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The **MMCD Association (MMCD)** is a Non-Profit Society funded by British Columbia municipalities and associate members who use MMCD documents for design and construction of certain categories of municipal infrastructure, including water, sewer, drainage, roads and traffic control. Its main products are the Master Municipal Construction Document, and the training programs which support its use. Other related documents have been produced by MMCD including an infrastructure design guideline manual and this supplement. The Province of British Columbia supports the Master Municipal Construction Document for the construction of municipal services.

Currently, MMCD Design Guidelines are published to assist designers utilizing the Master Municipal Contract Documents. The MMCD Green Design Guideline Manual is intended to supplement the MMCD Design Guideline Manual by describing alternative design practices which support environmentally friendly initiatives in municipal infrastructure and land development projects.

MMCD Green Design Guidelines are formatted to replace or augment MMCD Design Guidelines. Expectations or observations related to many Green Guidelines are tabulated to provide the designer with additional information about the implications of adoption as related to initial cost, operating cost, maintenance, sustainability, and other performance factors, insofar as initial experience has indicated.

MMCD Green Guidelines are expected to evolve and expand as more demonstration projects are initiated and as current projects are evaluated. In many cases, long term evaluation of Green Initiatives has not been completed. In recognition of the evolving nature of the Green Guidelines, regular scans of Green practices will be incorporated in to the Manual's evolutionary process. Proposed modifications will be posted regularly for public comment on the MMCD website. Designers are encouraged to submit information pertaining to the performance of Green initiatives to www.MMCD.net.

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1.0 SUSTAINABLE DEVELOPMENT IN LOCAL INFRASTRUCTURE

Sustainable Development is the practice of meeting the needs of society today without compromising the ability of future generations to meet their own needs. Many high level policies and financial support programs promote sustainable development initiatives. For instance, the Kyoto Accord, drafted in 1997 and ratified by 141 nations including Canada in February 2005, will promote sustainable development by focusing on the reduction of greenhouse gas emissions. The cumulative effect of these policies and programs is to encourage and support sustainable development initiatives at the local government level.

The federal and provincial governments are key contributors to sustainable development in local infrastructure. The Federal Department of Fisheries and Oceans, (DFO), works to provide safe and accessible waterways, healthy and productive aquatic ecosystems, sustainable fisheries and aquaculture. They have formal and established guidelines for the protection of fish habitat. The Provincial Ministries of: Community, Aboriginal, and Women's Services; Health Services; Sustainable Resource Management; and Environment prepare policies and procedures that promote sustainable development concepts in municipal planning. Sustainable Development principles can provide the impetus to introduce non-traditional infrastructure at the local government level: these initiatives are known as "Green Infrastructure"

Green infrastructure can be issue-focused, targeting pollution prevention, habitat management, climate change, material reduction, reuse, and recycling, demand management, risk management, and energy conservation. Green infrastructure can also be practice-oriented, promoting compact, complete communities, increased transportation choice, reduced water and energy consumption, protection of urban greenspace, lighter development 'hydrologic footprints,' and heightened stream protection practices. Green infrastructure is an evolving and expanding field.

For the purposes of the MMCD Green Design Guidelines, source information on Green infrastructure has been drawn from a variety of sources, including:

2.0 INFRAGUIDE: THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

A joint effort between the Federation of Canadian Municipalities, National Research Council Canada, Infrastructure Canada, and the Canadian Public Works Association, the collaborative effort has produced The National Guide to Sustainable Municipal Infrastructure, (InfraGuide). "Infraguide identifies and disseminates best practices and encourages innovation to support sustainable municipal infrastructure decisions and actions to protect and enhance the quality of life of Canadians."[1]

[1] InfraGuide Innovations and Best Practices "Adopting Sustainable Approaches to Infrastructure Services: Principles and Guidelines for Municipalities" January 2004

Discussed within this document are the following Infraguide Best Management Practices: *Stormwater Management Planning; Source and On-Site Controls for Municipal Drainage Systems;* and *Conveyance and End-of-Pipe Measures for Stormwater Control.*

3.0 MINISTRY OF ENVIRONMENT (MOE)

The Ministry of Environment publications *Stormwater Planning: A Guidebook for British Columbia* and *Urban Runoff Quality Control Guidelines for the Province of British Columbia, June 1992* have been discussed in this document.

Environmental Best Practices for Urban and Rural Land Development in British Columbia has been prepared to assist those who are involved in planning, implementing, reviewing, and/or approving land developments in British Columbia. Its primary purpose is to provide province-wide guidelines for the maintenance of environmental values during the development of urban and rural lands. It also discusses ways that environmental protection and stewardship can benefit the community, the property owner, and the developer, as well as the natural environment. The document is presently well-developed and in the late stages of public comment.

4.0 GREEN INFRASTRUCTURE PARTNERSHIP (GIP)

The Green Infrastructure Partnership is a joint effort between the MMCD, the Ministry of Community, Aboriginal & Women's Services, the Water Sustainability Committee of the B.C. Water & Waste Association, and the West Coast Environmental Law Association. GIP works to develop tools for introducing Green infrastructure at the local level.

5.0 GREATER VANCOUVER REGIONAL DISTRICT (GVRD)

- ***Stormwater Source Control Design Guidelines 2005***
- *Integrated Stormwater Management Planning,* May 2002
- *Effectiveness of Stormwater Source Control*, December 2002
- *Best Management Practices Guide for Stormwater* and *Construction Site Erosion and Sediment Control Guide,* October 1999
- *Estimated Urban Runoff Character and Contaminant Loadings in the GVRD,* April 2003

6.0 CAPITAL REGIONAL DISTRICT (CRD)

- *2004 Review of the Strategic Plan for Water Management*
- *Regional Source Control Program 2002*

7.0 LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED)

"The LEED (Leadership in Energy and Environmental Design) Green Building Rating System® is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings."[2]

Developed by the U.S. Green Building Council, and adapted by the Canada Green Building Council, the *LEED Green Building Rating System Reference Guide – LEED Canada – NC Version 1.0* dated December 2004 promotes sustainable strategies in the areas of Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Innovation & Design. The prerequisites and credits within this program are congruent with the concepts outlined in this document. Targets within the program include reduction or elimination of potable water for landscaping, incorporation of water efficient designs, and reduced reliance upon municipal water and wastewater systems.

The LEED system is gaining widespread implementation through Green Building Ordinances introduced in the City of Vancouver as well as several U.S. cities that mandate new buildings achieve a particular rating under the program. Reference Guides for Existing Buildings, Homes, and Neighborhood Development are currently under development.

8.0 SUSTAINABLE URBAN LANDSCAPES

Released in August 2003, the *Site Design Manual for BC Communities* outlines a variety of integrated processes and principles that produce sustainable communities within the context of communities within British Columbia. Published by the University of British Columbia James Taylor Chair in Landscape and Livable Environments, Chaired by Mr. Patrick Condon, this manual develops alternative development and engineering standards for the design of new (and for the retrofit of existing) communities in British Columbia.

9.0 URBAN NATURALIZATION IN CANADA: A POLICY AND PROGRAM GUIDEBOOK

Published by Evergreen, a non-profit environmental organization with a mandate to bring nature to our cities through naturalized projects, this 2001 manual promotes sustainable development and provides case studies of the successful implementation of various policies throughout the country.

[2] U.S. Green Building Council Website http://www.usgbc.org/ February 18, 2005

10.0 UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA)

The EPA is a leader in research, education, and the development and enforcement of regulations for achieving goals related to:

- Clean Air and Global Climate Change
- Clean and Safe Water
- Land Preservation and Restoration
- Healthy Communities and Ecosystems
- Compliance and Environmental Stewardship
- Homeland Security

The USEPA document *The Use of Best Management Practices (BMPs) in Urban Watersheds* September 2004 has been referenced throughout this document.

11.0 CENTER FOR WATERSHED PROTECTION

"The Center has developed and disseminated a multi-disciplinary strategy to watershed protection that encompasses watershed planning, watershed restoration, stormwater management, watershed research, better site design, education and outreach, and watershed training."[3]

- *National Pollutant Removal Performance Database for Stormwater Treatment Practices* 2nd Edition, June 2000

12.0 NATURAL RESOURCES DEFENSE COUNCIL (NRDC)

"The Natural Resources Defense Council's purpose is to safeguard the Earth: its people, its plants and animals and the natural systems on which all life depends."[4]

13.0 SMART GROWTH NETWORK

"The Smart Growth Network is a network of private sector, public sector, and non-governmental partner organizations seeking to create smart growth in neighbourhoods, communities, and regions across the United States." [5]

[3] CWP Website, http://www.cwp.org/mission.htm, June 20, 2005
[4] NRDC Website, http://www.nrdc.org/about/, March 16, 2005
[5] Getting to Smart Growth: 100 Policies for Implementation

14.0 GREEN INFRASTRUCTURE SHOWCASE

The Green Infrastructure Showcase is dedicated to illustrating how the incorporation of simple alternatives will have a significant impact upon the environmental impact of developments throughout British Columbia. Several of these initiatives are demonstration projects which utilize new and innovative approaches in order to evaluate the effectiveness of Green infrastructure.

