	25.961	31.240	35.263	39.378
• Coefficient B	-0.442	-0.457	-0.466	-0.474	-0.479	-0.484
Zone 5						
• Coefficient Ac	17.149	23.588	28.365	34.878	40.113	45.564
• Coefficient B	-0.441	-0.467	-0.483	-0.503	-0.518	-0.533
Zone 6						
• Coefficient Ac	19.254	25.169	29.292	34.650	38.480	42.329
• Coefficient B	-0.403	-0.416	-0.424	-0.436	-0.443	-0.451

Design Rainfall Pattern. The 1-hour pattern fitted curve as shown on Figure 15 shall be used for durations shorter than six hours. The 12-hour pattern fitted curve as shown on Figure 16 shall be used for storm durations of 6 hours or more.

Design Hyetograph. A synthetic rainfall shall be used for the design rainfall hyetograph. The synthetic hyetograph may be developed by use of Figures 7 through 14 in conjunction with Figures 15 and 16 for the applicable storm duration and intensity relationships.

4.2.2(b) Time of Concentration

To find the design peak discharge for the drainage area, the time of concentration must be calculated. If the slope and land use of the overland flow reach are known, the average flow velocity may be read from Figure 17 (U.S.D.A., S.C.S., 1975). The travel time is then calculated by dividing the total overland flow length by the average velocity. By adding an inlet time, the total time of concentration may be estimated. When appropriate, Figure 17 may be used to calculate inlet time where none is specified. The time of concentration may be determined by adding the inlet time and the travel time.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(c) Time to Peak (T_p)

The T_p is generally assumed to be 2/3 of the time of concentration, unless recorded hydrographs show otherwise. T_p is a parameter of OTTHYMO models.

4.2.2(d) Curve Number (CN)

Drainage sub-catchments should have uniform runoff characteristics; each should be represented by a single hydrologic soil cover complex. The hydrologic soil cover complex is determined by a combination of soil group and land use conditions; its effect on the runoff is represented by the curve number, CN. For multiple land uses found in urban areas, a composite weighted CN shall be determined for the drainage area. The CN value is to be confirmed by the City; it should reflect the land use and soil types of the study area.

The soil of the catchment area is classified as A, B, C or D for increasing order of runoff potential. The classifications are described below.

A - Soils that have high infiltration rates even when thoroughly wetted and consist chiefly of deep, well-drained to excessively-drained sands or gravels. These soils have a high rate of water transmission.

B - Soils that have moderate infiltration rates when thoroughly wetted and consist of moderately deep to deep, moderately well-drained to well-drained soils within moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C - Soils that have slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D - Soils that have slow infiltration rates when thoroughly wetted and consist chiefly of clays that have a high swelling potential, a permanent high water table, or a clay pan or clay layer at or near the surface, and shallow soils that are over nearly impervious material. These soils have a very slow rate of water transmission.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(d) Curve Number (CN) cont'd

The cover condition is also included in the description of the soil cover complex, as in Table 4-5, through the runoff curve number, CN. The hydrologic condition of the soil-cover complex must be estimated.

Three levels of antecedent moisture conditions (AMC) are possible. The heavier the antecedent rainfall, the higher will be the runoff potential. AMC III is to be used to calculate runoff in the City for winter storms or rainfall on snowmelt. AMC II may be used for short duration summer storms, as described below. AMC I is not to be used for design flows but may be used to estimate pre-development flows.

AMC I - Soils are dry but not to the wilting point (Five day average sunny condition for non-irrigated areas).

AMC II - An average condition, and representative of normal conditions in the City. Type AMC II is normally to be used for minor drainage design.

AMC III - Heavy or light rainfall and low temperatures have occurred during the five days preceding the design storm, and the soil is nearly saturated.

The CN values for AMC II are shown in Table 4-5. Table 4-6 can be used to convert CN values from AMC II to AMC III and AMC I. Figure 18 can be used for Type A soils, and Figure 19 for Type B, C and D soils.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(d) Curve Number (CN) cont'd/

TABLE 4-5

RUNOFF CURVE NUMBERS FOR SELECTED LAND USE TYPES (ANTECEDENT MOISTURE CONDITION II, AND I_A = 0.2S)

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated Land 1)	: without conservation treatment	72	81	88	91
	: with conservation treatment	62	71	78	81
Pasture or Range Land	: poor condition	68	79	86	89
	: good condition	39	61	74	80
Meadow	: good condition	30	58	71	78
Wood or Forest Land	: thin stand, poor cover, no mulch	45	66	77	83
	: good cover 2)	25	55	70	77
Open Spaces, Lawns, Parks, Golf Courses, Cemeteries, etc.					
Good Condition	: grass cover on 75 percent or more of the area	39	61	74	80
Fair Condition	: grass cover on 50 percent or more of the area	<u>49</u>	<u>69</u>	<u>79</u>	<u>84</u>
Commercial and Business Areas (85 percent impervious)		89	92	94	95
Industrial Districts (72 percent impervious)		81	88	91	93
Residential 3)					
Average Lot Size	Average Percent Impervious 4)				
0.005 ha (1/8 acre or less)	65	77	85	90	92
0.01 ha (1/4 acre)	38	61	75	83	87
0.013 ha (1/3 acre)	30	57	72	81	86
0.02 ha (1/2 acre)	25	54	70	80	85
0.04 ha (1 acre)	20	51	68	79	84
Paved Parking Lots, Roofs, Driveways, etc.		95	95	95	95
Streets and Roads:					
Paved with Curbs and Storm Sewer		95	95	95	95
Gravel		76	85	89	91
Dirt		72	82	87	89

NOTES:

- For a more detailed description of agricultural land use curve numbers, refer to National Engineering Handbook, Section 4, Hydrology, Chapter 7, August 1972.
- Good cover is protected from grazing and litter and brush overgrown cover soil.
- CNs are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur. (Refer to appropriate section for other conditions). Where roof drains are directed towards lawns, reduce CN by 5 percent.
- The remaining pervious area (lawn) are considered to be in good pasture condition for these CNs.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

TABLE 4-6 - RUNOFF CURVE NUMBERS CONVERSION TABLE
CURVE NUMBERS (CN) AND CONSTANTS FOR THE CASE I_A = 0.2S

1	2	3	4	5	1	2	3	4	5
CN for Condition II	CN for Conditions		S Values (mm)	Curve* starts where P=(mm)	CN for Condition II	CN for Conditions		S Values (mm)	Curve* starts where P= (mm)
	I	III				I	III		
100	100	100	0	0	60	40	78	169	33.8
99	97	99	2.6	0.5	59	39	77	177	35.3
98	94	99	5.2	1.0	58	38	76	184	36.8
97	91	99	7.8	1.5	57	37	75	192	38.4
96	89	98	10.6	2.0	56	36	75	200	39.9
95	87	98	13.4	2.8	55	35	74	208	41.7
94	85	98	16.2	3.3	54	34	73	216	43.2
93	83	97	19.1	3.8	53	33	72	225	45.0
92	81	97	22.1	4.3	52	32	71	234	47.0
91	80	96	25.1	5.1	51	31	70	244	48.8
90	78	96	28.2	5.6	50	31	70	254	50.8
89	76	95	31.5	6.4	49	30	69	264	52.8
88	75	95	34.5	6.9	48	29	68	274	54.9
87	73	94	37.8	7.6	47	28	67	287	57.4
86	72	94	41.4	8.4	46	27	66	297	59.4
85	70	93	44.7	8.9	45	26	65	310	62.0
84	68	93	48.3	9.7	44	25	64	323	64.5
83	67	92	52.1	10.4	43	25	63	335	67.1
82	66	92	55.9	11.2	42	24	62	351	70.1
81	64	91	59.4	11.9	41	23	61	366	73.2
80	63	91	63.5	12.7	40	22	60	381	76.2
79	62	90	67.6	13.5	39	21	59	396	79.2
78	60	89	71.6	14.2	38	21	58	414	82.8
77	59	89	75.9	15.2	37	20	57	432	86.4
76	58	88	80.3	16.0	36	19	56	452	90.4
75	57	88	84.6	17.0	35	18	55	472	94.5
74	55	87	89.2	17.8	34	18	54	493	98.6
73	54	86	94.0	18.8	33	17	53	576	103.1
72	53	86	98.8	19.8	32	16	52	538	107.7
71	52	85	104	20.8	31	16	51	564	112.8
70	51	85	109	21.8	30	15	50	592	118.4
69	50	84	114	22.9					
68	48	84	119	23.9	25	12	43	762	152.4
67	47	83	125	24.9	20	9	37	1016	203.2
66	46	82	131	26.2	15	6	30	1440	288.0
65	45	82	137	27.4	10	4	22	2286	457.2
64	44	81	142	28.4	5	2	13	4826	965.2
63	43	80	149	29.7	0	0	0	4	4
62	42	79	156	31.2					
61	41	78	162	31.5					

* for CN in column 1. Source: U.S. Soil Conservation Service

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(e) Number of Linear Reservoirs (N)

The number of linear reservoirs is a parameter that defines the shape of a hydrograph when using OTTHYMO NASHYD commands for estimating rural runoff. The number N shall be 3 unless the slope of the catchment is greater than 15 percent, in which case, the number N shall be 5.

4.2.2(f) Roughness Coefficients (n)

The Mannings "n" for open channels shall reflect the condition of the invert and side banks, as shown below.

• Smooth concrete	0.013
• Rough concrete	0.017
• Smooth asphalt	0.012
• Rough asphalt	0.016
• Packed clay	0.020
• Sandy silts	0.030
• Cobbles gravels	0.040
• Grass	0.030
• Weedy vegetation, crops	0.040
• Shrubs, bushy vegetation	0.050
• Dense weeds up to flow depth	0.080
• Dense brush, trees	0.100

4.2.2(g) Pervious and Impervious Surfaces

The SWMM and HYDSYS models estimate the runoff from pervious and impervious surfaces separately. The runoff from impervious surfaces may be directly connected to the urban drainage system such as driveways or roofs connected to the storm sewer system, or indirectly connected as in the case where the roof drains onto the yard before the runoff reaches the storm sewer system. Table 4-7 may be used as a guide in modelling urban areas with SWMM or HYDSYS models.

4.2.2 Computer Rainfall/Runoff Simulation Models cont'd/

4.2.2(g) Pervious and Impervious Surfaces cont'd/

TABLE 4-7

HYDSYS LAND USE ZONES

Zone	Description	Contributing Pervious Percentage (Grassed Area)	Contributing Indirectly Connected Impervious Percentage	Contributing Directly Connected Impervious Percentage
Res1	Residential – low density	50	5	45
Res2	Residential – medium and high density	15	5	80
Park	Parks and Open Space[(1)]	65	5	15
School	Public and Institutional	65	5	30
Crops	Rural Agricultural[(1)]	75	5	10
Comm	Urban and Community Commercial	10	5	85
Ind1	Light Industry and Service Commercial	10	5	85

(1) Where percentages do not add to 100 percent, the difference is assumed not to contribute to runoff.

5.0 STORMWATER MANAGEMENT PLAN

The City will over time complete individual Watershed Studies throughout the City. Development proponents are to develop a Stormwater Management Plan for each development, such that the Stormwater Management Plan fits within the appropriate Watershed Study. This Manual, City policies and bylaws, and senior government policies and regulations provide additional details and engineering requirements. In the absence of a Watershed Study, the Stormwater Management Plan shall be completed according to the requirements and criteria set out in this Manual. Where a Watershed Study is in place, additional or alternative requirements and criteria may be identified and shall be incorporated into the Stormwater Management Plan.

The Stormwater Management Plan shall be submitted in two Phases. Each phase shall be based on the guidelines included in this manual, and on detailed specifications included in relevant City bylaws. The two phases of submission required are described in Sections 5.1 and 5.2.

A hydrogeologic investigation is required for all proposed developments within the City. The timing of this investigation is contingent upon the nature of the development and relevant concerns; however, investigations will generally be completed in two phases in conjunction with the Stormwater Management Plan, Phase 1 and 2 reports. As such, the two phases will contain differing levels of detail. The scope of the investigation will be determined by the nature and the specifics of the development.

5.1 Stormwater Management Plan, Phase 1 – Preliminary Planning Report

The Phase 1 - Preliminary Planning Report is a stormwater management concept plan that supports a rezoning, or subdivision or building permit application. Phase 1 is a general investigation that forms the basis for the drainage requirements of individual developments, or of development phases contained in a longer term development. The Phase 1 Report must be submitted to and approved by the City to support the rezoning, or subdivision or building permit application.

5.1 Stormwater Management Plan, Phase 1 – Preliminary Planning Report cont'd/

5.1.1 Objectives

1) to define the boundaries of sub-basins for further detailed investigations;
2) to define the boundary conditions of the sub-basins, sufficient to allow further investigations in isolation;
3) to determine what portions of the subject site are suitable and not suitable for development;
4) to identify major infrastructure requirements such as trunk storm drains, stormwater control facilities, and outfalls;
5) to identify existing major site features such as wetlands and ponds, and to address the impact of development on those features;
6) to identify the impacts of development on the drainage infrastructure;
7) to review potential for harmful alteration, disruption or destruction (HADD) of fish habitat;
8) to review the need for detailed soil analysis; and
9) to review existing versus proposed impervious surface cover on the development site.
10) to identify potential or constraints for infiltration.

5.1.2 Scope

The Stormwater Management Plan, Phase 1 – Preliminary Planning Report shall be based on criteria contained in this Manual and on the concepts and criteria developed in the Watershed Studies. The Stormwater Management Plan, Phase I must also identify any constraints to development planning and design in the area under investigation.

The potential drainage constraints affecting the development must be clearly defined. These constraints include the following:

(1) the requirements for flood control such as major systems, and the acceptable level of flood;
(2) the requirements for erosion and sediment control such as the watercourse erosion and bank stability criteria set out in Section B, Part 2.9;
(3) the determination of downstream system capacity; and
(4) the evaluation of other constraints imposed by the natural environment or by City and senior government bylaws, regulations and policies.

5.1 Stormwater Management Plan, Phase 1 – Preliminary Planning Report cont'd/

5.1.2 Scope cont'd/

The Phase 1 report shall utilize topographic data to clearly identify the drainage catchment area(s) within which the development is located. Topographic as well as any other relevant data are to be used to identify drainage sub-catchments (sub-basins) and their respective boundary conditions. Each sub-basin will have its own individual connection point to another downstream sub-basin. Stormwater management facilities are to be kept to a minimum and must be justified in the Phase 1 report.

The criteria used in the formulation of the Phase 1 report shall conform to the requirements for sizing of the minor and major systems and facilities. The Development proponents are expected to carry out the work necessary to meet the objectives. All boundary conditions and details provided must be sufficient to provide a smooth transition to subsequent reports and allow for continued development.

Hydrologic studies shall describe the model parameters and the criteria for selection, as well as input and output data. The development proponent has the responsibility for the computations for the land development, and the City may review the main assumptions and the input data. Modelling of the pre-development and post-development conditions must show how the runoff criteria set out in this Manual will be met. Management measures to be used for achieving flow control and water quality control are described in Section C of this Manual. Alternative measures may be acceptable where it can be shown that equivalent benefit will be achieved.

A temporary or permanent water quality control plan may be required at the City's discretion as part of the Stormwater Management Plan, where there are reasonable grounds to anticipate the discharge of prohibited or restricted materials to the drainage system as defined in City bylaws or Provincial or federal regulations, or of materials that may detrimentally impact the quality of ground or surface water and related ecology. A Water Quality Control Plan (if required) shall be prepared by a Professional Engineer and submitted under professional seal. The Water Quality Control Plan shall be referred to the Ministry of Water, Land and Air Protection, where a discharge is identified to a natural watercourse.

5.1 Stormwater Management Plan, Phase 1 – Preliminary Planning Report cont'd/

5.1.2 Scope cont'd/

The following is a listing of minimum requirements to be included in the Stormwater Management Plan, Phase 1 – Preliminary Planning Report (a checklist for Phase 1 is included in Table B1 of Appendix B):

1) determination of all lands draining through the proposed development area using topographic information;
2) size of the study area;
3) present land use;
4) proposed/future land use;
5) delineation of sub-catchments;
6) sediment control plan (see City Bylaw No. 4403);
7) lot grading plan;
8) description of soils, surface and subsurface drainage, and determination of the need for detailed soils analysis (e.g., for infiltration);
9) water quality control plan (if required);
10) land requirements/rights-of-way needed;
11) types, locations and approximate sizes of major stormwater management facilities (e.g., lakes, ponds) under post-development conditions;
12) downstream system capacity and development impact;
13) upgrading requirements and timing (if required); and
14) a schematic diagram of the tributary area which includes the following:
    a) major flow routes;
    b) an outline in red pencil of the proposed storm sewer from the last completed upstream existing storm sewer pipe to the downstream end of the development – storm sewer pipe together with any stormwater control structures proposed to be installed should be shown with a solid line and existing pipe with a broken line – the schematic shall show the pipe diameter;

5.1 Stormwater Management Plan, Phase 1 – Preliminary Planning Report cont'd/

5.1.2 Scope cont'd/

c) an outline of the drainage area in a solid green line, indicating the tributary area of all surface water added to the proposed storm sewers below the last existing storm sewer pipe – when the development is at the upper end of the drainage system, the green line shall outline the tributary area of all water added to the proposed storm sewer;

d) a broken green line indicating within this drainage area, the sub-areas of additional drainage added at each tributary drainage facility; and

e) the calculated numerical values of major and minor flows Q in litres per second, tributary area A in hectares and time of concentration T in minutes at the downstream end of the subdivision – when the subdivision is not at the upper end of the drainage system, the same information noted above shall be provided at the upstream end of the subdivision.

5.2 Stormwater Management Plan, Phase 2 – Detailed Design

Following the preliminary findings from the Phase 1 planning study, a Phase 2 Stormwater Management Plan that defines the drainage pattern for the proposed development and is compatible with this Manual and the appropriate Watershed Study, shall be designed, tested and presented in detail.

The requirement for the Stormwater Management Plan, Phase 2 – Detailed Design is to be specified by the City. If the rezoning/subdivision application straddles two individual drainage basins, then individual reports will be required to outline the required stormwater infrastructure in each basin.