East Clayton Neighbourhood Concept Plan is a joint effort between the City of Surrey and various Green design experts that involves the coordinated design and construction of a 250-hectare site that will house as many as 13,000 people within close proximity to the Agricultural Land Reserve and three important rivers. The development incorporates downspout disconnection and infiltration trench designs with the intent of absorbing 90% of the total annual rainfall.

The **Burke Mountain** development is a one of the largest and most integrated Master Planned Green Communities in British Columbia. To contain as many as 7,000 homes within Northeast Coquitlam, the development incorporates a wide variety of Green initiatives. On a neighbourhood scale, biofiltration streams, integrated wetlands, and oil/grit separators are used to provide high-quality stormwater.

The **UniverCity Community** project at Simon Fraser University will plan and develop 65-hectares of land surrounding the SFU campus on Burnaby Mountain. It is an important project as it will become a Master Planned Community, but also because the mountain is tributary to three fish-bearing watercourses.

The Municipality of Whistler has adopted **The Natural Step** as a sustainability framework for watershed management plans, public transportation initiatives, bicycle master plans, and geothermal heat exchange system demonstration projects.

Southeast False Creek is a 13.6-hectare private development within the City of Vancouver focusing on promoting sustainability, stewardship of ecosystem health, economic viability and vitality, and social and community health.

Lower Mill Creek Watershed Program sought to address watershed health concerns with the implementation of a tree revetment stabilization program and erosion control blanket stabilization program.

The **Silver Ridge** development in Maple Ridge includes 393 units and is located adjacent the Blaney Bog and Anderson Creek, which is an important fish-bearing habitat. The integrated stormwater management program included detention ponds, roadside swales and rain gardens, lot-level disconnected roof leaders, amended soils, rock pits, and rain gardens.

The **Crown Street Demonstration Project** in the City of Vancouver involved the reconstruction of a local street based on new environmental design criteria. The design includes open swales for in-line detention and infiltration as well as conveyance, with no storm sewers. The objective was to capture 90% of the surface runoff and return it into the ground.

The **Country Lanes Project** in the City of Vancouver allowed city engineers to evaluate three different Green approaches to the design of rear laneways. In this project three existing lanes were re-constructed with substantial public involvement using combinations of permeable pavements and pavers, structural soils, and recycled materials in order to create Green laneways with reduced Effective Impervious Areas, and subsequently, reduced stormwater runoff.

The **Fetterly Place** demonstration project in the City of Chilliwack is a 24-lot residential development covering an area of approximately 1.5 hectares that utilizes traditional design criteria for the lot layout, pavement size and road drainage features (catchbasins), but on-lot soakaway pots for roof and foundation drainage, boulevard exfiltration trenches with side-inlet catchbasins, and on-lot interceptor swales to convey overland runoff to detention facilities.

The **Bryant Place on Marble Hill** demonstration project in the City of Chilliwack is a slightly larger residential development comprising 22 lots over an area of approximately 2-hectares. This project includes reduced pavement widths with rural cross-sections, lot-level soakaway pits, and boulevard infiltration trenches.

15.0 SUMMARY

The adoption of Green infrastructure programs at the local government level has the potential to create sustainable development. Designers and municipalities are encouraged to examine current Best Management Practices (BMPs) and promote Green infrastructure on future initiatives.

The MMCD aims to provide a tool for introducing, by substitution, various Green infrastructure practices in local infrastructure. The decision to employ these supplementary practices remains with the Design Professional responsible for the design. Accordingly, where information is available, MMCD has attempted to tabulate some of the potential decision factors which may influence the choice of a "Green Infrastructure" Supplementary clause in the Contract Documents.

The MMCD approach includes categorization of the relative impact of Green Guideline Supplementaries by ease of implementation. For instance, some Green Infrastructure Guidelines have low or negligible barriers to adoption. Other initiatives may have significant implications as to cost or sustainability, which have yet to become evident through long term experience. As a result, as a tool for Design Professionals, there is an initial "Impact Assessment" component of the Green Design Guidelines, a component that will be regularly updated and expanded as more experience is documented.

1.0 GENERAL DESIGN CONSIDERATIONS

Green Design initiatives can be incorporated into many projects including water, sanitary, storm, road, lighting and signalization infrastructure projects. This section will outline several of the general considerations that could apply to projects. Some practices can have significant impact upon the sustainable development contribution of a project.

Environmental Protection Compliance

Of utmost importance in the design of Green infrastructure is the protection of the existing natural environment. Legislation such as the Environmental Protection Act and the Fisheries Act establish regulations with which all projects must comply. Additional documentation, such as the Department of Fisheries and Oceans (DFO) and Ministry of Environment *Land Development Guidelines for the Protection of Aquatic Habitat* or *Access Near Aquatic Areas* establishes guidelines to ensure the protection of natural habitats.

Site Protection of Soils and Vegetation

Avoidance of clearcutting of a site, minimizing disturbance of soils across the entire site, and minimizing removal of all natural vegetation is a fundamental principal of Green design. Adequate protection for all substantial natural vegetation and trees should be established. Soils will be disturbed and moved on an as-needed basis, with stabilization and re-vegetation implemented wherever possible. Aggregate will be reused wherever possible to preserve our non-renewable natural resources.

Communication of Objectives

The intention of various design details, especially non-traditional practices, must be communicated to the contractor, maintenance crew, homeowner, and/or the public in general

1.1 SUSTAINABILITY AND ASSET MANAGEMENT

Asset management is an important component of sustainable infrastructure. The concept of quantifying the useable life and incorporating the replacement cost into budgets has spawned the implementation of life-cycle costing for all infrastructure projects. Due to financial constraints, infrastructure is often required to remain in service well beyond its optimal design life, resulting in higher operating and maintenance costs, and ultimately in an infrastructure deficit.

Life-cycle costing is also integral to the implementation of sustainable development. Green designs often involve higher construction costs. However, by valuing infrastructure in terms of their life-cycle costs, by considering the cost savings of lower maintenance, energy efficiency, and the environmental remediation measures avoided, combined with government grants that are

often available for Green building projects, Green infrastructure can often be the less expensive alternative in the long term.
Designers should incorporate these life-cycle costing decisions into the decision matrix for all infrastructure decisions. Initial construction cost is only one component. Projects that require higher levels of ongoing maintenance or repairs should be avoided.

1.2 INDEPENDENT UTILITIES COORDINATION

Subsurface Utility Engineering (SUE) can achieve significant cost savings on construction projects. Previously the cumulative effects of delays, repairs, redesigns, relocates, and safety hazards resulting from encountering unidentified infrastructure were significant. However, recent advances in SUE are allowing for the accurate identification and location of these services.

Technology such as Ground Penetrating Radar, resistivity survey equipment, and pipe and cable locators are quickly and accurately locating existing services. Where exposure of utilities is required, the application of high-pressure water combined with vacuum excavation equipment (hydroexcavation) has been demonstrated to be safe and efficient. These technologies are Green insofar as they eliminate the need for costly exploratory excavations, minimize the impact upon surrounding landowners, and prevent the damage and subsequent repair of existing services.

With regard to proposed utility infrastructure, since independent utilities conduct a design and construction function separate from the overall project design, they are often not consulted in the planning stages of projects. This results in very limited options with regards to utility servicing. However, their inclusion at the planning stages of road and subdivision projects can be crucial. By integrating these utilities into the project design, many valuable benefits can be realized.

The most common benefit from the integration of utility requirements is the use of common trenches. Requiring less space within a right-of-way and significantly easier to install, common trenches should be utilized wherever possible. Designers need to initiate discussions with the independent utilities at the outset of the project planning stage in order to provide for their efficient and effective integration into the overall design.

1.3 UTILITY RIGHTS-OF-WAY

One aspect of sustainable development is designing and constructing infrastructure that addresses immediate and long-term needs. This involves foresight and consideration of future situations. Designers are encouraged to allow additional room within their right-of-ways for the expansion or addition of services to accommodate future demands. Twinning of sewers and watermains, expansion of utilities, and widening of pavement are all regular occurrences, and if provided for during the design stage, the impacts of these expansions can be minimized.

Further, by their very nature, utility right-of-ways create an interconnected network that extends into most every development. There is an opportunity to share these lands and implement a natural network of greenways, pathways, and natural habitat that facilitate human and animal movement and allow for natural cover. Wherever possible, utility right-of-ways should incorporate many of the Green initiatives outlined later within this manual.

1.4 UTILITY SEPARATION

Refer to MMCD Design Guideline Manual.

1.5 TRENCHLESS TECHNOLOGIES

Trenchless technologies have revolutionized the construction industry, and are generally congruent with the objectives of Green design. Their ability to install services underneath a watercourse, railway, or roadway presents an environmentally friendly, stakeholder considerate, and often a cost effective construction methodology.

Corporations, organizations and universities across Canada are continually improving existing and devising new technologies for trenchless applications. For example, the introduction of PVC pipe suitable for trenchless applications is an important development. The acceptance of HDPE material for watermains, sanitary, and storm sewers is also broadening the scope of trenchless technology applications.

Discussions of the specific details of each methodology are beyond the scope of this manual; however, for more information designers are directed towards the Infraguide Best Practice *Selection of Technologies for Sewer Rehabilitation and Replacement* and the MMCD "Platinum" version of the construction documents.