5.2.1 Objectives

1) define all design criteria related to stormwater infrastructure and provide the basis for detailed design;
2) define necessary drainage improvements/infrastructure, including BMP's, for the specific development;
3) define the conditions at the development boundary relevant to future rezoning and subdivision applications;
4) develop a staged implementation plan for the storm infrastructure and facilities; and
5) provide an operation and maintenance plan for stormwater control facilities.

5.2 Stormwater Management Plan, Phase 2 – Detailed Design cont'd/

5.2.2 Scope

The Stormwater Management Plan, Phase 2 - Detailed Design is intended to build upon the concepts and information developed in the Phase 1 - Preliminary Planning Report. Phase 2 will normally include a detailed Pre-Design (Phase 2) Report, and the subsequent submission of Detailed Design Drawings, after the City has reviewed the Phase 2 Report. The Phase 2 Report is to detail the stormwater infrastructure requirements in order for the development to proceed to detailed design drawings. Approval of the Phase 2 Report is required before commencement of detailed design and construction.

The criteria used in the formulation of the Phase 2 Report are to conform to the requirements for sizing of the minor and major systems and stormwater control facilities as set out in this Manual. Development proponents are expected to carry out the work necessary to meet the objectives.

The Phase 2 Report shall include (but not be limited to) the following requirements (a checklist for the Phase 2 report is included in Table B2 of Appendix B):

1) tables of pre-development and post-development hydrologic criteria;
2) runoff simulation modelling parameters utilized;
3) runoff simulation modelling output;
4) details of minor drainage system:
    a) connection points to downstream system,
    b) connection points for upstream existing and future flows,
    c) pipe alignment, size, grade and capacity,
    d) minor return period peak flows, and
    e) representation of the 100-year grade line within the piped system;
5) details of major drainage system:
    a) connection points to upstream system,
    b) discharge points to downstream system,
    c) road grades,
    d) overland flow paths and 100-year return period peak flows, and
    e) ponding depths;
6) figure(s) showing storm system (minor and major) layout and the road network over a topographic base;

5.2 Stormwater Management Plan, Phase 2 – Detailed Design cont'd/

5.2.2 Scope cont'd/

7) details of stormwater control facilities:
   a) controlled discharge rates,
   b) type (wet, dry, infiltration, etc.),
   c) design details (size, capacity, etc.); and
   d) outfall details.
8) implementation plan and schedule
9) operation and maintenance plan
10) sediment control plan.

A Stormwater Management Plan which requires works or facilities to control stormwater discharge will include detailed plans and specifications of the works or facilities sealed by a professional engineer. Facilities to control stormwater are described in Section C of this Manual. Where a Stormwater Management Plan requires works or facilities, the professional engineer shall submit a letter of supervision which is an undertaking to inspect and certify the construction of the control works and facilities.

A Stormwater Management Plan must include an Operation and Maintenance Plan for all structural works whether located on public or private property, including an inspection and maintenance schedule and methodology. Where structural works are located on private property, the Operation and Maintenance Plan must include the name and address of the person responsible for inspection and maintenance, and an emergency contact phone number.

For facilities located on private property, a record of all maintenance work carried out must be maintained by the Owner. The record of maintenance must be submitted to the City if requested. The operation and maintenance plan must be signed and sealed by a Professional Engineer registered in good standing with the Association of Professional Engineers and Geoscientists of British Columbia, unless otherwise approved in writing by the City. An Operation and Maintenance Plan must include a letter of undertaking signed by a Professional Engineer which commits to undertake the program of management set out in the plan. Refer to Section C of this Manual for guidance on maintenance procedures for stormwater control facilities.

5.2 Stormwater Management Plan, Phase 2 – Detailed Design cont'd/

5.2.3 Detailed Design Drawings

The requirement for submission of design drawings is included in the Subdivision and Development Servicing Bylaw. The Phase 2 - Detailed Design Report must be completed and approved prior to the submission of Detailed Design Drawings.

The Design Drawings are to be based on, and consistent with, the Stormwater Management Plan Phase 2 Report. The objectives of the Detailed Design Drawings are as follows:

- to define all details of the stormwater infrastructure and water quality control measures prior to construction; and
- to provide future developments with information as to connection points.

Drawing requirements are based on the Subdivision and Development Servicing Bylaw, and other relevant City bylaws. The Design Drawings must include the following items (a checklist is included in Table B3 of Appendix B):

(1) Site plan maps on City standard sheet sizes with approved scales (1:2500) showing the following:

(a) boundaries of affected drainage basins,

(b) pre-development and post-development topography with legal mapping,

(c) points along the subdivision project boundaries that receive run-off from offsite drainage areas,

(d) pre-development and post-development drainage network (pipes, culverts, inlets, manholes, swales, open channels, etc.) and catchments tributary to each pipe or culvert inlet, as well as the following information in tabular format on the drawings:
- length, size and slope of each pipe,
- tributary area,
- calculated minor and major flow rates and capacities of each reach,
- inlet and total area for off-site areas tributary to a storm sewer or culvert,
- existing and future land use classification,

(e) pre- and post-development run-off control measures, and

(f) where required for "latecomer" service, all excess or extended service in bold;

5.2 Stormwater Management Plan, Phase 2 – Detailed Design cont'd/

5.2.3 Detailed Design Drawings cont'd/

(2) the hydraulic grade lines produced by the actual captured flows from the 1:100-year storm shall be plotted on the detailed pipe design drawings;

(3) lot grading plans shall be provided as part of detailed design;

(4) sediment control plan shall be provided as required by City bylaws;

(5) water quality control plan shall be provided if required;

(6) mitigation statement; and

(7) plans to be completed to City Drawing Standards and sealed by a Professional Engineer who is experienced in hydrology and is registered in British Columbia.

SECTION C – STORMWATER MANAGEMENT MEASURES

Section B of this Manual sets out design criteria for control of storm runoff, and refers to this Section C for guidance on selection and design of appropriate stormwater control measures. Stormwater control measures are necessary to mitigate the adverse impacts associated with development, including the following:

- increased impervious surface (roofs, roads etc.) reduces the amount of precipitation that infiltrates into the ground, with a resulting increase in surface runoff flow rates and volumes, which in turn causes increased flooding and erosion, and tends to reduce groundwater reserves and dry season flows in streams;
- infilling of natural detention storage (depressions, wetlands, etc.) reduces natural hold up of surface runoff, increasing peak runoff flow rates and reducing infiltration;
- removal of trees and other natural vegetation reduces natural hold up and evapotranspiration of precipitation, increasing surface runoff flow rates and volumes;
- reduced species diversity due to destruction of habitat and natural food sources; and
- increased contamination of surface water and groundwater caused by urban activities, particularly those associated with the operation of motor vehicles.

In the past, stormwater control measures were aimed primarily at protection of life and property, and the design focus was on flood and erosion control through the following measures used singly or in combination:

- upgrading the hydraulic capacity of the drainage system;
- detention storage to control peak runoff discharge flow rates; and
- diversion of major runoff flows resulting from large, infrequent storm events via piped systems or open channels in order to bypass areas susceptible to flooding and/or erosion (diverted flows are normally discharged to downstream components of the drainage system that have the capacity to accept these flows).

The above “traditional” solutions are still valid, and they often form integral components of stormwater management plans, although straightening and armoring of stream banks to increase hydraulic capacity is no longer considered acceptable where fish or fish habitat would be adversely affected.

In recent years, stormwater management has focused on the protection of natural hydrologic processes and water quality, as well as flood and erosion control; stormwater management measures that include these additional objectives are commonly referred to as Best Management Practices (BMPs). A large number of structural and non-structural Best Management Practices have been developed. In general, the non-structural approaches are designed to preserve the predevelopment natural hydrologic condition as far as possible, and the structural approaches attempt to replace key components of the natural hydrologic system that were removed or destroyed by development (e.g., infiltration, natural detention storage, evapotranspiration and holdup by trees and vegetation, removal of contaminants by aquatic and terrestrial microorganisms and plants).

An important aspect of the current approach to stormwater management is to control the frequency and duration of erosive flows in natural stream channels. Detention storage was traditionally used to limit the post development peak flow rate in the drainage system to that of the predevelopment condition for one or more storm return periods. However, since the total volume of runoff is significantly increased by development, the duration of the peak runoff flow rate will be longer for the post development condition if the peaks of pre and post development peak flow rates are simply matched. In addition, the frequency of occurrence of the pre-development peak runoff flow rate will be greater after development occurs, since this runoff flow rate will be generated by a smaller (more frequent) storm event.

The increased frequency and duration of peak runoff flow rates resulting from relatively small, frequent storm events after development has occurred has a detrimental impact on streams, due to increased erosion. It is therefore important to further reduce both the frequency and duration of the peak flow release rate for the post development condition, particularly for smaller storms. Ideally, this should be undertaken through Best Management Practices designed to promote infiltration and holdup of precipitation, mimicking as closely as possible the predevelopment condition. In cases where infiltration is not feasible due to site-specific constraints (e.g. unsuitable soils, high groundwater table), management measures such as diversion of peak runoff flows around sensitive steam reaches and/or reduced discharge rates from detention facilities can be used to limit erosion in streams caused by frequent storm events.

It is the City of Coquitlam policy to encourage the use of Best Management Practices that preserve and restore the natural (predevelopment) hydrologic condition as far as possible. The remainder of this Section C provides a list of acceptable Best Management Practices that can be used to meet the stormwater design criteria set out in Section B of this Manual. Alternative measures such as hydraulic improvements, diversion of peak flows, and innovative approaches not described in this Manual will be considered, where it can be shown that the requirements of this Manual and other applicable policies and regulations will be met.

1.1 The GVRD Best Management Practices Guide

The Greater Vancouver Regional District (GVRD) has developed a Best Management Practices Guide for Stormwater (Dayton & Knight Ltd. et al, 1999) as a component of the regional Liquid Waste Management Plan. The GVRD Guide contains descriptions, design guidance, costing formulas, and recommended operation and maintenance and activities for Best Management Practices that are appropriate for local conditions. Development proponents should obtain the Best Management Practices Guide and the separately bound Appendix H: Construction Site Erosion and Sediment Control Guide for use in identifying and selecting stormwater control measures that meet the requirements of this Manual. The GVRD Guide together with Appendix H can be downloaded from the GVRD website at http://www.gvrd.bc.ca/services/sewers/drain/BestMgmtGuide.html.

Alternatively, the documents can be obtained on a compact disc from the GVRD (contact the City of Coquitlam Development Manager for GVRD contact information). Other locally developed guidance on Best Management Practices is also available in the Provincial Stormwater Planning Guidebook (CH_2M Hill and Lanarc, 2002).

The GVRD Guide or other similar documents can be used by development proponents in preparing Stormwater Management Plans, and by the City in reviewing Stormwater Management Plans submitted by development proponents. Section 2 of the Guide can also be used by the City in helping to set goals and objectives for Watershed Studies, and in selecting appropriate community Best Management Practices.

The Best Management Practices in the GVRD Guide are divided into the general categories of non-structural, structural, and operation/maintenance practices. Guidance on use of the GVRD Guide by both the City and by development proponents for selection of appropriate Best Management Practices in each of these categories is summarized below.

1.2 Non-Structural Best Management Practices

Non-structural Best Management Practices as described in the GVRD Best Management Practices Guide are listed below, followed by an overview of recommended applications. In general, non-structural approaches can be applied both by the City in preparing Neighborhood plans and in considering revisions to the Citywide Official Community Plan, and by development proponents (normally in combination with structural Best Management Practices) in meeting the criteria set out in Section B of this Manual. The reader is referred to the GVRD Guide for more detail regarding costs and benefits of individual Best Management Practices (Dayton & Knight Ltd. et al, 1999).

1.2 Non-Structural Best Management Practices cont'd/

BMP NS1: Buffer Zones/Preservation of Key Drainage and Habitat Features – preserves and protects key natural drainage and habitat features that help to store, infiltrate, evaporate, and cleanse storm runoff by preventing development in these areas – this requires consideration of stormwater management as a core element in planning communities and individual developments, rather than attempting to design drainage plans to suit existing development plans.

BMP NS2: Reduction/Disconnection of Impervious Area – preserves natural infiltration processes, reduces runoff peak flows and volumes and replenishes groundwater, by minimizing the impervious area created by development and by eliminating direct connections between impervious surfaces and the drainage conveyance system.

BMP NS3: Construction Design/Review/Inspection/Enforcement – prevents environmental damage and encroachment on protected areas through regulation of construction methods and practices.

Several components that can be used to address the above non-structural Best Management Practices are as follows:

a) where feasible within the existing Official Community Plan and Neighborhood Plans, encourage low impact developments that concentrate housing into compact areas on smaller lots, resulting in more open (undeveloped) space and less impervious infrastructure (roadways, etc.) than conventional grid development;

b) encourage development in the downtown core, which facilitates walking, cycling, and public transport, resulting in reduced vehicle use (and less pollution);

c) encourage linking of open spaces (e.g., protected natural areas and parks), with transportation via walking or cycling between linked areas;

d) discourage development in special natural areas identified in the Citywide Official Community Plan and Neighborhood Plans by designating Development Permit Areas;

e) protect watercourses and riparian areas through establishing Development Permit Areas;

f) discourage or prohibit development within floodplains, on steep slopes and on unstable areas;

g) minimize disturbance of local vegetation and slopes caused by construction of buildings and roads, and require re-vegetation of disturbed soils; and

h) prevent activities that modify or impact natural shoreline processes.

In addition to the above, development planning should include consideration of the space requirements for structural Best Management Practices, since it is very difficult to retrofit these facilities to existing urban developments. Structural Best Management Practices that include detention and storage of collected runoff with subsequent controlled release rates should be planned on a watershed-wide basis where possible.

1.3 Structural Best Management Practices

The structural Best Management Practices described in the GVRD Best Management Practices Guide are listed below, together with brief descriptions. The reader is referred to the GVRD Guide for design guidance, costing formulas, maintenance requirements and expected benefits (Dayton & Knight Ltd. et al, 1999).

BMP S1: Coalescing Plate Separator – typically an underground vault containing a bundle of oil-attracting corrugated plates - suitable for treatment of runoff that is heavily contaminated with oil and grease (repair yards, industrial facilities).

BMP S2: Water Quality Inlet – typically an underground three-chamber vault designed to trap heavy sediment, floating debris, and oil and grease - suitable for limited removal of floating oil and gas films and trapping of small spills.

BMP S3: Manhole Sediment Trap – similar to a conventional manhole, except for the inclusion of a sump to maintain a permanent water pool and promote settling of solids – suitable for limited trapping of floating trash and heavy sediment.

BMP S4: Trapped Catch Basin – similar to a conventional catch basin, except for the inclusion of a sump and baffle to maintain a permanent water pool and promote settling of solids – suitable for limited trapping of floating trash and heavy sediment.

BMP S5: Dry Detention Basin – may be incorporated into sports fields, parks, roof tops or parking lots - designed to temporarily store collected runoff, to release the stored water at a controlled rate, and to empty completely between storms – conventional dry detention (typical detention time 3 to 4 hours) is suitable for controlling runoff flow rates, and extended dry detention (typical detention time 48 to 72 hours) has the added benefits of lower water release rates and gravity settling of particulate contaminants.

BMP S6: Wet Pond – similar to dry extended detention basin except that a permanent pool of water is maintained to promote settling and biological filtering/removal/conversion of contaminants – suitable for controlling runoff flow rates and removal of particulate and dissolved contaminants, some infiltration may also occur.

BMP S7: Dry Detention Vault and Wet Vault (dry detention could also include storage in oversized storm sewer pipes) – typically underground concrete vaults or corrugated pipe tanks designed for temporary storage and controlled release of collected runoff – dry vaults empty completely between storms and have similar applications to dry detention basins, while wet vaults maintain a permanent water pool and enhance settling of particulate contaminants.

1.3 Structural Best Management Practices cont'd/

BMP S8: Constructed Wetlands – similar in nature and application to wet ponds, except that wetlands are normally relatively shallow and typically include emergent vegetation and marshy areas - suitable for controlling runoff flow rates and removal of particulate and dissolved contaminants, some infiltration may also occur.

BMP S9: Grassed Channel/Wet Swale – wide, shallow vegetated channels designed to convey and filter collected runoff, typically used as an alternative to curb and gutter and/or piped systems, dry swales do not contain water between storms and wet swales include permanent standing water to enhance settling and biological removal of contaminants – both may be designed to convey the runoff from large, infrequent storms while providing water quality improvements for small, frequent storms, some infiltration may also occur.

BMP S10: Vegetated Filter Strip (also referred to as bio-filters) – broad areas that promote sheet flow of precipitation over a sloped vegetated surface – designed to slow runoff and filter particulate contaminants, some infiltration may also occur.

BMP S11: Off-Line Infiltration Basin – designed to capture and temporarily store runoff in a surface pond until it gradually infiltrates into the ground through the bottom, which is constructed of a porous matrix – suitable only where ground conditions allow – mainly suitable for infiltrating small, frequent storms for climatic conditions in the City of Coquitlam (larger flows should be bypassed).

BMP S12: Roof Downspout Systems – a type of on-parcel infiltration system - collected roof runoff is routed to subsurface infiltration trenches or tanks, dry wells, surface dispersion trenches or similar variants - suitable for infiltrating roof runoff only (not designed for general site runoff).

BMP S13: Porous Pavement – permeable paving material that allows precipitation to percolate through the pavement to a porous (gravel) underlying base layer – some temporary storage of water in the base layer - suitable for infiltration only where ground conditions allow and only practical for low traffic areas (parking, lanes, driveways etc.).

BMP S14: Concrete Grid and Modular Pavers – strong structural pre-cast paving units with regularly spaced void areas filled with soil or other pervious material – this provides a load bearing surface that allows infiltration through the void areas suitable for infiltration only where ground conditions allow and only practical for low traffic areas (parking, lanes, driveways etc.).

1.3 Structural Best Management Practices cont'd/

BMP S15: Bio-retention and Dry Swale with Underdrains – Bio-retention is a type of stormwater filtering systems where runoff is temporarily stored in a shallow depression and then allowed to gradually infiltrate through a constructed filter bed of soil and plants to an underlying drain system - dry swale with underdrains is a design variant of bio-retention where the swale is designed to temporarily store water behind a weir and allow gradual infiltration through a soil bed to an underdrain – suitable for water quality improvement for the runoff from small, frequent storms (runoff from large storms is bypassed).

BMP S16: Sand Filter – captured storm runoff is infiltrated through a bed of sand to remove particulate contaminants and collected by an underdrain system – bacteria developing in the sand bed may also remove dissolved contaminants – suitable for water quality enhancement of the runoff from small, frequent storms (larger flows are bypassed).

BMP S 17: Catch Basin Filter (also called Catch Basin Insert) – filtration media installed in catch basins designed to remove specific contaminant as the stormwater passes through the media – suitable where a specific contaminant in storm runoff has been identified as a problem.

BMP S18: Organic Filter – similar to sand filter (BMP S16), except that filtration medium is composed of compost or a peat-sand mixture contaminants – suitable for water quality enhancement of the runoff from small, frequent storms (large flows are bypassed).

BMP S19: Multi-Chambered Treatment Train – special purpose device designed to treat heavily contaminated runoff from sites where space restrictions prevent the use of other techniques - includes screening to remove large particulates, aeration to remove volatile compounds, enhanced settling using inclined plate or tuber settlers, removal of oil by floating absorbent pads, and filtration through a bed of sand or peat - relatively experimental in nature but based on proven unit processes - suitable for water quality enhancement of the runoff from small, frequent storms (larger flows are bypassed).

Some structural Best Management Practices lend themselves to stormwater management on a relatively large scale (e.g. publicly owned and operated wet ponds and constructed wetlands); these will be addressed in the Watershed Studies. Other structural Best Management Practices (e.g., oil-water separators, media filters, etc.) are more suited to on-site stormwater management for relatively small public and privately owned areas such as commercial/ industrial developments and vehicle repair/maintenance facilities. Dry detention basins, infiltration facilities, permeable pavements, vegetated swales and filter strips can be considered for all types of development, including residential.

1.3 Structural Best Management Practices cont'd/

The use of structural Best Management Practices for development must be supported by regulations that restrict or prohibit the discharge of environmentally harmful substances to the storm drainage system (e.g. City of Coquitlam bylaws, federal and provincial regulations) and/or specify detention requirements if on-site detention is required (see Section B of this Manual). Structural Best Management Practices must be compatible with existing infrastructure and with the Building Code. Responsibilities must be clearly defined for proper operation and maintenance of structural Best Management Practices; otherwise, these facilities can quickly become liabilities. The typical maintenance requirements for structural Best Management Practices described in the GVRD Guide can be used by development proponents in preparing operation and maintenance plans as required in Section B of this Manual. In general, maintenance schedules for individual facilities should be modified if maintenance activities and inspection shows that maintenance frequency should be increased or decreased.

1.4 Operational and Maintenance Best Management Practices

Operational and maintenance Best Management Practices as described in the GVRD Best management Practices Guide are listed below, together with brief descriptions. The reader is referred to the GVRD Guide for more detailed descriptions (Dayton & Knight Ltd. et al, 1999).

BMP OM1: Maintenance of Structural Best Management Practices – failure of structural Best Management Practices is often attributed to inadequate maintenance – proper maintenance is essential if Structural Best Management Practices are to function as designed - depending on the facility, maintenance activities may include removal of captured trash, sediments and other contaminants, control of vegetation, and corrective maintenance.

BMP OM2: Detection, Removal, and Prevention of Illicit Connections – illicit connections between the storm and sanitary sewer systems can result in significant contamination of stormwater – illicit connections should be prevented in new developments and redeveloping areas and identified and removed in existing developments – City bylaws prohibit the discharge of sewage to the storm drain system.

BMP OM3: Spill and Complaint Reporting and Response – designed to prevent contaminants resulting from spills from reaching the stormwater conveyance system – elements include reporting of spills to the proper authority, a planned response aimed at stopping the source of the spill, containment, cleanup, and proper disposal of the spilled material.

1.4 Operational and Maintenance Best Management Practices cont'd/

BMP OM4: Street Cleaning – the use of modern vacuum assisted street sweepers can be used to reduce contamination carried by road runoff in ultra-urban areas.

BMP OM5: Maintenance of Runoff Conveyance Systems, Stream Banks and Hill Slopes – includes removal of accumulated sediments and illegally dumped materials from open watercourses and piped systems, and protection of stream banks from erosion – prevents loss of hydraulic capacity in the drainage systems and reduces contaminant loads through removal of sediments.

BMP OM6: Catch Basin Cleaning – regular catch basin cleaning prevents re-suspension of accumulated sediments during the initial phase of storms, and helps to prevent sediment accumulation downstream – this is particularly true where sediment trapping catch basins (BMP S4) are used.

BMP OM7: Roadway and Bridge Maintenance – modification of these activities can reduce the generation of oil and grease, salt, heavy metals, sediments, bird guano, pavement particles, paints, cleaners, and abrasives, and so help to prevent contamination of storm runoff.

1.5 Screening and Selection of Best Management Practices

Section 2 of the GVRD Best Management Practices Guide contains a six-step procedure for identifying and screening Best Management Practices on the basis of specific goals and objectives, level of development, land use activity, and site-specific physical constraints. Best Management Practices designed specifically for control of erosion and sedimentation during construction are contained in a separately-bound Appendix H of the GVRD Guide (Dayton & Knight Ltd. et al, 1999).

The selection process set out in the GVRD Guide is intended to allow the designer to select the most effective Best Management Practices for local conditions, based on a site-specific set of Goals and Objectives. The candidate Best Management Practices include structural, non-structural and operational approaches as summarized in Sections 1.2 through 1.4 above.

Figure 2-1 in Section 2 of GVRD Guide provides an overall flow diagram of the selection process, beginning with the preparation of a watershed inventory and the development of site specific Goals and Objectives for each individual watershed. This Step 1 is relevant mainly to the City for developing Watershed Studies. Steps 2 through 6 can be used by the City in developing Watershed Studies and by development proponents to assist in preparing Stormwater Management Plans.

1.5 Screening and Selection of Best Management Practices cont'd/

Figure 2-2 in the GVRD Guide provides a summary of candidate Objectives, which are grouped under four categories (Goals), namely Protection of Life and Property, Protection of Fish Habitat, Protection of Water Quality, and Community Support/Acceptance. Where a Watershed Study has been completed, specific Goals and Objectives will have been developed by the City, and these can be used by the City and by development proponents to select the Best Management Practices that best meet those Goals and Objectives (e.g., groundwater recharge, control of water temperature, community aesthetics). In the absence of a Watershed Study, development proponents can proceed directly to Tables 2-1 through 2-5 to select a list of Best Management Practices that best meet the criteria set out in Section B of this Manual (e.g., control of flooding frequency, prevention of erosion, meet regulatory agency requirements) and are suitable for the development site. This will result in an initial list of candidate Best Management Practices.

The list of candidate Best Management Practices is then screened based on suitability for the specific development situation using Tables 2-6 through 2-8 in the GVRD Guide. This includes level of development (fully developed, green field, redeveloping) and the type of land use (residential, commercial, industrial, parks and green space). Best Management Practices that are shown to be unsuitable for the specific development situation are dropped from the list of candidate measures.

The structural candidate Best Management Practices remaining on the candidate list are then screened on the basis of site-specific physical constraints (topography, soils, area served, etc.) using Table 2-9 in the GVRD Guide.

The design and implementation requirements are then developed for the Best Management Practices remaining on the short list, using the design guidance, costing formulas, maintenance requirements, and other detailed information contained under the descriptions of individual Best Management Practices in Sections 3 through 5 of the GVRD Guide. The design size of individual facilities will depend on the site characteristics and the results of the runoff analysis for the pre and post development conditions. Once the approximate design requirements of the needed facilities have been developed, the costs and other implementation requirements can be weighed against the expected benefits, to determine the most cost effective solution.

The above procedure provides the development proponent and the City with a method for selecting a short list of Best Management Practices that meet the requirements of this Policy and Design Manual and/or the objectives developed in a Watershed Study. The procedure also provides the City with a guide for reviewing the Stormwater Management Plans submitted by developers.

1.6 Green Roofs

Green roofs have considerable potential to assist in the management of stormwater, potential that has not been utilized in Greater Vancouver except in a few innovative projects.

Green roofs are veneers of living vegetation that help manage stormwater by mimicking a variety of hydrological processes normally associated with landscaped open space. Green roofs capture rainwater in foliage, roots, and soil and increase rates of evapotranspiration with the result that the quantity of stormwater is reduced prior to entering stormwater management systems. Green roofs are especially effective in controlling frequent, intense, short-duration storms.

Key considerations for implementation of green roofs include structural and load bearing capacity, plant selection, waterproofing, and drainage or water storage systems. Generally, two types of green roofs are defined. Extensive green roofs involve a relatively light drainage and filtering system and a thin layer of soil mix planted with drought-tolerant herbaceous vegetation. These roofs are designed for low maintenance and no active use. Intensive green roofs are more complex and employ deeper soils to permit planting of trees and shrubs and to support human use. As a result, intensive green roofs require higher structural load capacity. More detail regarding Green Roofs including design guidance, costs and benefits can be found in the Provincial Stormwater Planning Guidebook (CH_2M Hill and Lanarc 2002).

1.7 Landscaping Standards

Best Management Practices for Stormwater Management require an integrated approach that encompasses traditional engineering, ecological processes, and landscape design and, therefore, involve professionals in these fields. The *Stormwater Management Policy and Design Manual* has been prepared with the involvement of Landscape Architects to ensure that landscape best practices have been integrated into the manual wherever applicable.

Stormwater Planning: A Guidebook for British Columbia, prepared in 2002 with the participation of the City of Coquitlam provides a thorough discussion of the rationale for integrated stormwater management. As described in this report:

> "the foundation of integrated stormwater management solutions…mimic the most effective stormwater management system of all – a naturally vegetated watershed."

It is this imperative of using natural systems in human developments that integrates landscaping into stormwater management.

1.7 Landscaping Standards cont'd/

The Guidebook addresses the importance of planning for stormwater management at four scales – regional, watershed, neighbourhood, and site. Each of these scales has a landscape component driven by the objectives of retaining substantial areas at the highest possible level of infiltration and moderating flow rates. At the regional and watershed level this requires that large tracts of public land be preserved in natural or naturalized conditions and is reflected in a trend toward ecological rehabilitation and away from manicured landscapes in regional and City parks. At the neighbourhood and site scales, stormwater management policy leads to landscape designs that foster permeability through reduced and different paving, street standards, and soft landscape treatments.

Best management practices with a landscape component and complex and site-specific and involve:

- Integration of appropriate recreational uses into watershed areas;
- Revegetation of disturbed areas to promote permeability and ecological values;
- New standards for streets, parking lots, driveways and other paved areas that direct rainfall into landscaped areas or other collection areas designed to slow the rate of their arrival in receiving systems;
- Composition and depth of soil to facilitate permeability;
- Selection and planting of landscape materials, including alternatives to extensive areas of lawn;
- Many types of design options for swales, ditches, trenches, boulevards, culverts, and other means to improve the permeability of a site;
- A wide variety of paving and decking details that achieve some level of permeability
- Site grading design that considers the effective control of rainfall;
- Strategies for the reuse in the landscape of collected and stored rainwater;
- Site design that inserts new structures into vegetated sites with minimum disturbance of existing vegetation and soil structure;
- Protection and relocation of existing trees and other landscape materials during construction and selection of replacement vegetation;
- Construction techniques to minimize erosion and avoid debris buildup in stormwater systems;
- Maintenance approaches for streets and parking lots that avoid placing pollutants and debris in stormwater systems;
- Maintenance standards for landscaping that reduce or avoid the use of herbicides and pesticides that will find their way into watersheds; and
- Collaboration on the design of wetlands, wet and dry ponds, and other retention facilities.

1.7 Landscaping Standards cont'd/

Best Management Practices for the above landscape-related approaches have been extensively published and are readily available on websites. These Best Management Practices manuals comprise hundreds of suggested details and are regularly updated as new products and techniques are added to the toolkit.

The BC Landscape Standard (BCSLA and BCLNA, 2002) identifies seven landscape design and maintenance standards. These classifications integrate several aspects of landscape in keeping with legislation applicable in British Columbia, including:

- Functional objectives for the use of the landscaped area;
- Appearance standard for the level of maintenance and tolerance for weeds, debris, and invasion by native species;
- Appropriate types of plants;
- Traffic activity levels;
- Maintenance practices, including mowing, fertilizing, pest control, watering, seeding, weed control, and repair;
- Growing media.

In general, the lowest appropriate maintenance level with the highest appropriate utilization of native plant species will optimize stormwater management and sustainable development best practices. These levels and their main objectives are:

Level 1 – Well Groomed
Main objective is first-class appearance, always impeccably clean and well groomed. Plants are kept manicured and lawns in near perfect health.

Level 2 – Groomed
Main objective is to present a neat, orderly, groomed appearance. Plants are healthy and vigorous; lawns are regularly mowed and trimmed.

Level 3 -- Moderate
Main objective is a generally neat appearance with some tolerance for wear and tear and natural processes.

Level 4 – Open Space/Play
Main objective is an orderly appearance adapted to play and heavy traffic with considerable tolerance for such use. Appearance is secondary to functional requirements.

Level 5 -- Background
Main objective is to preserve natural conditions while accommodating low intensity activities. Weeds and debris are tolerated.

1.7 Landscaping Standards cont'd/

Level 6 – Service and Industrial

Main objectives are to manage vegetation for functional rather than aesthetic concerns and to protect adjacent areas from impacts.

Level 7 – Restoration

Main objective is to achieve a natural, self-sustaining area. Litter and foreign debris are removed.

Given the complexity of these landscape design approaches, two standards for the City of Coquitlam have been established:

1. A professional landscape architect registered with the British Columbia Society of Landscape Architects shall be engaged on all projects on which a Professional Engineer is required.

2. The most current version of the BC Landscape Standard (BCSLA and BCLNA) shall be referenced as a guide to landscape design and maintenance requirements to ensure that legislated requirements and best practices are used.

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GLOSSARY

Antecedent Moisture - In drainage modelling or hydrologic calculations, moisture from previous rainfalls may be accounted for in runoff calculations. This rainfall is referred to as antecedent moisture.

Apron Swale - An impervious circular collection area forming a depression around a catch basin to encourage flow into the catch basin. Asphalt aprons are common construction.

Buffer Strip - Vegetation fringe left intact along a stream, river or lake after logging. Can be deciduous or a mix of deciduous and coniferous species, including a complete assemblage of natural forest. cf. leave strip, riparian zone.

Catchment - See Drainage Area.

Critical Depth - Unstable, turbulent depth where the flow has a Froude number equal to one, (velocity equal to the square root of the depth times gravitational acceleration product).

For any specific energy, other than minimum, two depths of flow are possible and separate: subcritical (deep) and supercritical (shallow) flow. At minimum specific energy, the two depths coincide and flow is critical at critical depth.

Critical Flow - See Critical Depth.

Debris Flow - Failure of predominantly coarse saturated material which deforms continuously as a more or less viscous slurry usually in a pre-existing channel.

Debris Slide (Debris Avalanche) - Failure of predominantly coarse unsaturated material which slips down a hillside in rapidly disintegrating blocks.

Debris Torrent - A debris flow of predominantly coarse materials characterized by a high water content and confined in a steep channel.

Design Frequency - The average lapsed time between the occurrence of two events (storms, floods, etc.) equal to or exceeding a specified value (intensity, low, etc.).

Discharge - The rate of flow, or volume of water flowing in a stream; usually expressed as cubic metres per second (formerly cubic feet per second).

Discretize - To break up into separate distinct parts.

Downcutting - Lowering of stream bed due to stream erosion.

Drainage Area or Drainage

(1) An area surrounded by a continuous height of land within which all runoff is expected to join into a single flow stream, and which extends to the point of junction of the flow stream with some predefined point of discharge at the lowest height of land of the drainage.

(2) The area served by a drainage system receiving storm and surface water, or by a watercourse.

Drainage Basin - See Drainage Area.

Drainage Density – A parameter measuring the ratio of the watershed channel length to drainage area (km/km^2).

Drainage Zone, Discharge Area - A groundwater source, supply or spring.

Ecosystem - Any complex of living organisms together with all the other biotic and abiotic (non-living) factors which affect them. For example, a forest ecosystem is that part of a forest area which is uniform in climate, parent materials, physiography, vegetation, soils, animals and micro-organisms.

Ephemeral Stream - Refers to flows of water which occurs only after precipitation or snowmelt and which does not flow long enough or with sufficient volumes to create well-defined channels.

Episodic Erosion or **Periodic Erosion** - An abrupt channel response to slow cumulative effects of a progressive sedimentologic change when a threshold is exceeded.

Erosion or **Progressive Erosion** is the slow change in grades and landscape adjustments due to river activity. For this study, it is restricted to changes in riverbank or bank line recession.

Fisheries Stream Classification - Fisheries classify the streams or watercourses in various orders of 1 through 5 or higher which represent as 1, the extremities of a watercourse in a watershed and as 5 or higher, a major receiving stream. Each of these are classified as Perennial, (year round flow, well defined channels), Intermittent, (half year flow only), and Ephemeral, (flow occurs only on snow melt or heavy precipitation, not well defined channels, low order streams 1 or 2).

Floodplain - The relatively flat or lowland area adjoining a river, stream, watercourse, ocean, lake or other body of standing water which has been or may be covered temporarily with floodwater. For administrative purposes, the floodplain may be defined as the area that would be inundated by the 1:200-year storm flows.

Flood Proofing - A combination of structural changes and adjustments to properties subject to flooding primarily for the reduction of flood damages.

Floodway - The strip of land that would be flooded by the 1:100- or 1:200-year storm flow.

Freshet - A sudden rise in the level and streamflow of a stream or river, due to heavy rains or rapid melting of snow and ice.

Gullying - The formation of scars in a landscape by erosion.

Hard Point - Durable rock or compact soil not readily eroded by stream action and representing a boundary condition in the valley floodplain or valley flat.

Hydrograph - A graph showing the discharge of water with respect to time for a given point on a stream or conduit.