Trenchless technologies appropriate for municipal infrastructure include:

Rehabilitation - Non-Structural Lining

- Cement Mortal Lining
- Epoxy Lining (Internal Joint Seals)
- Chemical Grouting

Rehabilitation - Structural Lining

- Sliplining
- Diameter Reducing Sliplining (Close-Fit Pipe)
- Fold and Form Pipe
- Cured-in-Place Pipe
- Panel and Section Inserts

Replacement

- Horizontal Directional Drilling
- Full Tunneling/Microtunneling
- Jack-and-Bore
- Pipe Eating
- Pipe Bursting

1.6 SEISMIC DESIGN STANDARDS

Refer to MMCD Design Guideline Manual, or for more information, see the City of Surrey Design Criteria Manual.

1.7 EVALUATION OF GENERAL DESIGN ALTERNATIVES

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Reduced Site Disturbance	↑	↓↓		↓↓	
Site Material Re-cycling	↑	↓↓	↓	↑	
Life Cycle Costing	↑↑	↓↓↓↓	↑↑↑↑	↓↓↓	↑↑↑
Subsurface Utility Engineering	↓	↓↓↓		↓↓	
Common Trenching	↑	↓↓	↓		
Promote Utility Coordination	↑	↓↓↓		↓↓	
Employ Trenchless Technology	↓↓		↓		

2.0 WATER DISTRIBUTION

2.1 GENERAL

Water distribution systems are the first component of municipal infrastructure that interconnects society to the natural environment. Significant time and resources have been dedicated to the implementation of demand-side management, which is designed to curb excessive consumption. New government legislation such as the Water Conservation Plumbing Regulation which mandates the use of low-flow fixtures or local Lawn Watering Bylaws which curb peak water demand are new tools to reduce total water consumption.

One recent development in the demand-management portfolio is water recycling. New technologies and methodologies have been implemented to recycle rainwater and greywater, reducing or eliminating the use of potable water for irrigation.

2.2 METERING

Metering is an important component of every water distribution system; however, the scale of the metering program should be tailored to meet the needs of individual municipalities. Highlighted by the demand-management initiative, it is important to quantify the consumption of users to size infrastructure accordingly, and to track anomalies that may occur within the system. Coupled with recent advances in SCADA, (Supervisory Control and Data Acquisition systems) technology, real-time consumption data should become widely available and valuable in the conservation of our water resources.

On a system-wide basis, a universal metering program allows for the analysis of anomalies within the system. These anomalies may indicate extraordinarily high rates of consumption, unauthorized connections, or leaks and/or breakages. By identifying areas of concern, system upgrades and improvements can be directed to locations where they will be most effective.

On an individual basis, metering has also been shown to reduce per-capita demand. Contrary to common perception, it is not the personal uses of water that strain the water supply system. "By far the largest portion of maximum day use will be for lawn and garden watering."[6] Therefore, by measuring and billing for above-average water consumption, residents are encouraged to conserve water. Further, it may be feasible to implement similar initiatives as in the electricity industry with regard to real-time pricing and billing which encourages users to shift their consumption outside of peak hours. Although conservation of water at all times is important, it is the peak demands that must be addressed. By reducing the demand during peak hours, the water supply systems will be able to provide for a greater number of consumers.

[6] Design Guidelines for Rural Residential Community Water Systems, BC MOE, 2000

Caution must be exercised when considering the implementation of this type of program. Recent GVRD studies have determined that the cost/benefit of individual metering programs in the Lower Mainland is in the order of 2:1 and therefore implementation at this time appears premature. Areas with less abundant supplies of fresh water and/or higher treatment and distribution costs can more easily cost justify a comprehensive metering program. The costs associated with implementing and maintaining a universal metering program must be weighed against the costs of treating and distributing additional fresh water, and collecting, treating, and releasing wastewater that could be conserved through this program. Metering programs, as a component of the demand management initiative, should be implemented on an appropriate scale within each municipality.

2.3 PER CAPITA DEMAND

Per capita demand is one of the most important factors in the sizing of water treatment, storage, and distribution systems. However, reliable demand information is rarely available. The current design standard is to utilize an average annual daily demand of 600L/c/d and peak hour demand of 1,800L/c/d. This is supported by recent water consumption data that indicates the municipal consumption within the GVRD in recent years has been as high as 600L/c/d. Prior to widespread implementation of lawn watering restrictions; consumption had reached as high as 700L/c/d.[7]

However, municipal consumption includes a wide range of uses including industrial, commercial, street cleaning, fire-fighting, and lawn-maintenance. In fact, residential use accounts for just over half of the total municipal water consumption.[8] "Canadians currently use approximately 340 litres of water per person per day – twice the amount of Europeans."[9] "Basic in-house use is well established at about 230 litres per capita per day and varies only slightly with locality."[10] "The average indoor water usage was 747 L/household/day, or approximately 260L/person/day."[11]

Historical values for per capita water consumption may no longer be applicable. Water efficient fixtures, as required under the Water Conservation Plumbing Regulation, lawn watering restrictions imposed by municipal by-law, combined with several of the Green initiatives identified in Section 4 designed to reduce the use of potable water for landscaping will ultimately reduce the demand on the water distribution system.

[7] The Greater Vancouver Water District Water Consumption Statistics, 2003 Edition
[8] Flushing the Future? Examining Urban Water Use In Canada. Brandes, Oliver and Ferguson, Keith pg. 14
[9] LEED Green Building Rating System Reference Guide, December 2004, CaGBC, pg. 125
[10] Design Guidelines for Rural Residential Community Water Systems, BC MOE, 2000
[11] Residential Water Usage Part 1: Water Usage by Unmetered Single-Family Households – Direct Measurements at Last, KWL, 2005

Therefore, 600L/c/d is a conservative estimate, especially once a peaking factor is applied. The problem is that conservatism is not necessarily good. Excess capacity increases the age of water in the system and subsequently results in a decrease in chlorine residual. If the chlorine residual decreases and is identified, then extra resources must be applied to re-chlorinate the system. However, if this condition is not identified, water supply systems may become prone to contamination. Designers are cautioned to use the most appropriate per capita demand value for their analysis.

Designers are also cautioned to re-examine the relevancy of peaking factors applied to average per capita demands given recent changes in the industry. In Sanitary Sewer design, peaking factors generate values of up to 4.0 for Peak Hour demand dependant upon population. However, these factors are being applied to a base flow of 300L/c/d. In Water Distribution design, the constant peaking factor of 3.0, regardless of population, combined by the average daily demand of 600L/c/d generates significantly higher flows. The relevance of these peaking factors must be examined and verified using actual measured conditions wherever possible.

2.4 NON-RESIDENTIAL DEMAND

Designers are cautioned against the use of equivalent population calculations as non-residential demands fluctuate greatly. Historical information should be utilized wherever possible. Figure 2.1 of the MMCD *Design Guideline Manual* provides typical demand for various commercial and institutional facilities.

2.5 FIRE FLOWS

Designers must ensure that the minimum fire flow rates to be provided as per the MMCD *Design Guideline* and Fire Underwriters Survey *Water Supply for Public Fire Protection* Manual are provided based upon a minimum residual pressure of 140 kPa in the adjacent watermains.

2.6 DESIGN FLOWS

Refer to MMCD Design Guideline Manual

2.7 WATER PRESSURE

Water pressure has a significant impact upon the safe and efficient operation of a water distribution system. Under low pressure circumstances, the system must maintain pressures of 140kPa while providing fire flow and maximum day demand. However, low pressure also creates the potential for contamination from Cross Connections. As a result, backflow preventers are recommended on all connections where low pressures are reasonably foreseeable or have been experienced.

Under high pressure circumstances, normally more than 850kPa but sometimes as high as 1035 kPa, the water distribution system is operating at its maximum pressure. Leaks and losses are magnified under high pressure circumstances. Fixtures and leaks consume more potable water under higher pressure circumstances. Consideration should be given to evaluating the costs of additional pressure zones and pressure zone management versus the costs of watermain bursts, increased leakage, and consumption. Where feasible, designers are encouraged to implement more stringent water pressure controls on their supply and distribution systems. Further, where the maximum pressure exceeds 515 kPa, plumbing systems must be individually protected by pressure reducing valves where the service enters the building.

2.8 HYDRAULIC DESIGN

Although the Hazen-Williams equation is a useful tool for the analysis of individual mains, dynamic simulation is recommended for situations where water supply, storage and pumping scenarios are known.

Hydrant flow tests should be used where appropriate to verify that the theoretical pressures are in fact realistic given existing flow conditions. Local municipalities must be contacted prior to any hydrant flow testing.

Other municipalities in Canada are investigating potential links between water hammer and water main breakages. Although this is not exclusively a design issue, and includes various operations and maintenance methodologies, reasonable precautions should be taken to minimize the impacts of water hammer on a water distribution system. Operational procedures relating the opening and closing of valves are effective, as are the design analysis of high-flow, long lengths of pipe, and sudden changes of velocity within water mains.

2.9 MINIMUM PIPE DIAMETER

Refer to MMCD Design Guideline Manual

2.10 MAINTENANCE PRACTICES

As discussed in Section 1.1, Asset Management programs will assist in the determining an appropriate schedule for maintaining and replacing water distribution infrastructure. However, consideration should be given to the methodology of maintenance procedures. Keeping in mind that any time a system is taken out of service, leaking, or under repair, there is potential for contamination and health implications.