Hydrology - The science of engineering that deals with the aspects of rainfall and the nature of its subsequent collection or discharge.

Hyetograph - A graph showing average rainfall, rainfall intensities or volume over specified areas with respect to time.

Ice Contact Materials - Materials in content with ice during glacial activity.

Impervious - A term applied to a material through which water cannot pass, or through which water passes very slowly.

Imperviousness Ratio - The ratio of impervious surfaces to total surface area within a watershed or drainage area. If rainwater leaders are not connected directly to the storm sewer system, but are discharged onto splash pads or into soak-away pits, the impervious roof area may be neglected in calculating the imperviousness ratio. Similarly, if rainwater is temporarily stored on a flat roof or in underground storage to simulate the pre-development agricultural condition of runoff, such impervious surfaces may also be neglected.

Incision – Down-cutting of stream bed, sometimes due to lack of sediments (e.g. Mission Creek incision into older fan deposits due to now lower lake level). In local areas, this is sometimes referred to as gullying during an active incision process.

Infiltration -

(1) The entering of water through the interstices or pores of a soil or other porous medium.
(2) The entrance of water from the ground into a sewer or drain through porous walls, breaks, defective joints.
(3) Absorption of water by the soil either as it falls as precipitation, or from a stream flowing over the surface.

Integrated Resource Management - The process of setting goals, objectives, strategies and policies in a cooperative framework among all watershed resources and resource uses.

Intensity - As applied to rainfall, the rate at which precipitation falls in a given period, usually expressed in millimetres per hour or inches per hour.

Intermittent Stream - A stream with a defined channel, but which is dry for periods of the year; usually the late summer and fall period of low precipitation and no snow melt.

Isohyetals - The graphed distribution of rainfall intensity for a particular storm duration.

Lag Time - The time difference between two occurrences, such as between rainfall and runoff.

Major Drainage System - The storm drainage system which carries the runoff from the major design storm. The major system will function whether or not it has been planned and designed, and whether or not developments are situated wisely with respect to it.
The major system usually includes many features such as streets, gulches, and major drainage channels. Storm sewer systems may reduce the flow in many parts of the major system by storing and transporting water underground.

Meander (bendway) - The loop in a river representing the alignment of the river thalweg.

Minor Drainage System - That storm drainage system which is frequently used for collecting, transporting and disposing of snowmelt, miscellaneous minor flows, and storm runoff up to the capacity of the system. The capacity should be equal to the maximum rate of runoff to be expected from the minor design storm which may have a frequency of occurrence of once in two, five or ten years.

The minor system is sometimes termed the "convenience system", "initial system", or the "storm sewer system".

The minor system may include many features ranging from curbs and gutters to storm sewer pipes and open drainage ways.

Morphology - The study of the physical character of a watershed's initial and present relief, drainage network and valley character, and its components which form the majority of variables of the fluvial system.

Mud Flow (Earth Flow) - Failure of predominantly fine saturated material or an earth slide characterized by a high water content.

Natural Boundary - The water course limits recognized as the wetted stream flow width occurring at bankfill flow conditions in a modified or unmodified channel or section throughout the full length of the stream.

Neap Tide - A tide of minimum range occurring at the first and third quarter of the moon.

Orogeny - The affects of mountainous terrain on climate.

Overcompetent Streams - Streams capable of transporting and eroding sediments (down grading) (contrast undercompetent streams).

Overcontrol - Use of detention or retention storage to reduce storm flow below some minimum such as pre-development flows.

Overland Flow - The flow of water over the ground surface before it flows to channels, swales and ditches.

Perennial Stream - A stream which has flowing water all year.

Pervious - Applied to a material through which water passes relatively freely.

Planning - The process of determining of the goals and objectives of an enterprise, and the selection, through a systematic consideration of alternatives, of the policies, programs and procedures for achieving them. An activity devoted to clearly identifying, defining and determining courses of action necessary to achieve predetermined goals and objectives.

Precipitation - Any moisture that falls from the atmosphere, including snow, sleet, rain and hail.

Rainfall Excess - That part of a rain of a given storm which falls at intensities exceeding the infiltration capacity and is thus available for direct runoff.

Rainfall Mass Curve - Plot of accumulated precipitation against time from the beginning of the storm.

Riparian Zone - See Buffer Strip.

Routing, Hydraulic

(1) The derivation of an outflow hydrograph of a channel or stream from known values of upstream inflow.

(2) The process of determining progressively the timing and shape of a flood wave at successive points along a stream or channel.

Runoff - That part of the precipitation which reaches a stream, drain, sewer, etc., directly or indirectly.

Runoff, Direct -The total amount of surface runoff and subsurface storm runoff which reaches stream channels.

Runoff, Indirect - The total amount of surface and sub-surface storm runoff which reaches stream channels after detention underground or in open bodies of water for a substantial length of time.

Sinuosity - Curvature of a river defined by the ratio of the thalweg length and the valley length.

Specific Energy - In a channel flow, specific energy is the energy per unit weight of water in any section with respect to the bottom of the channel, and includes both depth of water and velocity components.

Spillway - A waterway in or about a dam or other hydraulic structure, for the escape of excess water.

Spring Tide - A tide of greater-than-average range around the times of new and full moons.

Stochastic Models - Hydrologic drainage models (particular to a study site) developed from statistical combinations of probably relevant parameters.

Storage (With Respect to Runoff Analysis) -

Storage, Detention - That water that is detained on the surface during a storm and does not become runoff until sometime after the storm has ended.

Storage, Depression - That portion of the rainfall that is collected and held in small depressions and does not become part of the general runoff.

Storage (With respect to Runoff Controls) -

Storage Upstream - The storage of storm runoff water near the points of rainfall occurrence.

Storage, Downstream - The storage of storm runoff water at some distance from the points of rainfall occurrence but before it reaches areas where it may endanger lives or property.

Storage, Off-line - The temporary storage of storm runoff water away from the main channel of flow.

Storage, On-line - The temporary storage of storm runoff water behind embankments or dams located on the channel.

Storm Drainage System - All facilities used for conducting the stormwater through and from a drainage area to a point of final outlet, consisting of any or all of the following: conduits and appurtenant features, canals, channels, ditches, streams, ravines, gullies, flumes, culverts, streets, and pumping stations.

Storm, Major Design - That storm used for design purposes, the runoff from which is used for sizing the major storm drainage works.

Storm, Minor Design - That storm used for precipitation running off from the surface of a drainage area during and immediately following a period of rain.

Stream - A watercourse which has a flow of water for all or part of the year and has a defined channel showing signs of scouring and washing.

Streambank - The rising ground bordering a stream channel.

Streambed - The bottom of the stream below the usual water surface.

Stream Management Area - Any area related to a natural stream or course of water susceptible of being part of the major flood path, where any modification of natural conditions of flow is restricted to protect the environment and private or public properties. The restrictions applicable are defined in the *Water Act*, *Land Titles Act*, City Master Drainage Plan or City Bylaws.

Stream Reach - A section of stream of reasonably uniform gradient, streambed, streambank and flow pattern.

Subcritical Flow - Tranquil laminar flow with a Froude number less then one (velocity less than the square root of the depth times gravitational acceleration product) and water depth greater than critical depth.

Supercritical Flow - Turbulent rapid flow with a Froude number greater than one (velocity greater than the square root of the depth times gravitational acceleration product) and water depth less than critical depth.

Surcharge - The flow condition occurring in closed conduits when the hydraulic grade line is above the conduit crown, or the transition from open channel to pressure flow.

Surficial Materials - Naturally occurring unconsolidated materials including soil which cover the earth's surface.

Suspended Load - Material held in suspension by the river flow and transported at a velocity virtually identical to that of the water. Movement is unrelated to other particles in suspension.

Sustainable Development Goal - A balance between environment and natural resource systems on which human life and well-being depend, brought about by economic activity that does not undermine or impair tomorrow's economic prospects or quality of life.

Synthetic Unit Hydrograph - A unit hydrograph developed for an ungauged drainage area, based on known physical characteristics of the basin.

Thalweg - The route of deepest river and main channel flow.

Time of Concentration - The time required for storm runoff to flow from the most remote point of a watershed or drainage area to the outlet or point under consideration. It is not a constant, but varies with depth of flow, grades, length and condition of conduit and/or channel.

Topography - A general term to include characteristics of the ground surface such as plains, hills and mountains, degree of relief, steepness of slopes, and other physiographic features.

Transmissibility - The flow rate of an aquifer (or pumped recharge into an aquifer) defined as the flow divided by the aquifer depth for a unit width of aquifer (Volume per unit of time per unit of projected area).

Trash Rack - A barrier constructed to catch debris and exclude it from a downstream conduit. An improperly maintained trash rack may render a conduit useless.

Undercompetent Streams - Streams unable to transport sediment inflows (aggrading) (contrast overcompetent streams).

Underfit Stream - A river cut valley presently occupied by a much smaller river or stream.

Ungulate - A hoofed mammal, such as a deer or goat.

Unit Hydrograph - A runoff hydrograph resulting from one inch of excess rainfall applied to a given watershed over some specified time interval; also called unit graph.

Valley Flat - Relatively flat surfaces on the valley floor subject to flooding.

Watercourse - A channel in which a flow of water occurs, either continuously or intermittently, and if the latter, with some degree of regularity. Such flow must be in a definite direction. Watercourses may be either natural or artificial, and the form may occur either on the surface or underground.

Watercourse, Artificial - A surface watercourse constructed by human agencies, usually referred to as channel, canal or ditch.

Watercourse, Natural - A surface watercourse created by natural conditions.

Watercourse Storage - The volume of water stored in a watercourse. Generally considered in the attenuation of the peak of a flood hydrograph moving downstream.

Watershed - See Drainage Area.

Watershed Study - A plan of a watershed, or group of watersheds, that sets out the City's intent for that watershed. It will then be used to guide development or redevelopment in that watershed. Its primary thrust will be preventative, but it will also set out remedial measures that are technically sound, socially desirable and financially viable.

ABBREVIATIONS

AMC	antecedent moisture conditions
BCSLA	British Columbia Society of Landscape Architects
BMP NS	Non-Structural Best Management Practices
BMP OM	Operational and Maintenance Best Management Practices
BMP	Best Management Practices
CN	curve number (the soils effect on runoff)
ha	hectares
IDF Curves	Rainfall intensity – duration – frequency curves
m	meters
m/s	meters/second
MBE	Minimum Building Elevation
mm	millimetres
MMCD	Master Municipal Contract Documents
MPa	megapascal
PVC Pipe	Polyvinyl Chloride Pipe
Tp	time to peak, parameter of OTTHYMO models

(i) Wherever possible the basin shall be excavated in natural, stable ground. Should topography dictate that a berm be constructed along one or more sides of the basin, the berm shall be designed as a dam with an impervious core and cut-off trench extending at least one metre below the existing grade on which the berm is being constructed. The fill material shall be compacted to a minimum density of 95 percent Modified Proctor (ASTM-D-1557) and anti-seepage collars shall be placed around any pipes crossing through or under the berm.

(ii) The floor of the basin shall slope positively towards the outlet at a grade of not less than two percent. Unless approved otherwise, a system of perforated underdrains shall be installed in the basin floor and drained to the storm sewer outlet, except in areas where the native material is granular with a percolation rate in excess of 25mm per minute and where the highest recorded groundwater table is at least one metre below the lowest point on the basin floor.

(iii) An overflow shall be provided to route any excess water to the designated 100-year flood route. Such an overflow can be in the form of a spillway or it may be incorporated in the flow control structure through oversizing of downstream pipes, provision of overflow pipes, or such other arrangement as the designer may devise.

(iv) Unless otherwise approved, the maximum permissible man-made ponding depth is one metre. Where naturally contoured confines are used for ponding, depths may be deeper than one metre. Where natural vegetation is removed, topsoil shall be placed to a depth of not less than 150mm over the entire basin, and a vegetative cover of grass or other such hardy plant material that effectively eliminates erosion and is unaffected by frequent flooding shall be planted. The City will not accept the works until the vegetative cover has become firmly established and well rooted.

(v) Signs that read "Warning: This area is subject to flooding during heavy rainfall" shall be placed at all locations where the public may gain access to the basin. Security fencing may be required.

(vi) The inlet-outlet structure shall be designed to keep flow velocities below one metre per second, and suitable protection shall be placed around the inlet to prevent scour and erosion. The structure shall be complete with a galvanized steel bar rating in accordance with the City's Engineering standards. Safety fencing shall be provided whenever the height of wingwalls exceeds one metre. In fish bearing streams the structure shall allow passage of fish along the stream bed or by an approved ladder.

(vii) The flow control structure shall be constructed in accordance with the City of Coquitlam's Engineering standards. A sump stilling well or filtration device shall be provided to trap sediment.

(viii) Vehicular access is to be provided for maintenance and cleaning.

Item	Description	Yes	No	Not Required	Comments
1	Determination of all lands draining through the proposed development area using topographic information				
2	Size of the study area				
3	Present land use				
4	Proposed/;future land use				
5	Delineation of sub-basins				
6	Sediment control plan				
7	Lot grading plan				
8	Water quality control plan				
9	Land requirements/rights-of-way needed				
10	Types, locations and approximate sizes of major stormwater management facilities under post-development conditions				
11	Downstream system capacity and development impact				
12	Upgrading requirements and timing (if required)				
13	Schematic Diagram of Tributary Area				

APPENDIX B – CHECKLIST FOR PHASE 2 OF DEVELOPMENT APPLICATION REVIEW – DETAILED DESIGN

Item	Description	Yes	No	Not Required	Comments
1	Tables of pre-development and post-development hydrologic criteria				
2	Identify runoff simulation modelling parameters utilized				
3	Runoff simulation modelling output				
4	Details of minor drainage system: a) connection points to downstream system				
	b) connection points for upstream existing and future flows				
	c) pipe alignment, size, grade and capacity				
	d) 10-year and 25-year return period peak flows (as required)				
	e) representation of the 100-year grade line within the piped system				
5	Details of major drainage system: a) connection points to upstream system				
	b) discharge points to downstream system				
	c) road grades				
	d) overland flow paths and 100-year return period peak flows				
	e) ponding depths				
6	Figure(s) showing storm system (minor and major) layout and the road network over a topographic base				
7	Details of stormwater control facilities:				
	a) controlled discharge rates				
	b) type (wet, dry, infiltration, etc.)				
	c) design details (size, capacity)				
8	Implementation plan and schedule				
9	Operation and maintenance plan				
10	Sediment control plan				

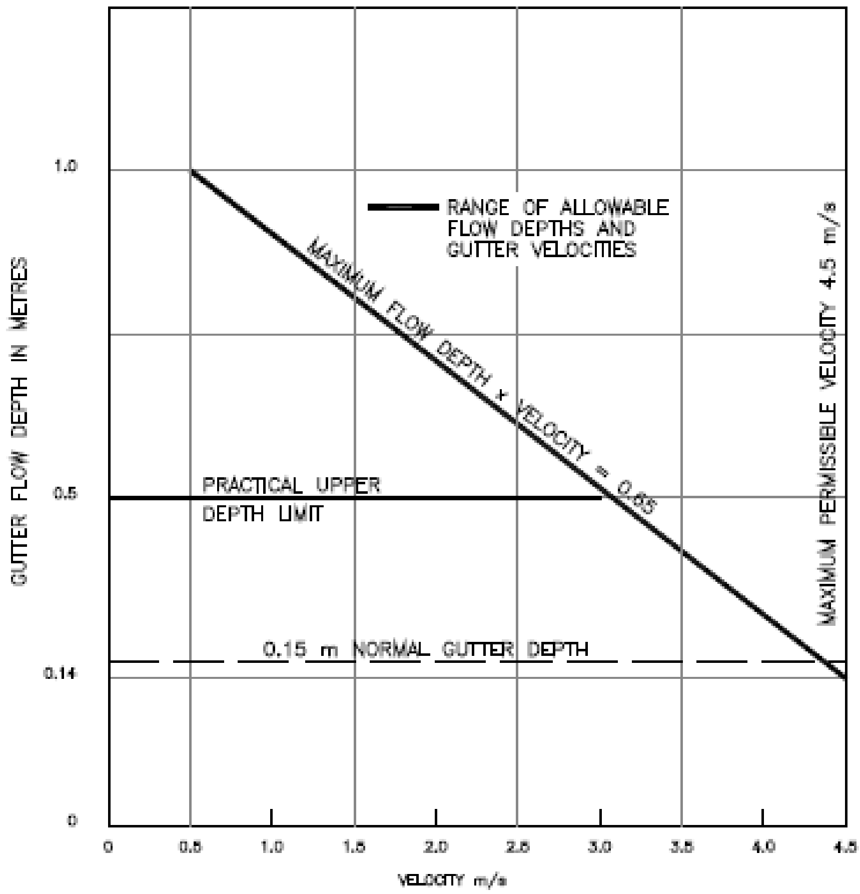
Item	Description	Yes	No	Not Required	Comments
1	Site plan maps on City of Coquitlam standard sheet sizes with approved scales (1:2500) showing the following:				
	a) boundaries of affected drainage basins				
	b) pre-development and post-development topography with legal mapping				
	c) points along the subdivision project boundaries that receive runoff from off-site drainage areas				
	d) pre-development and post-development drainage network (pipes, culverts, inlets, manholes, swales, open channels, etc.) and catchments tributary to each pipe or culvert inlet, as well as the following information in tabular format on the drawings:				
	- length, size and slope of each pipe				
	- tributary area				
	- calculated minor and major flow rates and capacities of each reach				
	- inlet and total area for off-site areas tributary to a storm sewer or culvert				
	- existing and future land use classification				
	e) pre- and post-development stormwater control measures				
	f) where required for "latecomer" service, all excess or extended service in bold				
2	The hydraulic gradelines produced by the actual captured flows from the 1:100-year storm shall be plotted on the detailed pipe design drawings				
3	Lot grading plans shall be provided as part of detailed design				
4	Sediment control plan shall be provided as part of detailed design per City bylaws				
5	Water quality control plan shall be provided as part of detailed design where required				
6	Mitigation statement				

Item	Description	Yes	No	Not Required	Comments
7	Plans to be completed to City of Coquitlam Drawing Standards and sealed by a Professional Engineer who is experienced in hydrology and is registered in British Columbia				

CITY OF COQUITLAM

STORMWATER MANAGEMENT POLICY AND DESIGN MANUAL

LIST OF FIGURES



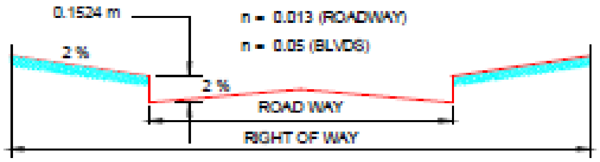
MAXIMUM ALLOWABLE GUTTER FLOW VELOCITY AND DEPTH OF FLOW

DAYTON & KNIGHT LTD.
Consulting Engineers

FIGURE 1

$$Q = \frac{1}{n} R^{2/3} \cdot S^{1/2} \cdot A$$
$$= K_t \cdot S^{1/2}$$

WHERE $K_t = \Sigma \left(\frac{1}{n_i} R_i^{2/3} A \right)$



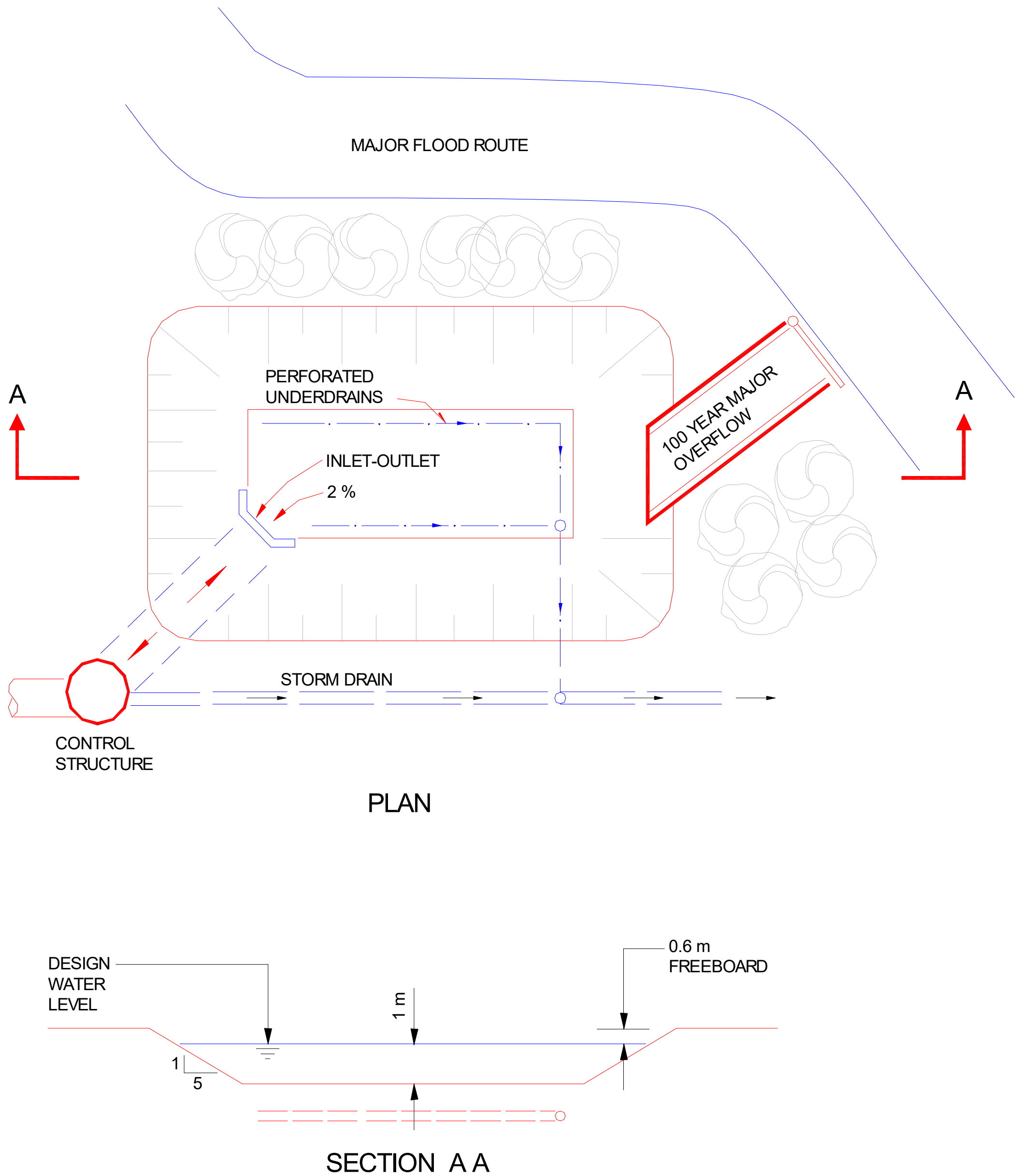
ROAD GRADE S %	S ½	DEPTH OF FLOW FROM GUTTER UP					
		R.O.W. = 17 m BLVD. = 4.5 m FLOW DEPTH = 242.4 mm		R.O.W. = 20 m BLVD. = 5.75 m FLOW DEPTH = 250.0 mm		R.O.W. = 30 m BLVD. = 8 m FLOW DEPTH = 150.0 mm	
		K_t = 42.6966	A = 2.0242 m^2	K_t = 47.7149	A = 2.2400 m^2	K_t = 15.7652	A = 1.1200 m^2
		CAPACITY Q m^3/s	VELOCITY V m/s	CAPACITY Q m^3/s	VELOCITY V m/s	CAPACITY Q m^3/s	VELOCITY V m/s
0.50	0.0707	3.033	1.498	3.374	1.506	1.115	0.996
0.60	0.0775	3.323	1.642	3.696	1.650	1.221	1.090
0.70	0.0837	3.589	1.773	3.992	1.782	1.319	1.178
0.80	0.0894	3.873	1.896	4.268	1.905	1.410	1.259
0.90	0.0949	4.070	2.011	4.527	2.021	1.496	1.336
1.00	0.1000	4.290	2.119	4.771	2.130	1.577	1.408
1.10	0.1049	4.499	2.223	5.004	2.234	1.653	1.476
1.20	0.1095	4.699	2.321	5.227	2.333	1.727	1.542
1.30	0.1140	4.891	2.416	5.440	2.429	1.798	1.605
1.40	0.1183	5.076	2.508	5.645	2.521	1.865	1.665
1.50	0.1225	5.254	2.596	5.844	2.609	1.931	1.724
1.60	0.1265	5.426	2.681	6.036	2.695	1.994	1.780
1.70	0.1304	5.593	2.763	6.221	2.777	2.056	1.836
1.80	0.1342	5.755	2.843	6.402	2.858	2.115	1.888
1.90	0.1378	5.913	2.921	6.577	2.936	2.173	1.940
2.00	0.1414	6.067	2.997	6.748	3.013	2.230	1.991
2.10	0.1449	6.217	3.071	6.915	3.087	2.285	2.040
2.20	0.1483	6.363	3.143	7.077	3.159	2.336	2.083
2.30	0.1517	6.506	3.214	7.236	3.230	2.391	2.135
2.40	0.1549	6.646	3.283	7.392	3.300	2.442	2.180
2.50	0.1581	6.783	3.351	7.544	3.368	2.493	2.226
2.60	0.1612	6.917	3.417	7.694	3.435	2.542	2.270
2.70	0.1643	7.049	3.482	7.840	3.500	2.590	2.313
2.80	0.1673	7.178	3.546	7.984	3.564	2.638	2.355
2.90	0.1703	7.305	3.609	8.126	3.628	2.685	2.397
3.00	0.1732	7.430	3.671	8.264	3.689	2.731	2.438
3.10	0.1761	7.553	3.731	8.401	3.750	2.776	2.479
3.20	0.1789	7.674	3.791	8.536	3.811	2.820	2.518
3.30	0.1817	7.793	3.850	8.668	3.870	2.864	2.557
3.40	0.1844	7.910	3.908	8.798	3.928	2.907	2.596
3.50	0.1871	8.025	3.965	8.927	3.985	2.949	2.633
3.60	0.1897	8.139	4.021	9.053	4.042	2.991	2.671
3.70	0.1924	8.252	4.077	9.178	4.097	3.032	2.707
3.80	0.1949	8.362	4.131	9.301	4.152	3.073	2.774
3.90	0.1975	8.427	4.185	9.423	4.207	3.113	2.779
4.00	0.2000	8.580	4.239	9.543	4.260	3.153	2.815

FROM: GIBSON, MICHAEL E.M., KENNETH L. CHUA, "ADVANTAGES OF INLET CONTROL IN LIMITING FLOWS", CIVIC PUBLIC WORKS, NOVEMBER 1980

DEPTH OF MAJOR FLOW ALONG CURBED STREETS AND ROADS

DAYTON & KNIGHT LTD.
Consulting Engineers

FIGURE 2



TYPICAL OFFSTREAM BASIN CONSTRUCTION

ACAD DWG. 138.43(FIGURE 03) 1:1 22-JUNE2002

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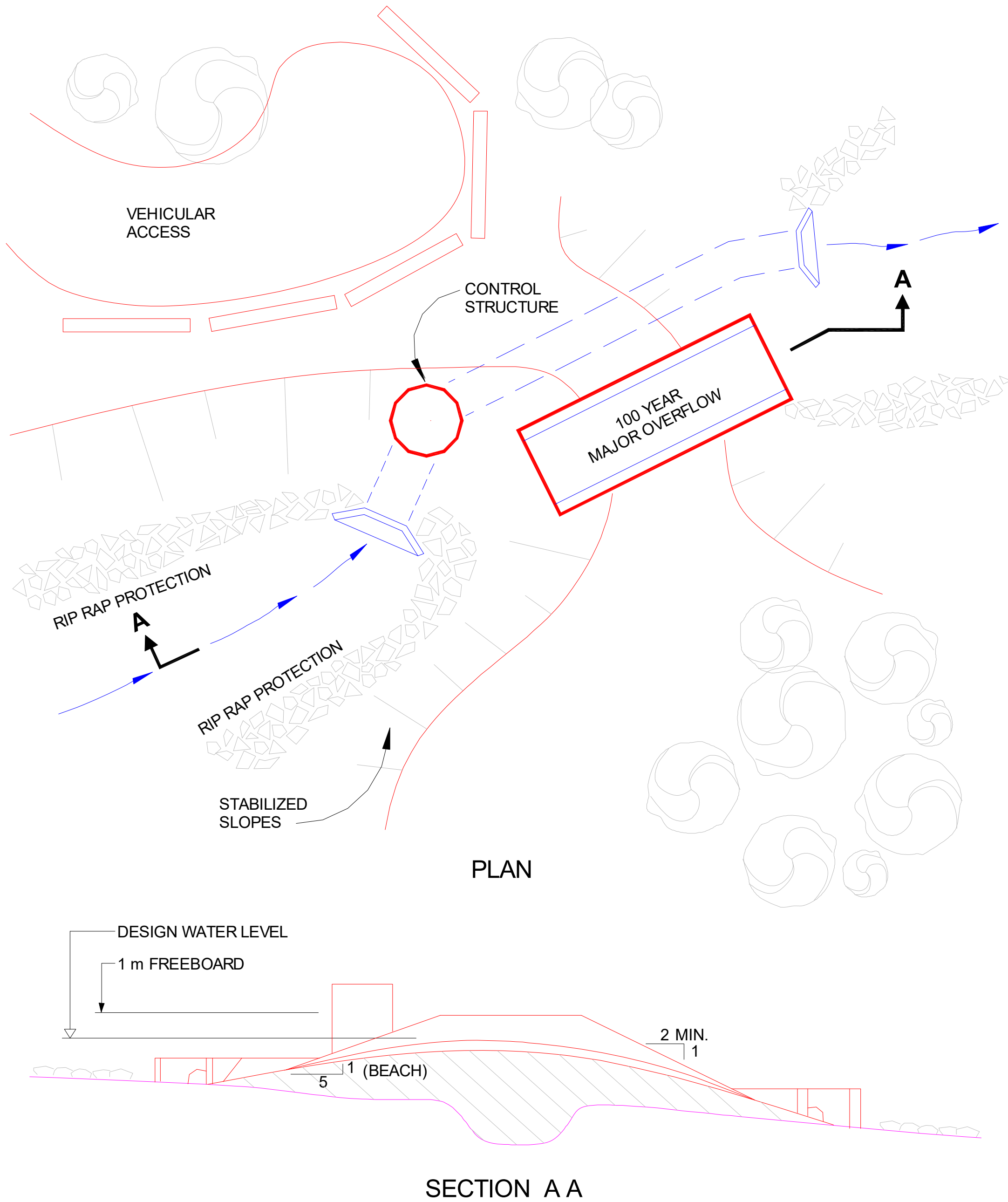
Consulting Engineers
DRAWN BY: GSAM
DWG. No. 138.43

FIGURE 3



TYPICAL ONSTREAM BASIN CONSTRUCTION IN NATURAL CHANNEL

ACAD DWG. 138.43(FIGURE 04) 1:1 22-JUNE2002

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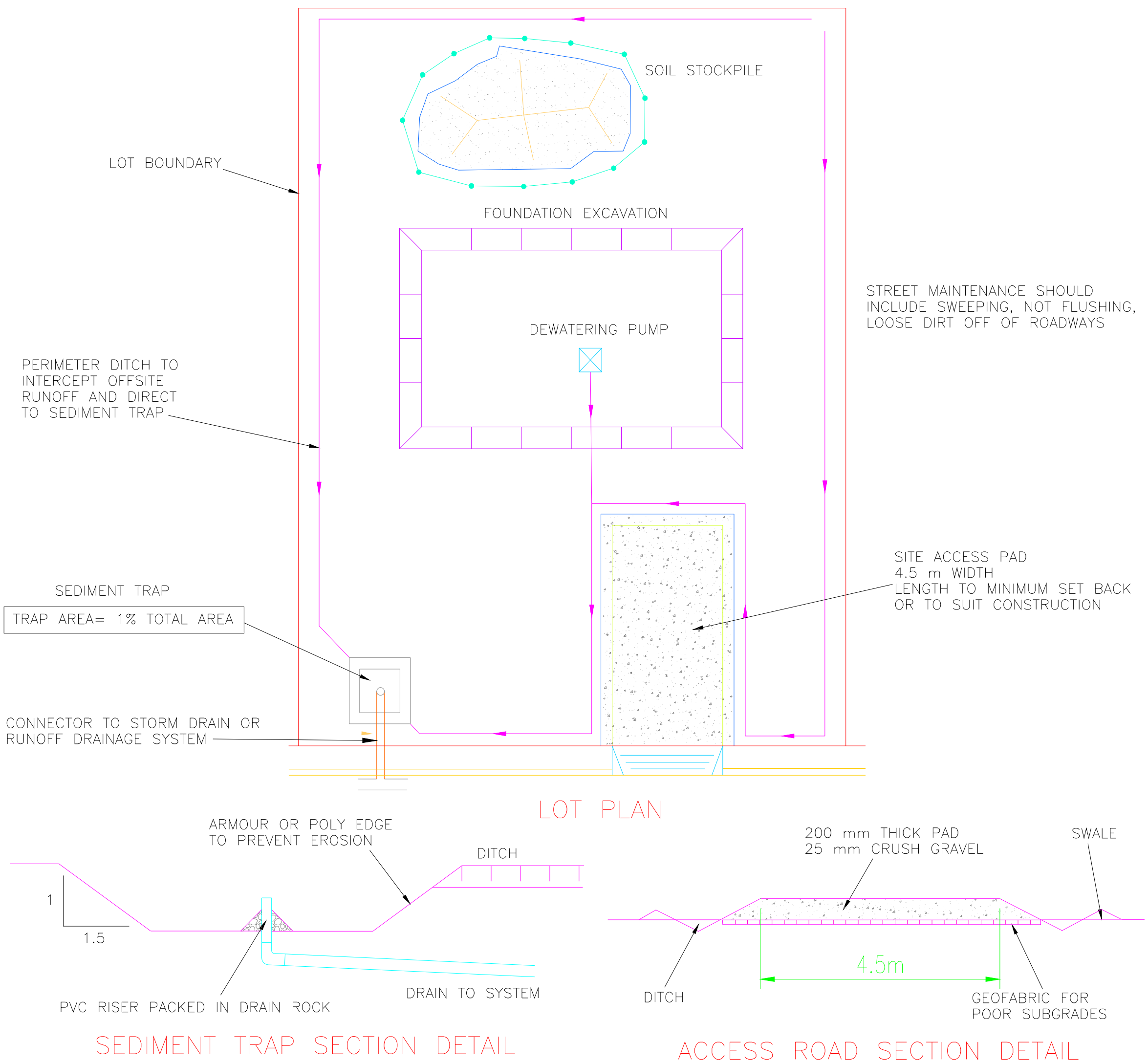
Consulting Engineers
DRAWN BY: GSAM
DWG. No. 138.43

FIGURE 4

Adopted July 21, 2003; Amended Jan 16, 2012,
Mar 30, 2015, Mar 14, 2016, Nov 2017, Feb 2019, Sep 2021



1. Erosion and Sediment Control to be installed prior to any other on site activities.
2. No sediment laden water is to be discharged from the site.
3. Soil Stockpiles to be covered with poly or surrounded with silt fencing
4. Site access pad 4.5m in width at all accesses to site.
5. Swales to be installed as needed based on lot grading.
6. These are guidelines. It is the owners responsibility to comply with Bylaw 3447.
7. Concrete truck wash and construction wash of exposed aggregate surfaces is not to be directed into any storm systems. Use of off site disposal for wash discharge is required.