Further, any time that a system is exposed, significant volumes of chlorinated water require proper disposal. Further discussed within the GVRD *Construction Water Use Guidelines*, chlorine can be toxic to aquatic habitat. In situations where flows discharge to roadways, ditches, or storm sewers, consideration must be given to mitigating the impacts of the chlorine on the downstream watercourse.

Concerns over chlorine concentrations, total suspended solids, and pH are of primary concern. Dechlorination can be effected through the addition of chemicals such as sodium thiosulphate or sodium sulfite. Designers are directed to the GVRD *Chlorine Monitoring and Dechlorinating Techniques Handbook.* Treatment of solids can be achieved through catchbasin sumps, lagoons, sand bagging of the roadway, or tanker truck removal. Ideally a filter box will be utilized to properly mitigate the potential detrimental impacts of this practice.

2.11 EVALUATION OF WATER DESIGN ALTERNATIVES

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Universal Metering	↑↑↑	↑↑	↓	↓↓↓	↑
Adjusting Per Capita Demand			↑↑	↓↓↓	
Non_ Residential Demand			↑↑	↓↓↓	
Fire Flows			↑↑↑		
Water Pressure	↑↑	↑	↑↑↑↑	↓↓↓↓	
Maintenance Practices	↑↑		↑↑↑↑	↓↓	

3.0 SANITARY SEWERS

3.1 GENERAL

Best practices have continued to evolve as the sanitary systems' impact upon public health and the surrounding environment are better understood. Although the design of these systems has improved tremendously, they are still not performing at the levels required of Sustainable Infrastructure. Sustainability requires that development not degrade natural resources to the detriment of future generations. Green design requires efficiency in construction and material selection as well as in energy requirements related to treatment processes.

Municipalities are faced with significant issues, including:

- aging and deteriorating infrastructure and limited resources to maintain them;
- rapid development of new infrastructure for which they must assume ownership;
- finite capacity in treatment plants that although adequate for normal operation, is exceeded by wet-weather flows, resulting in the release of untreated effluent into adjacent watercourses; and
- increasingly stringent effluent quality requirements requiring the investment of time and resources into establishing improved Best Practices.

Sanitary sewers are affected by wet-weather events. As a result of cross-connections as well as inflow and infiltration, stormwater and groundwater are still entering the sanitary systems and creating capacity problems both in the sewers and in the treatment facilities.

The Asset Management initiative implemented by many municipalities focuses on the life-cycle costs of infrastructure, as opposed to the simple construction costs. It assesses the condition of the infrastructure and proposes a preventative maintenance program designed to proactively identify issues and perform minor maintenance such as sewer cleaning or minor repairs instead of waiting until the problems become more significant and expensive to fix. Further it recommends the replacement of severely deteriorated infrastructure instead of undergoing a myriad of ineffective patchwork fixes.

Green design initiatives include a focus on the life-cycle costs associated with continuous surveillance of operating systems, addressing inflow and infiltration, and choosing alternative design parameters for future systems

3.2 PER CAPITA FLOW

The primary role of a designer is to ensure that the sanitary system they are designing and/or analyzing has adequate capacity to convey the flows from the area to be serviced. However, the inherent assumptions in converting a development area into a population, a population into a flow rate, multiplying the flow rate by a peaking factor, and adding in an infiltration allowance can compound to produce an inaccurate result. The intent is to design sewer systems that have adequate size, yet are not unnecessarily oversized.

Each of the assumptions made in the quantification of sanitary flows must be examined to establish their validity. With regard to population data, based upon the 2001 Census data, the average household in the GVRD contained 2.53 people. However, the variance was significant, with several municipalities averaging in excess of the 2.7-2.9 people commonly assumed. Similarly, the construction of high-rise towers illustrates the need to avoid using a per hectare population equivalent, and emphasizes the need for unit-count based population equivalents. Care should be taken to properly predict the actual population to be serviced by any sewage system.

With regard to per capita flow, governments have instituted a variety of initiatives designed to assist and improve sanitary sewage systems. Initiatives such as the implementation of legislation such as the Water Conservation Plumbing Regulation and the resulting low-flow fixtures, designed primarily to curb water consumption, equally impacts sanitary sewerage. Sewer-use by-laws define acceptable uses and effluent criteria, in addition to banning the connection of rainwater leaders and foundation drains to sanitary systems. Further, Best Management Practices that promote reduced lot grading and other stormwater controls will all have a positive impact upon sanitary systems. Although not yet part of Canadian Design Practices, at least ten U.S. cities have introduced Green Building Ordinances mandating that new buildings attain LEED certification. Designers must become aware of, and design to, these prescribed standards.

As a result, water consumption rates and subsequent sanitary flow rates should be re-examined. Although the Average Daily Dry Weather Flow currently used is 300L/c/d, with the implementation of various water-conservation techniques, water reuse, infiltration, and low-flow fixtures, it is possible that wastewater rates will be less than as above. In the US, it has been shown that the average daily residential wastewater flow is only 260L/c/d[12]. “Basic in-house use is well established at about 230 litres per capita per day and varies only slightly with locality.”[13] In-depth analysis into actual water waste rates should be applied to new developments to avoid unnecessary oversizing of services; however, peaking factors must still be used.

[12] Onsite Wastewater Treatment Systems Manual, pg. 3-3, February 2002, U.S. Environmental Protection Agency
[13] Design Guidelines for Rural Residential Community Water Systems, BC MOE, 2000

Historical averages are becoming more and more outdated. Flow tests are recommended wherever possible. Designers must anticipate and quantify the potential for reduced per capita flows that will result from new developments, and consider the lack of these recent initiatives when calculating flows in existing developments.

3.3 NON-RESIDENTIAL FLOWS

Non-residential flows vary greatly in quantity and characteristics. The underestimation of flows resulting from commercial, institutional, and industrial sites is having serious consequences on the capacity of downstream sewer systems. Particularly with commercial developments where cooking facilities, or extraordinary customer traffic, are known to generate above-average flows, designers are encouraged to obtain historical flow rates from such facilities wherever possible.

3.4 PEAKING FACTOR

Developed many years ago, peaking factors such as the Harmon or Babbitt formulae may no longer accurately represent the peak hour flows. Although there will be peaks during the morning and evening rushes, initiatives such as real-time energy pricing, and water-smart appliances designed to function in off-peak hours may help equalize the flows throughout the day.

Although peaking factors should be used, it is recommended that a maximum of 4 be used for the peak flow rate based upon the average daily per capita consumption. Designers are recommended to utilize the new Peaking Factor contained within the MMCD *Design Guideline Manual* as it represents recent analysis of flows within British Columbia.

3.5 INFILTRATION

Inflow and infiltration, (I/I), is a significant problem associated with most sewerage systems. Comprised of inflow from direct connections such as roof leaders, lawn drains, and foundation drains, and infiltration from groundwater seepage into the system, these flows unnecessarily consume precious conveyance and treatment capacity in the sewerage infrastructure, and can be the leading cause of sewer backups and sanitary/combined sewer overflows. Through preventative maintenance and regular inspections of infrastructure, coupled with flow monitoring in appropriate places, sources of inflow and infiltration can be identified and rectified. The causes of a significant percentage of the I/I flows are already known.

Massive campaigns have been mounted to promote the disconnection of roof leaders and foundation drains from sanitary infrastructure. Municipalities continually work to identify cross-connections and portions of their systems particularly affected by infiltration in order to address these problems. Decayed and failing infrastructure including sewers and manholes allows groundwater to enter the system. Equally as important is the ability of untreated effluent to exfiltrate from the sewer, concentrate in sewer and utility trenches, and contaminate the groundwater threatening drinking water supplies. Preventative maintenance programs aspire to address these issues.

However, although loose joints and deteriorated pipes are the primary source for infiltration, house lateral connections have been identified as a substantial source of infiltration flows. This source of infiltration is significantly more difficult to address as they occur on private property. Several local municipalities are employing smoke tests to identify leaky connections, and rectify this problem. Care must be taken to adequately protect new connections against leakage.

In conducting the analysis of sewerage susceptible to infiltration, failure of manholes was also identified as a recurring problem. It is now understood that Hydrogen Sulfates, naturally occurring in domestic sewage, can be converted to Sulfuric Acid through natural processes under particularly turbulent conditions. In severe instances the pH of effluent can reach 0.5. As a result, concrete pipes and manholes have corroded and failed. Recent research has proposed the avoidance of 90-degree changes in alignment and the unnecessary use of drop structures wherever possible. Further, the use of various alternatives, including PVC manholes, reinforced concrete sanitary sewers with a fibreglass reinforced polymer mortar liner should be considered where these problems can be reasonably foreseen. These are design considerations that lead to the construction of sustainable infrastructure.

With regard to I/I flows, actual observed results should be used wherever possible. The commonly-used 0.06L/s/ha (new systems) and 0.12L/s/ha (25^{+} years) may not accurately quantify infiltration flows. Several municipalities have adopted a minimum 0.13L/s/ha (11,200L/ha/d) for all system analysis. Other provinces utilize flows of 0.10-0.28L/s/ha. The MMCD *Design Guideline Manual* proposes an infiltration allowance of 0.17L/s/ha.

While new designs should include this revised infiltration allowance, caution must be used in the analysis of older infrastructure, particularly in areas with high groundwater, where leaks and structural damage make the system more susceptible to increased I/I flows.