FIGURE 5

City of Coquitlam

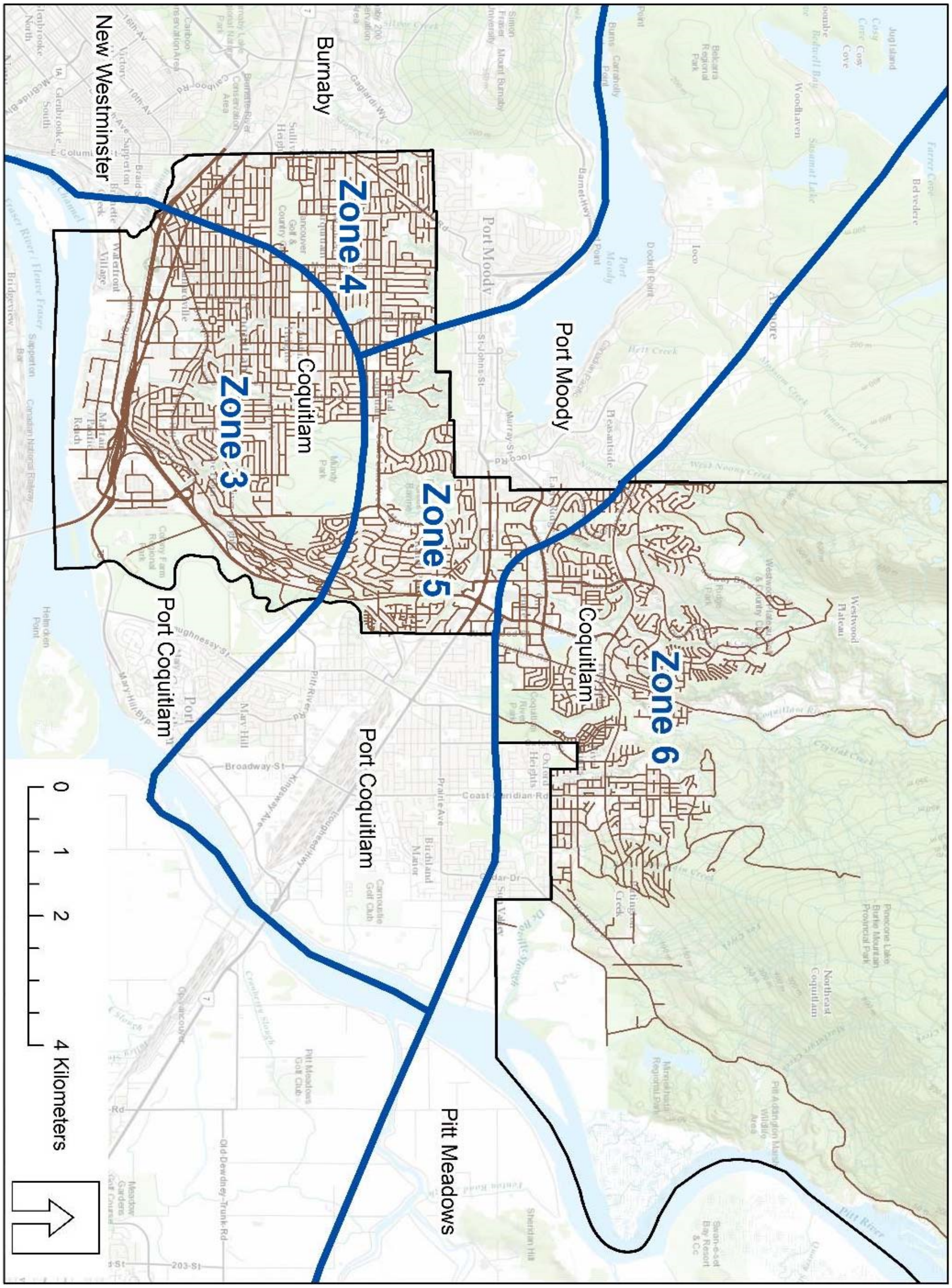
Single Lot Development
Erosion and Sediment Control Guidelines

REVISIONS	No.	DATE:	CKD.	APP.
ADD NOTE 7.	1	02/98	D.W.	

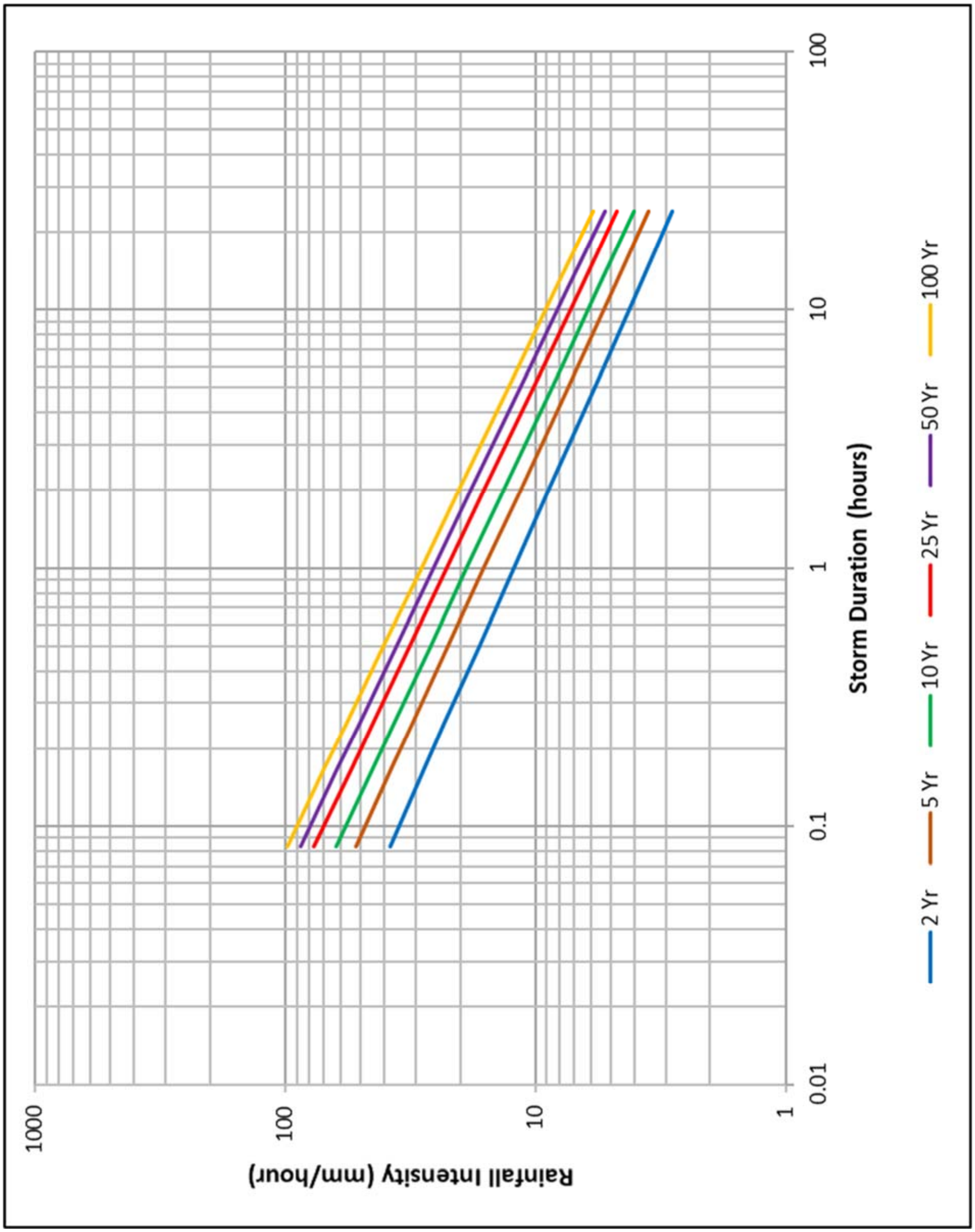
DESIGNED BY: M.I.	DRAWN BY: A.S.K.	CHECKED BY:	APPROVED BY:
SCALE: N.T.S.	DATE: SEPT. 20/96	X	DRAWING NO.: A4E06