3.6 DESIGN FLOW

Refer to MMCD Design Guideline Manual

3.7 BACKFLOW PREVENTERS

As sewer systems age and deteriorate, the risk of backup increases. Although addressing the symptom, and not the root cause of the problem, backflow preventers are a cost effective and reliable method of preventing backup into adjacent service connections. In areas where sewer backups have been identified, or in new developments where there is a risk of such occurrences, the implementation of backflow preventers is recommended.

3.8 ODOUR CONTROL

Odours emanating from sanitary systems are a nuisance and potential health hazard for surrounding passers-by and maintenance staff. As a result, there are Green initiatives designed to address this problem. Municipalities have attempted to address this issue in recent years with the use of sewer flushing programs or the use of chemical additives such as iron salts and nitrates. While achieving acceptable levels of success, these practices require ongoing attention, and are not necessarily sustainable solutions.

Consequently, there are manhole inserts available designed to prevent the oxidation of sulfides and the resulting odours. By directing the flows in a downward spiral instead of a straight drop, laminar flow can be maintained. In addition, the downward flow creates a down-draft, effectively creating a vacuum that directs odours downwards. In areas identified for problematic odour, or in new designs where turbulent flow is anticipated to generate unacceptable odours, odour control initiatives should be implemented.

3.9 GREYWATER SYSTEMS

One of the most recent advances in sanitary system technologies is in the construction of grey-water systems. Designed to reuse wastewater from sinks, bathtubs/showers, and washing machines, these systems can greatly reduce the consumption of potable water within a building. Dual-piping systems are required within the building and filtration and/or treatment is often necessary.

Alternatively, grey-water can be disposed of through traditional on-site leaching beds or landscaping features, significantly reducing reliance upon the municipal wastewater system.

Consideration should be given to the applicability of grey-water systems in new commercial and high-rise developments; however, they are not recommended for single family dwellings due to the cost of implementation and the relatively small reduction in potable water use. More information can be obtained through the MOE *Municipal Sewage Regulation Code of Practice for the Use of Reclaimed Water* issued May 2001, Canada Green Building Council *LEED Green Building Rating System Reference Guide*, and Capital Region District *Greywater Reuse Study Report* dated November 1, 2004.

Designers are recommended to contact their local Health Authority at the conceptual planning stage of any greywater system, as issues such as cross-connections and related health concerns may limit the implementation of such systems. The B.C. Building Code for Non-Potable Water Systems currently prohibits using non-potable water in sinks or toilets.

3.10 ALTERNATIVE COLLECTION SYSTEMS

Centralized sewage collection and treatment facilities have been proven to be the most efficient and cost effective sewer system in highly-populated urban centres. However, in remote areas, or in rural communities, the costs of conventional gravity collection systems are significant relative to cost of treatment and disposal. Connecting individual residences with long stretches of conventional sewer, and ultimately traversing substantial distances to connect to the nearest centralized system can make developments cost prohibitive. Particularly in areas of high groundwater, or varied terrain where overly-deep installation would otherwise be required, alternative collection systems should be considered.

Discretion and proper land planning are required to prevent alternative collection systems from being an instrument of urban sprawl. The intent is not to allow for development in a haphazard or piecemeal manner. The intent is to present sustainable and cost effective approaches to servicing land that has been properly planned and slated for development.

These systems have many benefits over the conventional gravity-based system. They allow for the use of lightweight small-diameter plastic pipe buried at shallow depths with fewer joints than traditional systems. This eliminates the need for shoring or excessively deep excavations. It allows designers to avoid rock outcroppings or high groundwater tables, and often can reduce the necessity for lift stations and the accompanying ongoing operation and maintenance expenses. These systems also provide alternatives where creek or watercourse crossings are required, and can help eliminate the need for traditional pump stations.

These benefits are particularly useful for phased development as there is less capital cost required upfront. Alternative collection systems are generally ideal for developments of between 50 and 200 homes, and can be beneficial in large developments and small municipalities of 10,000 people or less. However, with these systems, as some of the crucial infrastructure is on private property, homeowner acceptance, education, and support are crucial. Ongoing maintenance reports filed with the approving agency should be required. Reference regarding the design of these alternative conveyance systems should be made to either local design guidelines or the EPA *Alternative Wastewater Collection Systems Manual* dated October 1991.

3.10.1 Low Pressure Sewers

Traceable as far back as 1972, low pressure sewer systems involve the installation of either a grinder pump or a septic tank equipped with an effluent pump. The pumps convey flows via a 25 or 38mm service connection, fitted with a check valve to prevent backflow, to the sanitary main. The main, constructed of between 50mm and 150mm PVC or HDPE pipe, can be shallowly buried, follow the profile of the surface, and can be installed using trenchless technologies.

Due to the reduced number of manholes and joints required, in addition to the pressure maintained in the system, inflow and infiltration are virtually eliminated. Ultimately, well-designed pressure sewers have been relatively easy to maintain and have been quite successful in hundreds of applications across the United States and Canada.

3.10.2 Vacuum Sewers

First patented in the U.S. in 1888, vacuum sewers have also become a viable alternative to conventional gravity collection systems. By installing an effluent storage facility at each residence, wastewater flows via gravity to the facility. Valves, operated automatically by the hydraulic pressure of a predetermined volume of wastewater, release flows into the main.

The main is kept under negative pressure through a series of vacuum stations interspersed depending on the site topography and as necessary to keep adequate suction. These systems are not appropriate for widely varied terrain as it is more difficult to maintain adequate pressure across large changes (<6m) in elevation. Studies have shown that upon collection at the end of the system, effluent is generally highly aerated with dissolved oxygen as a result of the turbulence generated within the mains.

Although there are in excess of 50 vacuum sewer systems across the U.S., with several more being planned and designed, vacuum systems have been installed in local municipalities with varied results. Vacuum sewers may be effective under certain circumstances; however, their track record to date within the Lower Mainland has not been proven, and therefore should be avoided.

3.10.3 Small Diameter Gravity Sewers

Perhaps the most popular of the alternative collection systems and the one gaining the most widespread acceptance across the country right now is the construction of small diameter gravity sewers. First constructed in Australia in the 1960's, these were first used to battle failing septic tanks. Introduced in the US in the mid 1970's, these systems have been found to reduce construction costs by 30-65%, and reduce the ongoing operations and maintenances as well.

The system utilizes a septic tank on private property to collect effluent, and remove both floating and settleable solids. As a result, only liquid waste is conveyed via a 75-100mm service connection, fitted with a check valve or backflow preventer at the connection to the main. The main, generally 75-100mm in size as well, is generally shallowly-installed plastic pipe. Although the pipe must be laid with some grade, as there are no solids conveyed, pipes are not necessarily laid on a uniform gradient. Portions of the pipe can be depressed below the hydraulic grade line, and the pipe can be routed around obstacles as necessary. The number of manholes can be reduced, pipe costs are reduced, installation is easier, and the treatment requirements of the effluent at the treatment facility are greatly reduced.

These systems are very reliable as they still utilize gravity to convey flows, and have been found to be low maintenance and virtually problem free. Hybrid systems utilizing Septic Tank Effluent Pumping (STEP) and Small Diameter Gravity mains have been shown to be particularly effective.

3.11 DECENTRALIZED TREATMENT FACILITIES

The very concept of sustainability suggests that developments should be capable of meeting their own needs without simply exporting sanitary waste for treatment elsewhere. Much like centralized collection systems, in highly-populated urban areas, centralized treatment plants have been shown to be the most reliable and cost effective solution. However, in rural settings with small remote community development, consideration should be given to the long-term costs of connecting to this centralized treatment infrastructure, and the potential benefits of communal wastewater treatment facilities.

Advances in effluent treatment have made communal wastewater treatment a viable option. Technologies such as membrane filtration, rotating biological contactors, recirculating sand filters, sequencing batch reactors, and bio-filtration are all proving that they can meet the necessary effluent quality requirements and be cost effective for small developments. Although most systems require trained operators, most of these systems have become so reliable that a daily or weekly inspection and minor maintenance are all that are required to ensure that these facilities operate properly.

Decentralized onsite wastewater treatment facilities include composting toilets, septic tanks, extended aeration units, wastewater lagoons, wetlands, and ponds. In fact, these systems have been shown to be very cost effective in providing high quality treatment. As of 1996, over 25% of the population was serviced by septic tank systems.[14] There are at least 34 lagoons in operation in British Columbia alone, accounting for 31% of treatment facilities across the province. There are also an array of proprietary aerobic treatment systems, as discussed above, and trickling filter systems that are under investigation and performing extremely well across the country.

One of the better-known examples of decentralized treatment facilities resides within the C.K. Choi Building at the University of British Columbia. Combining the use of composting toilets and greywater recycling used for irrigation, the building is self-sufficient with no connection to the adjacent municipal services.

After treatment, there are also a variety of viable effluent disposal methodologies. Methods such as the conventional leaching bed, raised leaching bed; filter bed; shallow buried trench system, spray irrigation, and release to surface water may all be considered dependant upon the characteristics of the treated effluent.

It should be noted however that when decentralized treatment systems fail they often have serious implications on health and safety. Whereas centralized facilities may release untreated effluent to adjacent bodies of water in emergency situations, communal facilities often impact adjacent landowners and residents. These failures are most often attributable to under-design. Poor understanding of on-site soil conditions, or miscalculations with regard to incoming effluent volume and strength, combine to create serious health concerns. Diligence is required in the design of communal wastewater systems. Residential and commercial effluent characteristics must be fully investigated in order to be accommodated within a communal wastewater facility.
Further guidance on the design of decentralized treatment facilities can be obtained from:

- *Sewerage System Standard Practices Manual*– Ministry of Health Planning – 15/07/2004
- *Onsite Wastewater Treatment Systems Manual* – USEPA 02/2002
- *Constructed Wetlands Treatment of Municipal Wastewaters* – USEPA, 09/2000
- *Design Manual: On-site Wastewater Treatment and Disposal Systems* – USEPA 10/1980

[14] Nantel, Martin, Municipal Wastewater Pollution in British Columbia, May 1996

3.12 WASTEWATER BY-PRODUCTS

One of the highest-profile innovations with regard to Green initiatives in sanitary waste management is the evolution of energy reclamation from treatment byproducts. Wastewater treatment plants across the country are examining the feasibility of methane capture and incineration in order to produce electricity. Others are investigating the possibility of biosolids recycling for agricultural uses. These types of innovation are to be encouraged, and will be very effective in furthering the sustainable development initiative with respect to wastewater processes.

3.13 EVALUATION OF SANITARY SEWER ALTERNATIVES

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Adjust Per Capita Flow			↑↑	↓	
Adjust Peaking Factor			↑↑	↓	
Infiltration & Inflow Control	↑	↓↓↓	↑↑	↓↓	
Backflow Prevention	↑		↑	↓↓	
Odour Control	↑↑	↑	↑↑	↓↓	
Greywater Systems	↑↑	↓↓↓↓		↑	↑
Alternative Collection Systems	↓↓	↓↓	↑↑	↓	↑↑↑
De-Centralized Treatment Facilities	↓↓	↑	↓	↑↑	↑
Wastewater By-products	↑↑↑	↓↓↓↓	↑↑	↑	↑

4.0 STORM DRAINAGE

4.1 GENERAL

The design of storm drainage infrastructure and the intent of stormwater best management practices, (BMP's) have evolved drastically over the last few decades. Immense amounts of research and analysis have given designers a better understanding of the effects of land development on the hydrologic cycle, and the resulting implications on the natural environment. However, the methodologies employed to address these effects have achieved varying levels of success and oftentimes have negative side-effects of their own.

The challenge remains in creating storm drainage infrastructure that effectively protects private property from flooding while not harming the natural environment. However, harm to the natural environment includes more than creek degradation due to increased runoff. It includes the quality of the runoff and its effects on fish habitat, it includes water balance calculations to ensure that groundwater recharge is equivalent to pre-development conditions, and it considers the impact on water bodies that are used for water supply, aesthetics, and recreation. By considering stormwater as a resource, and not an inconvenience to be disposed of quickly, these concerns can all be addressed in a sustainable manner.

4.2 STORMWATER MANAGEMENT (SWM)

Stormwater is the component of precipitation that flows across the land as surface runoff. Land development can impede the natural infiltration and interception processes of the hydrologic cycle, thereby significantly increasing the proportion of precipitation that becomes surface runoff. Whereas natural land uses have been determined to generate as little as 10% surface runoff, developments which include large amounts of impervious surface, such as rooftops and paved areas, can generate as much as 80% surface runoff.

This significant increase in the rate and volume of stormwater poses a risk to personal property. Initially, engineers devised storm drainage systems to capture and convey stormwater as quickly as possible to the nearest watercourse. This system of curbs and gutters, ditches, and storm drain systems prevented flooding within developments, maintained roadways in useable condition even in large storm events, and helped prevent damage to personal property. However, this increased rate and volume of runoff draining to streams had many negative impacts: increased downstream flooding, loss of land due to erosion, and degradation of aquatic habitat.

Consequently, regional stormwater management facilities were proposed. Large detention ponds were designed to attenuate the rate of runoff to the pre-development levels and provide on-site detention for excess flows. This was intended to protect the watercourses from the effects of uncontrolled runoff. However, as these facilities were often constructed online with the watercourses, they had unforeseen effects on water quality, such as altering the temperature of

the outflow, and oftentimes exacerbated channel degradation problems due to the overall increase in volume of runoff even though peak flow rates were controlled.
Instead of mitigating the effects of increased stormwater runoff, the primary objectives of stormwater management currently are to mimic the pre-development runoff characteristics of the site considering a wide range of storm events. Design practices have evolved to consider on-site infiltration, retention, detention, and water quality issues before releasing runoff downstream. Achieving these objectives produces watercourses with natural flow patterns and high habitat quality.

The evolution of stormwater management continues. It is important to understand the implications of development and the cumulative impact of various BMPs on the natural environment. Designers are warned against using BMPs as a generic solution for stormwater management issues. Not every practice is appropriate for every site. For example, geotechnical investigations may be necessary in order to determine if the infiltration capacity of the soils are sufficient to support infiltration. In addition, designs must be appropriate for the full range of rainfall events, not simply 2, 5, or 100-year return storms. The majority of storm events are minor events. They must be considered.

Stormwater management must be conducted on a large scale, not a site-by-site basis, in order to be truly effective. The results of integrated BMPs are aquatic systems with natural hydrological cycles. More information can be obtained from the Infraguide *Stormwater Management Planning* and the Ministry of Environment *Stormwater Planning: A Guidebook for British Columbia.*

4.3 INTEGRATED STORMWATER MANAGEMENT PLANNING (ISMP)

Integrated stormwater management planning is “a planning approach to integrate watershed-based planning processes such as watershed plans, catchment plans, master drainage plans, and stormwater plans into relevant municipal planning processes to address the impacts of stormwater management on community values.”[15] It often involves intensive public consultation, and the integration of planning, engineering, and natural science.

“Although the Greater Vancouver region is spending about $33 million annually on stormwater management,…in many areas of the region, current approaches to stormwater management and land development do not adequately protect the environment of small streams in watersheds experiencing significant population growth.””[16]

The application of stormwater management initiatives and requirements solely on a site-by-site basis is less effective than on a neighbourhood or watershed basis. The overall objective of stormwater management initiatives is to protect personal property and control flooding in a

[15] Conveyance and End-of-Pipe Measures for Stormwater Control, Infraguide, January 25, 2005
[16] Stormwater Planning, MOE, Based on 1996 Dollars

manner that has no detrimental impact upon the watershed health. As a result, it is essential that stormwater management planning take place on four levels: Regional, Watershed, Neighbourhood, and Site to be effective.
The Local Government Act assigns responsibility for the volume and rate of drainage to municipalities. As members in regional governments, it is the Liquid Waste Management Plans (LWMP's) that outline regional planning initiatives. These are the overarching principles that guide stormwater management initiatives. From these plans ISMP's can be developed that reflect the needs of the community and guide development for the protection of the watershed as a whole.

The GVRD *Integrated Stormwater Management Planning Terms of Reference Template* purports that the primary watershed health indicators are: effective impervious area; riparian forest integrity; and benthic communities. "Perhaps the best way to measure watershed health, and calibrate the watershed classification system is to assess the benthic macroinvertebrate (streambed insects) communities in the creek systems using the Benthic Index of Biotic Integrity (B-IBI)."[17] The document outlines a process for measuring and monitoring watershed health, developing specific criteria to meet the no net loss principle of environmental habitat, and developing an integrated stormwater management plan to meet those criteria.

Its philosophy of taking an integrated approach to stormwater management, on a watershed basis, is not only for managing the quantity of flow, but also water quality. This integrated approach moves away from the traditional stormwater management solution to drainage issues by taking into consideration ecosystems, problem prevention, integrated design solutions, protection of property and resources, emulation of natural systems, working in partnership with other stakeholders, and to take a holistic view of the drainage regime.

It is important that the objectives outlined within the LWMP and the ISMP become integrated with the Official Community Plan, (OCP), Regional Growth Strategies, Neighbourhood Plans, Zoning By-Laws, Subdivision By-Laws, Development Permits, etc. It is imperative that a consistent and comprehensive set of guidelines be implemented to encourage and promote sustainable Green design initiatives.

Municipalities are at varying stages of implementation of ISMP's. For guidance in the preparation of such a document, reference can be made to the GVRD's *Integrated Stormwater Management Planning Terms of Reference Template.* For reference to a completed plan, the City of Chilliwack's *Policy and Design Criteria Manual for Surface Water Management* has received national recognition for Integrated Stormwater Management Planning.

4.4 MINOR AND MAJOR SYSTEMS

Refer to MMCD Design Guideline Manual

[17] Integrated Stormwater Management Planning Terms of Reference, GVRD, May 2002

4.5 RUNOFF ANALYSIS

Application of the Rational Method for the determination of peak flow estimates for design of the storm drainage system is still widely used for catchment areas that are less than 10 hectares in size. Hydrologic and hydraulic computer models such as SWMM, QUALHYMO, HSPF, and MOUSE are recommended for storm drainage modeling of larger areas.

The Water Balance Model for BC (WBM) is a software application that has been developed to allow the user to quantify the benefits of incorporating various source control strategies for different land use densities, surface runoff parameters, and subsoil conditions. Using actual rainfall data associated with the location under consideration, the model will allow the user to make comparisons between the natural and developed site conditions to quantify the effectiveness of site planning that incorporates different types of source controls. This approach allows the user to explore the impact of varying the different parameters in the model to achieve a specified target, such as to limit annual runoff to 10% of the annual rainfall. Accessible at www.waterbalance.ca this model is increasingly utilized throughout the province and across the country.