ACAD DWG. 138.43FIG5 1:50 03-FEB-2003

Dayton & Knight Ltd.
CONSULTING ENGINEERS
DRAWN BY: PTL
DWG. No. 138.43

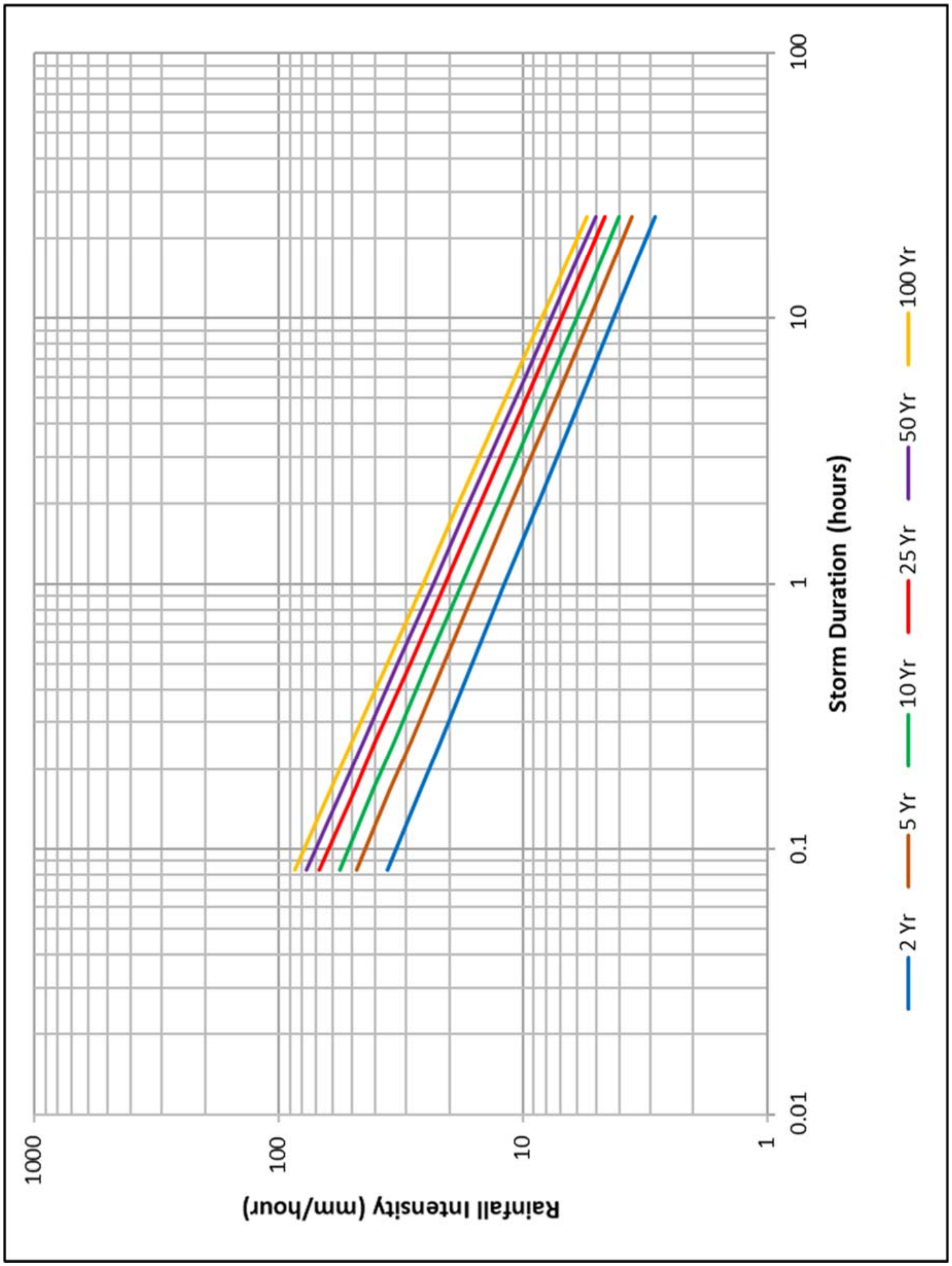


Coquitlam Rainfall Zona Map For Design IDF Curves **FIGURE 6**



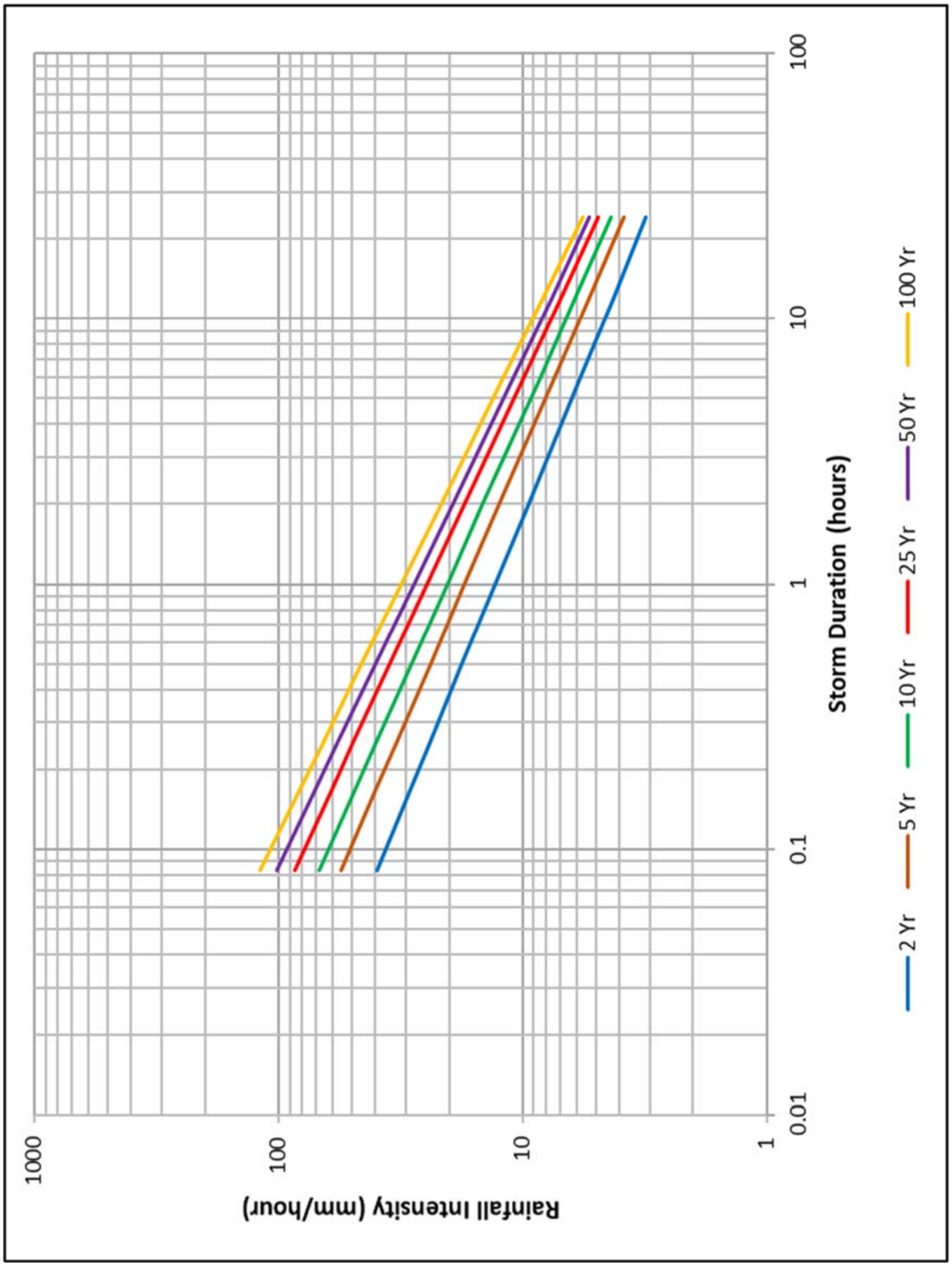
2021 IDF FOR ZONE 3

FIGURE 7



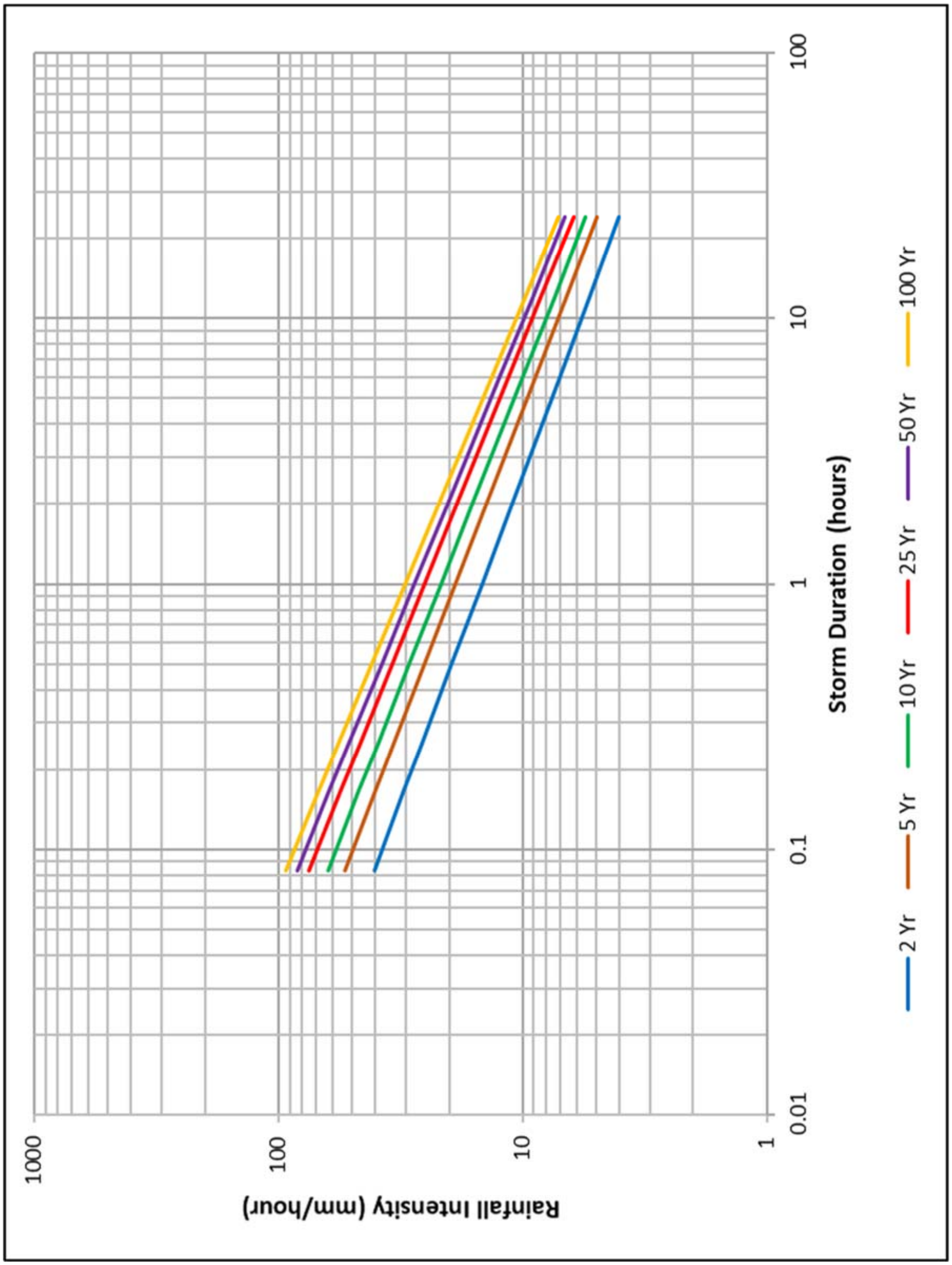
2021 IDF FOR ZONE 4

FIGURE 8



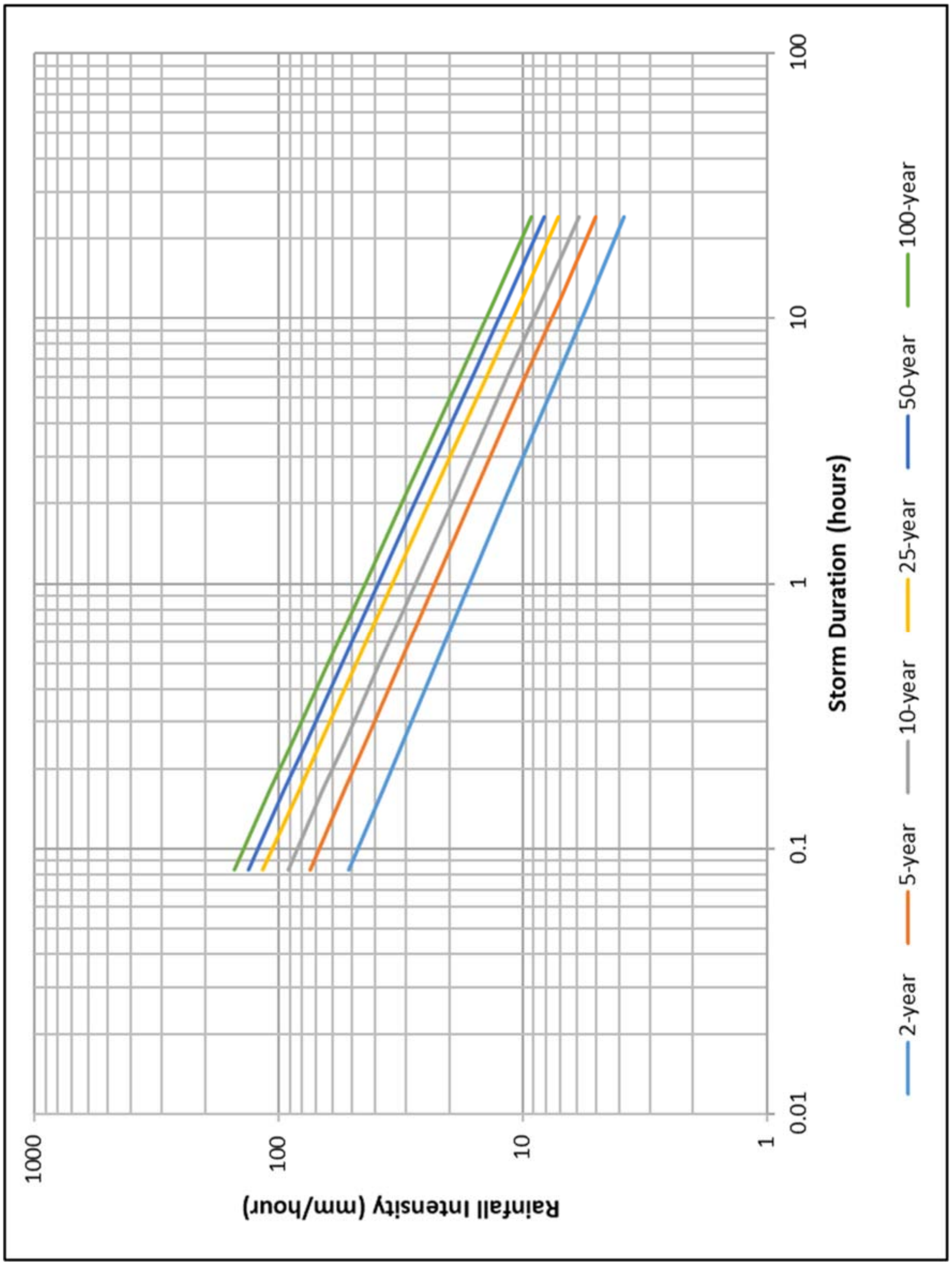
2021 IDF FOR ZONE 5

FIGURE 9



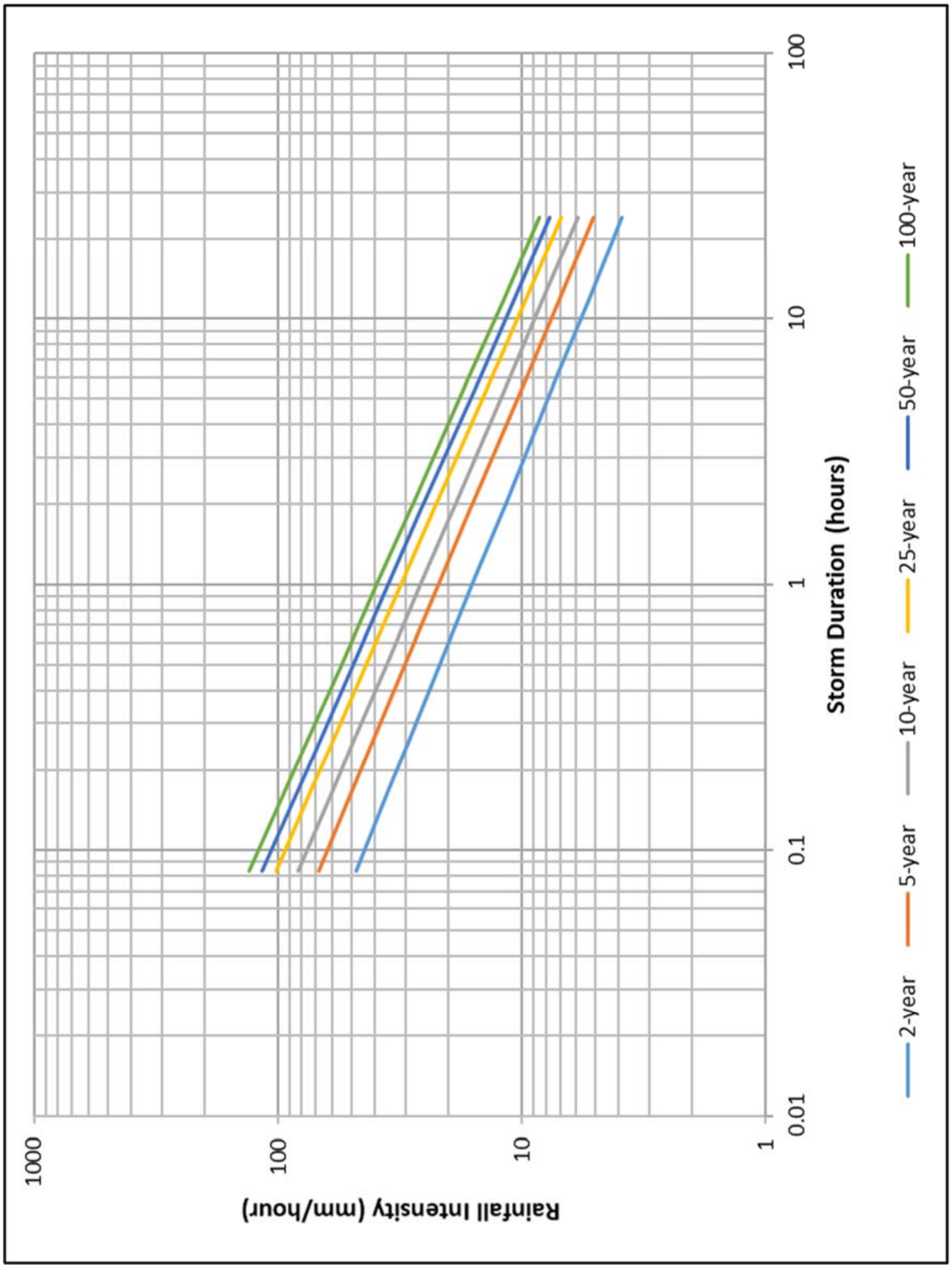
2021 IDF FOR ZONE 6

FIGURE 10



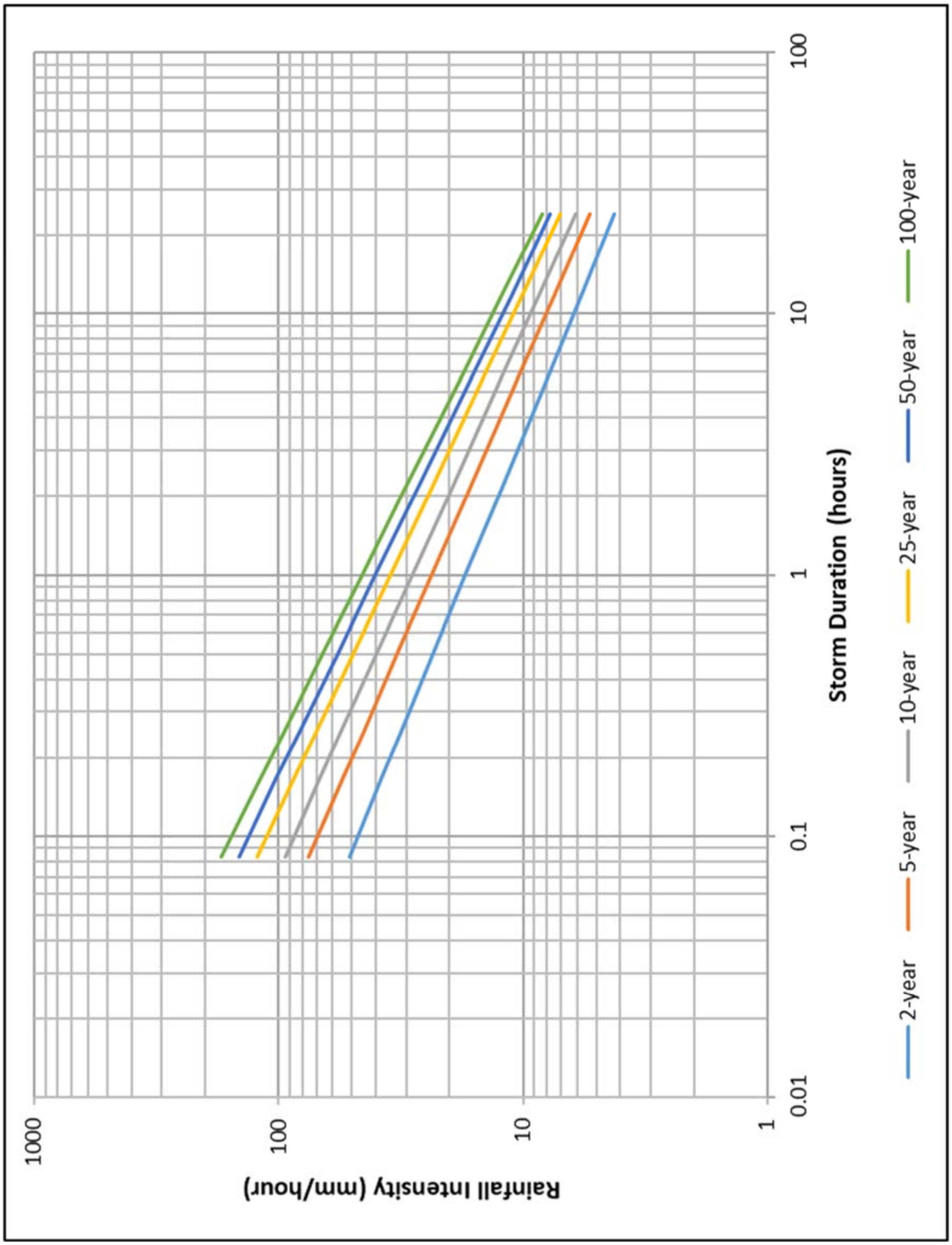
2050 IDF FOR ZONE 3

FIGURE 11



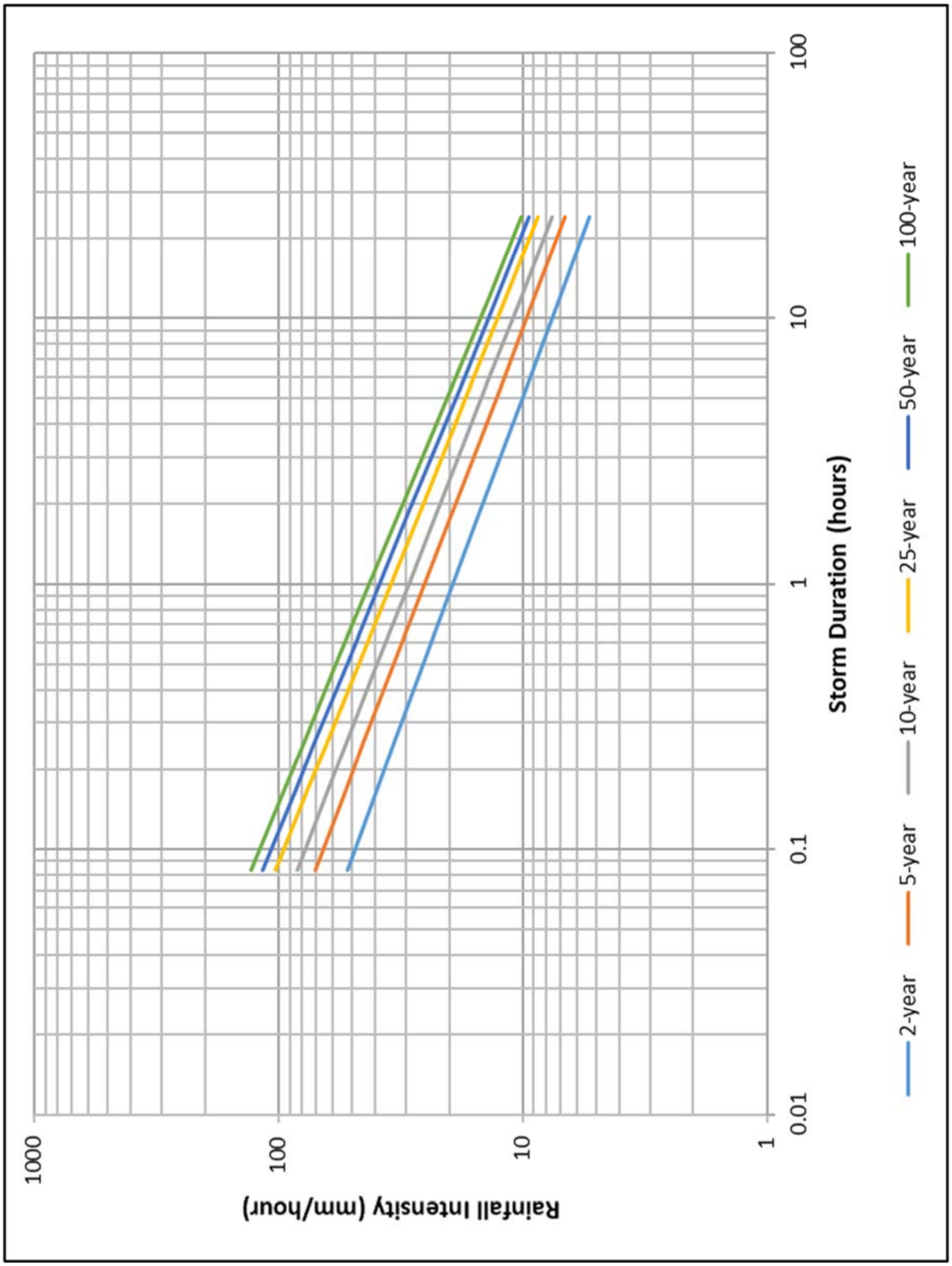
2050 IDF FOR ZONE 4

FIGURE 12



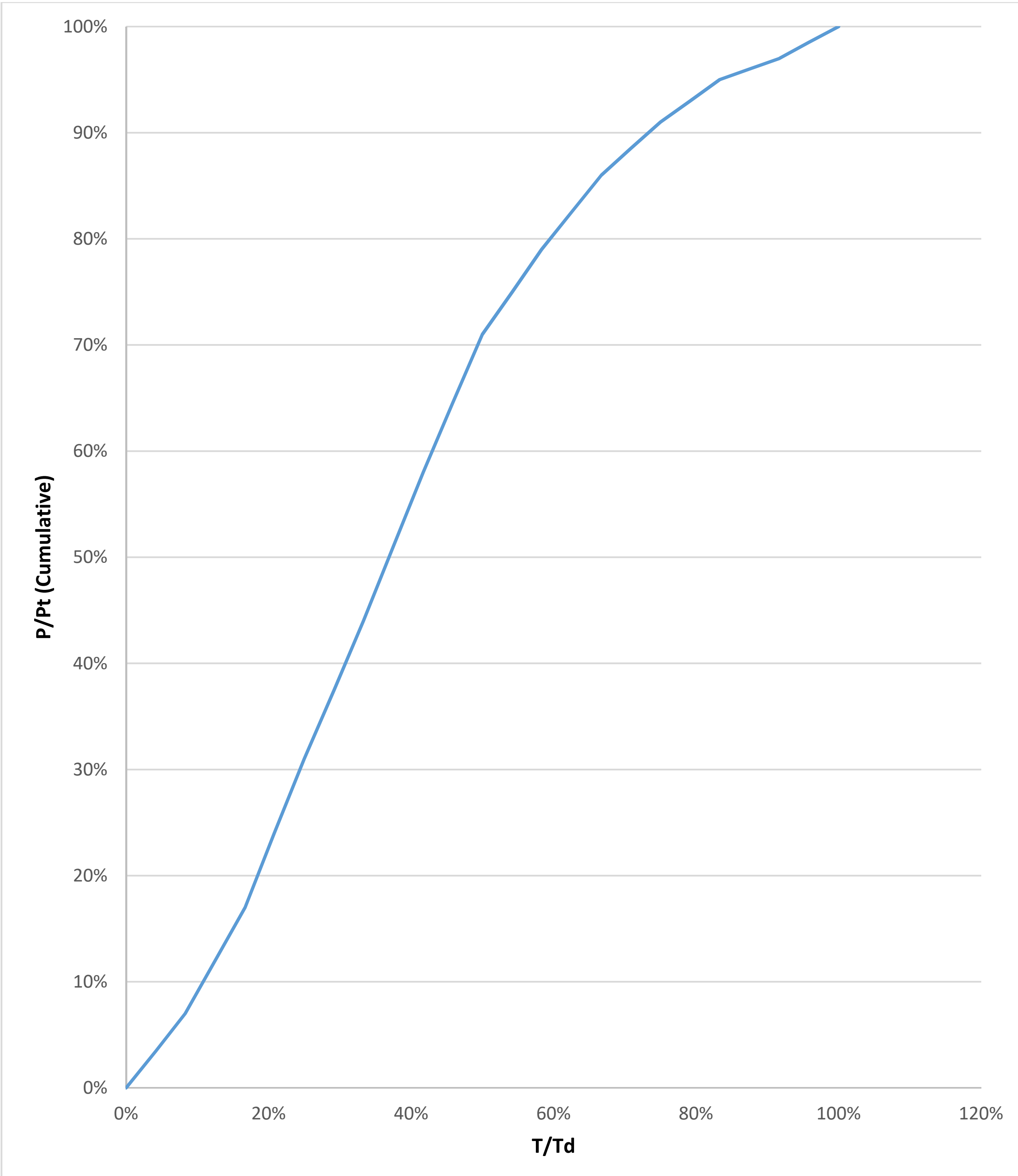
2050 IDF FOR ZONE 5

FIGURE 13



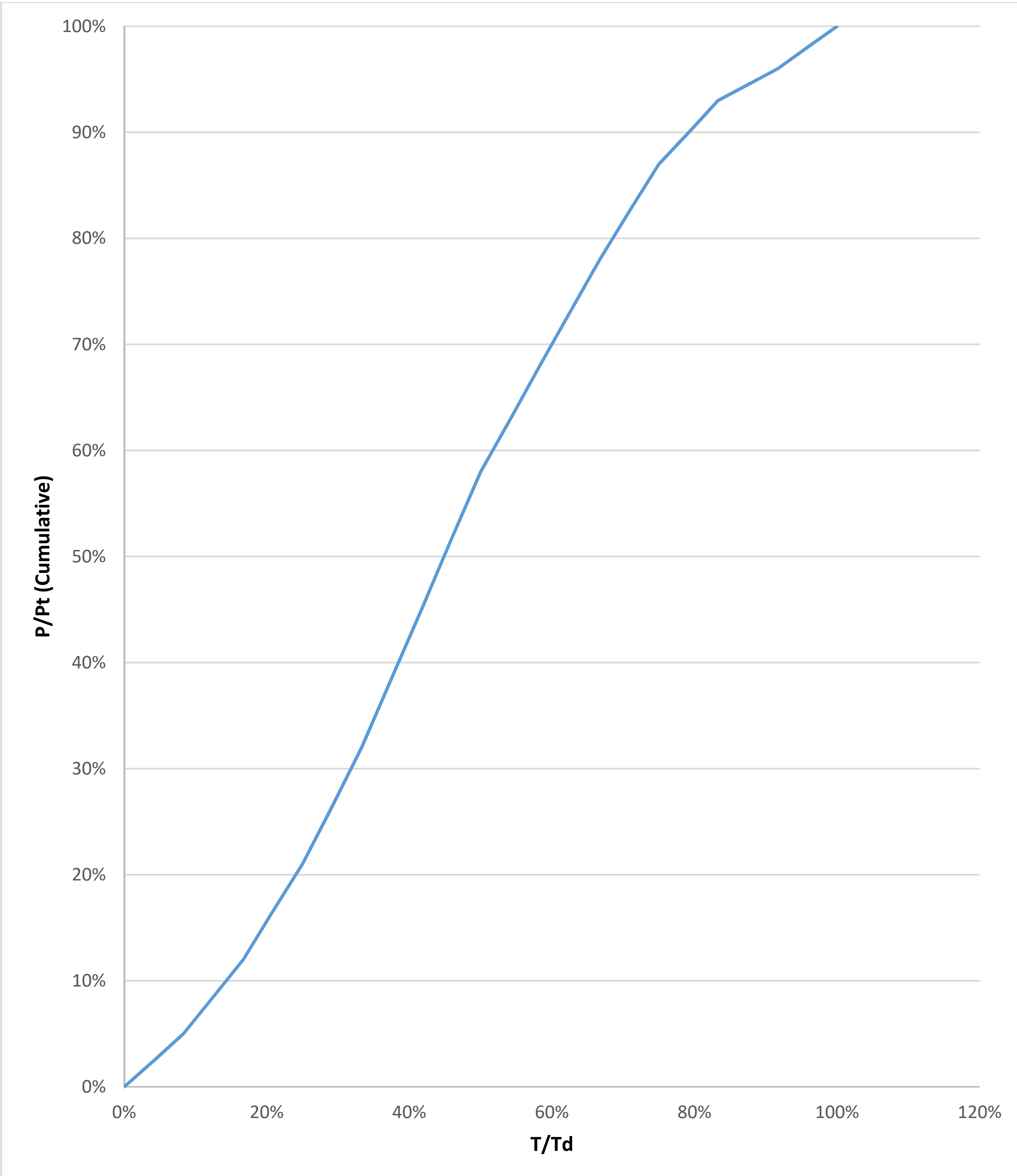
2050 IDF FOR ZONE 6

FIGURE 14



SHORT DURATION DESIGN STORM DISTRIBUTION (30 MIN, 1 HOUR, 2 HOUR EVENTS)

FIGURE 15



LONG DURATION DESIGN STORM DISTRIBUTION (6 HOUR, 12 HOUR, 24 HOUR EVENTS)

FIGURE 16

FIGURE 10 IS USED TO CALCULATE AN INLET TIME FOR A SHEET OF RUNOFF FLOWING OVER A LEVEL SURFACE SUCH AS A GRASSED LOT, PAVEMENT, ETC.

USE FIGURE 10 AS FOLLOWS :

- : ASSUME I FROM AN ESTIMATE OF THE TIME OF CONCENTRATION Ti
- : CALCULATE THE INLET TIME Ti FROM THE ASSUMED INTENSITY, I CHECK IF INTENSITY APPROPRIATE FOR THE ASSUMED Ti FROM FIGURE 6 OR 7
- : IF THE NEW INTENSITY IS HIGH OR LOW, TRY A NEW Ti REDO UNTIL Ti AGREES WITH INTENSITY

$$Ti = 0.93 \frac{L^{0.4}\ n^{0.3}}{I^{0.4}\ S^{0.3}}$$

EXAMPLE

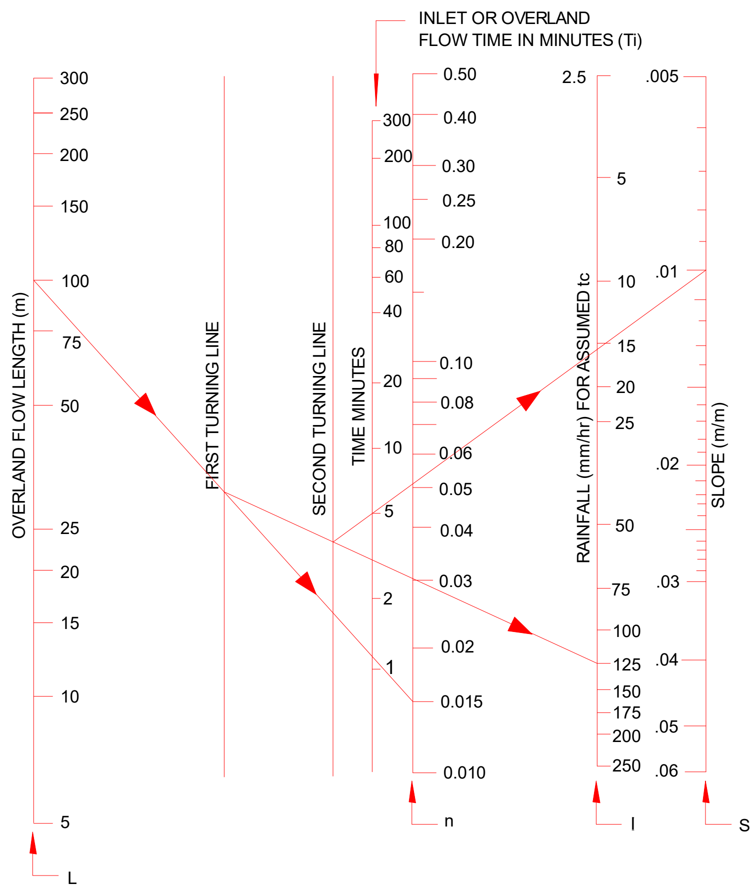
L = 100 m

n = 0.015

I = 125 mm/hr

S = 0.01 m/m

FIND Ti = 5.0 min.



NOMOGRAPH TO DETERMINE OVERLAND FLOW BASED ON KINEMATIC WAVE FORMULATION (BASICALLY FOR 300 METRES OR LESS OF INLET DISTANCE)

ACAD DWG. 138.42B(FIGURE 14) 1:1 22-JUNE2002

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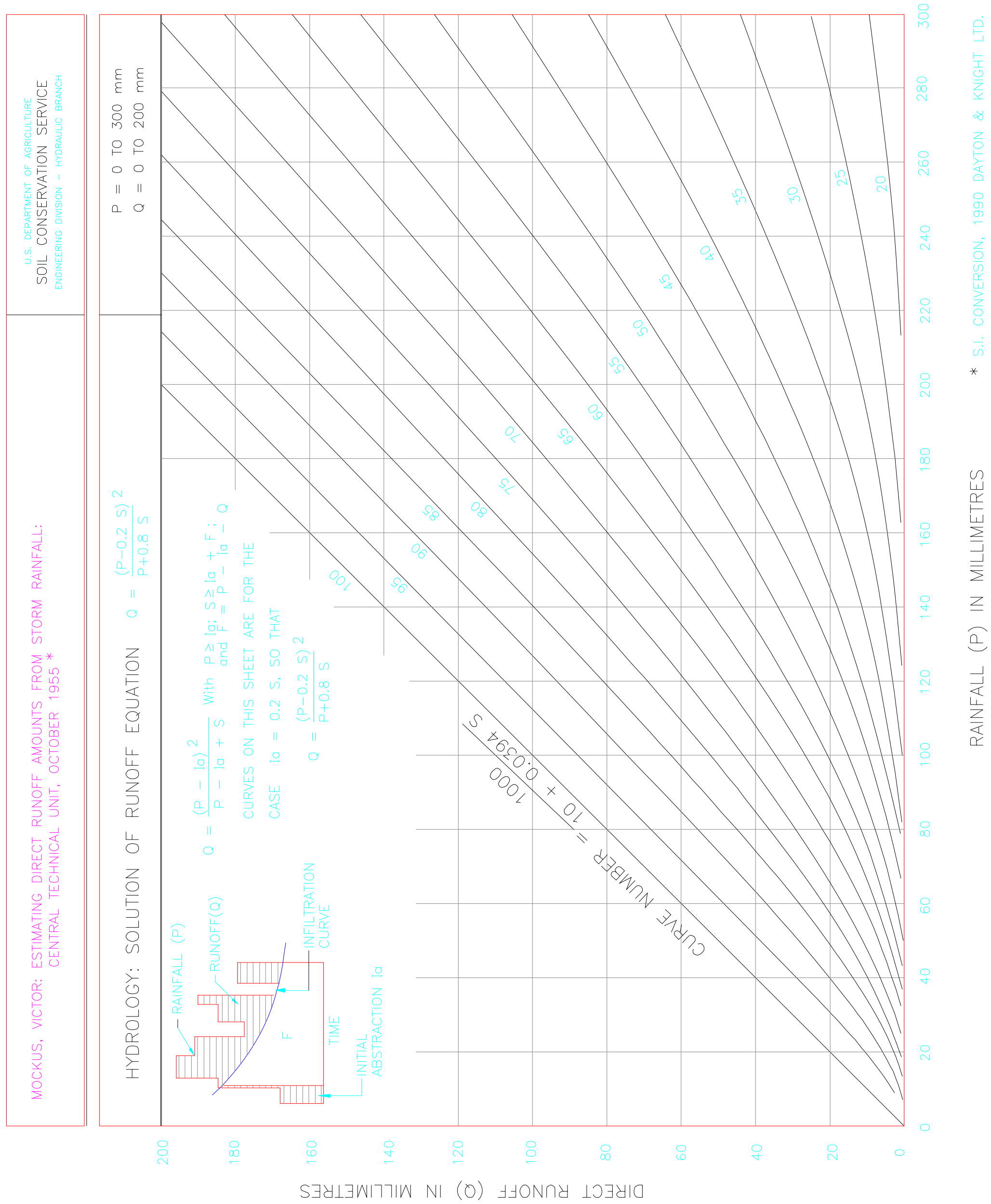
FIGURE 17



ESTIMATING RUNOFF AMOUNTS FROM STORM RAINFALL FOR HIGH ABSTRACTION CASE, (Ia = 0.2 S)

ACAD DWG. 138.42B(FIGURE 15) 1:1 22-JUNE2002

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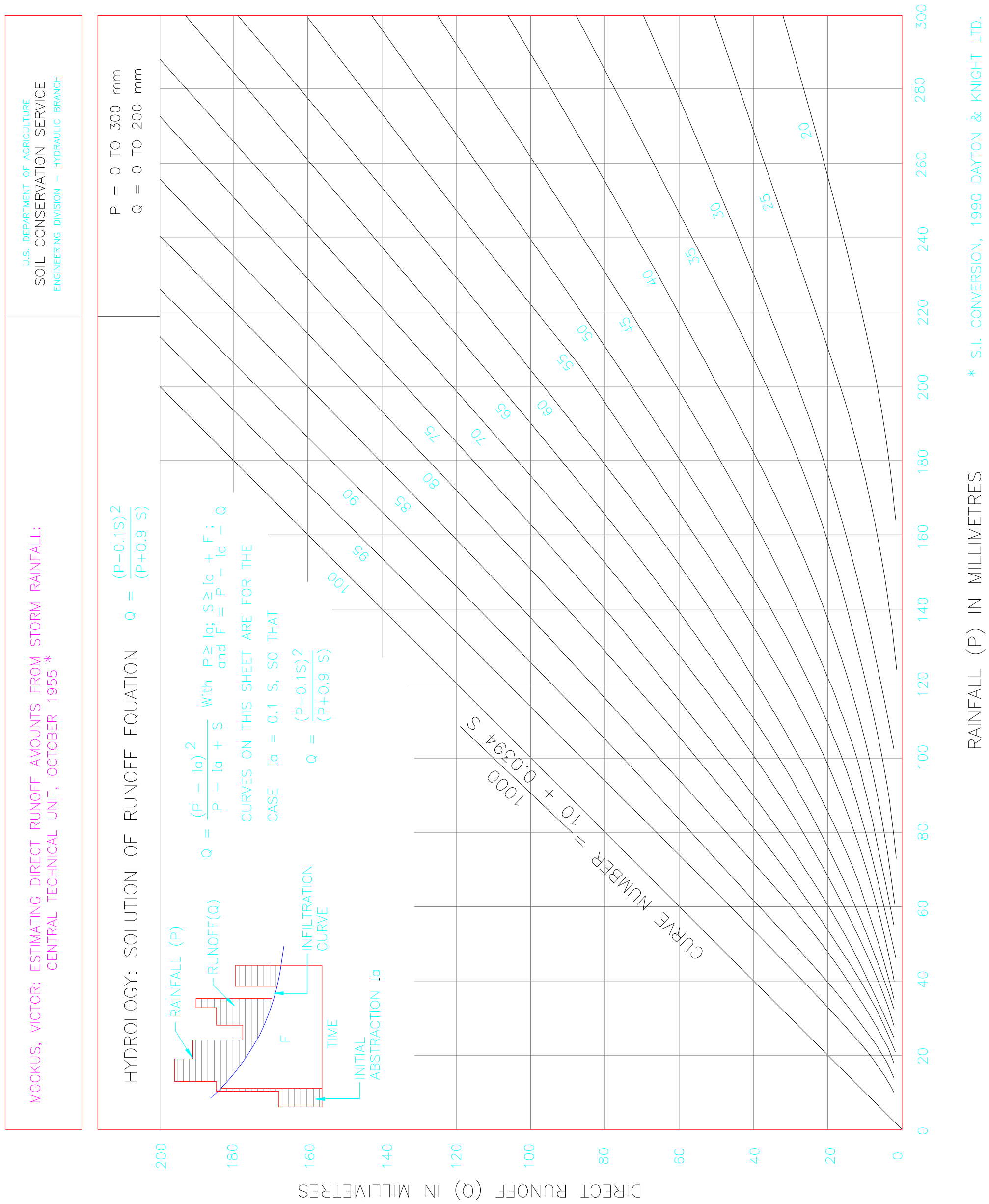
FIGURE 18



ESTIMATING RUNOFF AMOUNTS FROM STORM RAINFALL FOR LOW ABSTRACTION CASE, (Ia = 0.1 S)

ACAD DWG. 138.42B(FIGURE 16) 1:1 22-JUNE2002

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FIGURE 19