4.6 RAINFALL DATA

The analysis of all stormwater management and drainage initiatives is dependent upon accurate and reliable rainfall data. However, recent studies have shown that climactic change in recent years may cause current curves to over-estimate actual rainfall flows. Further, the hydrologic cycle is changing with increased rainfall in the fall and winter, less in the spring and summer, and ultimately more intense cloudbursts. Accurate Intensity-Duration-Frequency curve data is essential for all hydraulic analysis.

That said, it is no longer appropriate to consider simply specific return storm events and ignore intermediate rainfall events. As a result, there is a shift to consider rainfall distribution as follows:

- **Frequently Occurring Small Storms** – 75% of storms precipitate less than 30mm.
- **Infrequent Large Storms** – 20% of storms precipitate between 30 and 60mm
- **Rare Extreme Storms** – 5% of storms precipitate greater than 60mm.

4.7 DISCHARGE RATES AND QUALITY

4.7.1 Stormwater Quantity

The traditional approach to stormwater quantity control was to limit the post-development release rate of the site to the pre-development levels for a specific storm event, perhaps the five-year return storm. This approach has several inherent flaws. First, with an increase in the effective impervious area of a site, the volume of runoff increases. Detaining excess flows onsite does not reduce the total volume. As a result, delaying the peak flows from some sites can correspond with the peaks from others, to culminate in a significant increase in rate in the watercourses. Second, this approach is ineffective for minor storm events below the design storm utilized, which as above, represents the majority of the storm events.

Design of the system elements must be based on the overall philosophy of managing the complete spectrum of rainfall events through the use of retention, detention and conveyance. Performance Targets established by the City of Chilliwack are as follows:

- **Rainfall Capture** (retention) – Capture the first 30mm of rainfall per day and restore it to natural hydrologic pathways by promoting infiltration, evapo-transpiration or rainwater reuse.
- **Runoff Control** (detention) – Detain the next 30mm of rainfall per day and release it to drainage system of watercourses at natural interflow rate.
- **Flood risk management** (conveyance) – ensure that the stormwater plan can safely convey storms greater than 60 mm (up to the 100-year rainfall).

This approach to rainwater management differs from traditional approaches in that it manages the runoff volume, not just flow rate. In so doing, it requires designs for on-site drainage systems that reduce the volume at the source.

The design guidelines focus on two main areas:

- Rainfall capture and runoff control criteria:

i. Infiltrate and detain – for designing infiltration and detention systems that meet specific performance targets for rainfall capture

ii. Source control strategies – determination of the most appropriate source control strategy, subject to site-specific criteria such as soil type, land use, rainfall and groundwater characteristics

- Peak flow conveyance criteria:

i. Incorporation of 'escape routes' from rainfall capture and runoff control facilities for extreme storms be provided.

ii. Site grading to mitigate flooding problems from overland flow during extreme storms.

iii. Physical and hydraulic adequacy of the downstream drainage system.

iv. The Minor System to convey overflows from on-site capture and runoff control facilities resulting from storms up to a 10-year return frequency.

v. The Major System to convey peak flows resulting from storms up to a 100-year frequency via overland flow paths, roadways and watercourses.

An effective method of mitigating negative effects from stormwater is to reduce the volume of rainfall converted to runoff. Best management practices should be implemented to achieve desired results associated with discharge rates and water quality.

4.7.2 Stormwater Quality

The issue of stormwater quality is gaining attention in recent years as analysis into the degradation of natural aquatic environments uncovers significant pollutant loadings contained within stormwater. Particularly relevant to commercial and industrial sites where large paved areas coupled with high truck traffic and the potential for oil/grease and sediment loadings are highest, quality concerns are also prevalent in residential developments. Stormwater quality must be considered on all projects.

In April of 2003 the GVRD published the report *Estimated Urban Runoff Character and Contaminant Loadings in the GVRD.* This report analyzed stormwater quality data over a period of four years within 9 urban catchments, resulting in 70 sample points analyzing 189 separate parameters. Their analysis illustrates that typical contaminant loading of stormwater flows may be:

- Fecal Coliform Content - 10,300-39,300, with an average of 17,700 MPN/100mL
- Total Suspended Solids – 35-59, with an average of 44mg/L
- Bio-Chemical Oxygen Demand – 5mg/L avg.
- Ammonia Nitrogen – 0.18mg/L
- Total Kjeldahl Nitrogen – 0.8mg/L
- Total Phosphorus – 0.14mg/L

These values exceed the provincial water quality objectives. In fact, stormwater often contains contaminants at levels similar to sanitary waste. Unlike wastewater collection system flows which receive treatment prior to release to the environment, stormwater systems are generally released directly to receiving watercourses. Therefore, it is essential that stormwater quality be integrated into the design of all new drainage systems.

The *Urban Runoff Quality Control Guidelines for the Province of British Columbia, June 1992*, was a very significant step towards quantifying quality control for stormwater. It challenged the conventional approach to treating solely the "first flush" and recommended that variability among storms be considered. It analyzed the contaminants within stormwater and discovered concentrations even higher than those outlined above. It discussed the impacts of these contaminants on the watercourses and aquatic habitat. Further, it outlined a series of Best Management Practices and quantified the removal efficiencies of these facilities.

POLLUTANT REMOVAL EFFICIENCIES OF TREATMENT BMP'S							
BMP	**SOURCE OF DATA**	**RANGE OF REPORTED CONTAMINENT REMOVAL (PERCENT)**					
		TOTAL SUSPENDED SOLIDS	**CHEMICAL OXYGEN DEMAND**	**TOTAL LEAD**	**TOTAL ZINC**	**TOTAL PHOSPORUS**	**TOTAL NITROGEN**
Extended Detention Dry Basins	**Design Manuals**	50-100	0-60	75-90	30-60	0-60	0-40
	Field Studies	3-74	16-41	24-84	40-65	10-56	24-60
Wet Ponds	**Design Manuals**	60-100	20-60	20-80	20-80	40-80	20-80
	Field Studies	5-91	2-69	9-95	0-79	3-79	0-60
Wetlands	**Design Manuals**	80-100	60-80	60-80	60-80	40-60	40-60
	Field Studies	64-99	54-89	88-97	33-96	0-97	0-95
Grassed Swales	**Design Manuals**	0-40	0-40	0-20	0-20	0-40	0-40
	Field Studies	80	25	50-80	50-60	0	0
Vegetated Filter Strips	**Design Manuals**	20-100	0-80	2-100	2-100	0-60	0-60
Infiltration Basins and Trenches	**Design Manuals**	75-99	70-90	75-99	75-99	50-75	45-75
Porous Pavement	**Field Studies**	82-95	82	98	99	65	80-85

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Similarly, the Center for Watershed Protection produced their *National Pollutant Removal Performance Database for Stormwater Treatment Practices 2nd Edition* in June 2000 which quantifies the removal efficiencies of various BMP's as follows:

POLLUTANT REMOVAL EFFICIENCIES OF TREATMENT BMP'S							
BMP	**MEDIAN POLLUTANT REMOVAL % OF STORMWATER TREATMENT PRACTICES**						
	TSS	**TP**	**Sol P**	**TN**	**NOx**	**Cu**	**Zn**
Stormwater Dry Ponds	47	19	-6	25	4	26	26
Stormwater Wet Ponds	80	51	66	33	43	57	66
Stormwater Wetlands	76	49	35	30	67	40	44
Filtering Practices	86	59	3	38	-14	49	88
Infiltration Practices	95	70	85	51	82	-	99
Water Quality Swales	81	34	38	84	31	51	71

*PERMISSION TO REPRINT NOT YET REQUESTED

These studies support one another and suggest that there is significant variability between the performances of these BMP's. The appropriate practice must be selected and designed specifically for each site. However, in order to select BMP's, designers and developers need to work towards water quality objectives for stormwater.

Since the sources of, and contaminants within, stormwater are well documented, and the impacts upon the aquatic environment are significant, it is necessary to devise a plan to ensure suitable stormwater quality of urban runoff. DFO has been promoting the principle of No Net Loss of the Productive Capacity of Habitats for decades. However, although it is understood that contaminants contained within stormwater can be detrimental to aquatic habitat, the difficulty is in establishing an accepted and measurable benchmark for stormwater quality. The DFO expectation is that "Runoff water from the development site should contain less than 25mg/litre of suspended solids above the back-ground suspended solids levels of the receiving waters during normal dry weather operation and less than 75mg/litre of suspended solids above background levels during design storm events."[18] However, this can be difficult to assess as the subject site may be too far upstream of the watercourse to form an appropriate correlation.

[18] Land Development Guidelines for the Protection of Aquatic Habitat, DFO/MOE 1992

Alternatively, the GVRD is utilizing a "biologically-based receiving environment monitoring (REM) component which involves quantifying the existing biological conditions in the receiving environment, and using these conditions as a baseline against which to assess the effectiveness of stormwater management over time. The REM approach uses benthic macroinvertebrate community structure to measure water quality in the receiving environment."[19] Macroinvertebrates are believed to be indicative of watercourse health. It will provide analysis for watershed health in the long-term however is difficult to apply to individual site-specific analysis.

It is proposed to adopt a treatment train approach focusing on the removal of Total Suspended Solids for each development. The province of Alberta mandates the implementation of "Stormwater management techniques to improve water quality shall be included to effect a minimum of 85% removal of sediments of particle size 75µm or greater."[20] The province of Ontario requires the provision of enhanced protection for almost every development. "Enhanced protection corresponds to the end-of-pipe storage volumes required for the long-term average removal of 80% of suspended solids."[21] Consequently, both systems utilize a version of the following Water Quality Storage Requirements:

	Storage Volume (m^3/ha) for Impervious Level			
	35%	**55%**	**70%**	**85%**
Infiltration	25	30	35	40
Wetlands	80	105	120	140
Wet Pond	140	190	225	250
Dry Pond	140	190	210	235

These values are based upon a 24-hour drawdown time. For Wet Facilities, 40 m^3/ha of these values is extended detention, with the remainder representing a permanent pool. These values should be used as a guideline for the sizing of effective water quality features.

The City of Chilliwack have stipulated that land that is zoned CD, industrial, multi-family or commercial (according to their Zoning Bylaw) shall not be connected to a municipal storm sewer or infiltration system unless equipped with an oil and grit separator. Furthermore, they have developed mechanisms to enforce compliance with a Notice to Install that also includes the requirements for installation and maintenance. This is an appropriate measure for attaining the 80-85% TSS removal targets within sites that cannot provide infiltration or pond BMPs.

[19] Receiving Environment Monitoring Program for Stormwater Discharges within the Greater Vancouver Regional District, GVRD, August 2003
[20] Municipal Policies and Procedures Manual, Alberta Environmental Service, April 2001
[21] Stormwater Management Planning and Design Manual, Ontario Ministry of the Environment, March 2003

Water quality is becoming more of an issue during the construction phase of land development projects. Erosion control guidelines and the control of sediment that may be transported to adjacent creeks and watercourses require the design and construction of silt control facilities. The impact of excavation and other construction-related activities can also be mitigated through additional measures being taken by the contractor. Additional steps may need to be stipulated, implemented and monitored by the design professional for the storm drainage system. Development of detailed sediment and erosion control strategies by the design engineer, geotechnical engineer and environmental consultant should help contractors and developers work towards more achievable outcomes for mitigating silt-laden waters entering the storm drainage system during the construction period. Details of these strategies are located in section 4.14.10.

4.8 SITE AND LOT GRADING

Site and lot grading is a valuable component of a stormwater management plan. Since runoff is generated from impervious areas such as rooftops, the grassed portion of the site represents the first opportunity to infiltrate stormwater runoff. As a result, lot grading should be designed to direct water away from structures, but also provide ample opportunity for infiltration.

In many areas, an apron of 4-5 metres around any building must still be designed with a minimum 1-2% grade draining water away from the structure. However, it is recommended that 1% slopes be implemented wherever possible around the remainder of the lot. Further, there is the potential for the creation of on-lot interceptor swales, located along the rear property line of downhill properties, in order to intercept overland runoff and infiltrate and detain it, while overflows are safely conveyed off-site.

In addition, the use of terraced landscaping is receiving praise for its impact on stormwater runoff. By creating flat landscaped areas, infiltration is promoted and runoff is reduced. Lot-level controls can have an immense impact on stormwater runoff, and designers are encouraged to integrate new initiatives at this level.

4.9 MINIMUM BUILDING ELEVATIONS (MBE)

Refer to MMCD Design Guideline Manual

4.10 RATIONAL METHOD

Refer to MMCD Design Guideline Manual

4.11 HYDROGRAPH METHOD

Refer to MMCD Design Guideline Manual

4.12 MINOR SYSTEM DESIGN

Minor systems are not limited to the design of pipes and closed conveyance systems. In many cases, the design of an open natural drainage system is preferable. In these cases, it is recommended that natural channels be designed to simulate natural hydrological, geomorphological, and ecological processes in order to create functioning river systems. Natural channel design is very site specific and substantial data is required for proper implementation. Some important attributes of functioning natural channels are: efficient transport of a variety of flows and total sediment loads; well-vegetated but dynamic banks; a coarser substrate size in the channel relative to the bank with low amounts of fine substrate in interstitial spaces; and a hydrograph indicating a moderate response to sudden amounts of precipitation. These systems can become an integral component and amenity in new urban and rural developments.

4.13 MAJOR SYSTEM DESIGN

Major system design should be designed to consider the facilitation of fish movement and migration in order to promote various life cycle phases important for maintenance and productivity of present and future aquatic populations. Spanning bridges that maintain natural bank and bed structure are preferable. Open-bottom culverts do not limit fish passage and retain natural stream substrate; however, some riparian vegetation is lost. Culverts should not be less than 0.45m to allow for fish passage. Culvert design should include the following guidelines:

- current velocity < 1.2m/s for culvert lengths < 24.4m;
- current velocity < 0.9m/s for lengths > 24.4m;
- site specific approval by Fisheries and Oceans Canada and Ministry of Environment, Land and Parks for lengths > 61m;
- water depth > 0.23m at any point in the culvert;
- all culverts accommodating salmonid migration should be designed to hold a 100-year flood;
- culvert exit should include an outlet pool with tailwater control;
- effective slope defined as mean slope of water surface from culvert inlet to tailwater control point should not exceed;
- 0.5% for lengths > 24m unless baffles are used;
- 1.0% for lengths < 24m unless baffles are used; and
- 5.0% at any time even with baffles.

Culvert baffles are an effective method of providing fish with resting areas and resemble low weirs. They should be used in the culvert if the slope exceeds the above criteria. A successful baffle design is the offset baffle configuration consisting of paired baffles attached to sides and bottom of the culvert and extending out into the flow of water. This design minimizes interference with bedload and debris movement. Culvert capacity calculations including baffles should be estimated by subtracting the cross-sectional area displaced by baffles and by increasing the roughness coefficient.

Guidance in the selection of culverts that encourage aquatic habitat can be found within the *Stream Stewardship: A Guide For Planners and Developers* published by DFO and MOE, or alternatively in the *Design of Road Culverts for Fish Passage* published by the Washington Department of Fish and Wildlife.

However, culverts are often not the appropriate choice for watercourses. In fact, there is an increasing trend to opening up previously enclosed watercourses. Daylighting culverts exposes waterways buried in pipes, culverts, and decks by removing overhanging structure and re-establishing the natural channel. This method can increase hydraulic capacity and reduce runoff velocities and enhance aquatic habitat for fish and wildlife. In addition, exposing water to sunlight improves water quality indirectly by improving habitat for organisms which facilitate biodegradation and storage of pollutants.

4.14 RUNOFF CONTROLS

Stormwater Management includes the implementation of the most appropriate Best Management Practices (BMPs) to reduce the quantity and improve the quality of stormwater runoff from any given site. “Recent research shows that the stormwater related impacts typically start to occur once the impervious percentage of a watershed reaches about 10%. Therefore, an appropriate Performance Target for a healthy watershed is to limit total runoff volume to 10% (or less) of total rainfall volume, which means that 90% of rainfall must be returned to natural hydrologic pathways (i.e. infiltration and evapo-transpiration) or reused at the source.”[22]

The specification of BMPs must be performed in an integrated manner. Controls should include components of Pollution Prevention Planning, Source Controls, On-Site Controls, Conveyance Controls, and End-of-Pipe Measures. Consideration must be given to the appropriateness of controls given the site-specific conditions and constraints. Issues such as soils permeability and surface slope must be considered. Issues such as private ownership (and an assumed lack of maintenance) must be considered. Finally, the cost/benefit of certain controls should be examined. By designing an integrated treatment train, the cumulative impact of the various BMPs will be a healthy and natural watershed.

[22] Report on Effectiveness of Source Control, GVRD, December 2002

4.14.1 Pollution Prevention Planning

Pollution prevention is always preferable to mitigation. By setting performance targets with regard to runoff quantity and quality, conveyance requirements, flooding protection, and overall cost, the effectiveness of various BMPs can be evaluated and informed decisions regarding additional action can be made.

However, there are simple considerations that should be integrated into every project. By reducing the footprint of a development, the environmental implications are significantly reduced. Buffers and setbacks from natural features are very effective tools. Retaining natural vegetation is also a very valuable tool, and can be achieved on a well-planned construction site. Soil disturbance should be limited to the areas immediately under construction, and soil protection measures should be implemented at all times. Impervious areas should be disconnected and redirected to pervious areas. Natural Greenways and Buffers should be constructed wherever possible. Simple planning measures can have an immense impact upon the effectiveness of the various structural and non-structural BMPs implemented on a given site.

4.14.2 Source Controls

"Source Controls are measures designed to minimize the generation of, and entry of pollutants into, stormwater runoff, with emphasis on non-structural and semi-structural measures applied at or near source."[23] Source controls can also include measures to reduce the quantity of stormwater runoff. Regardless, they include a combination of public education, municipal planning, municipal by-law, and operations and maintenance initiatives designed to prevent stormwater pollution. Initiatives such as street sweeping, catchbasin cleaning, storm drain flushing, control of road de-icers, fertilizers, and pesticides, leaf clearing and removal, pool drainage, water conservation, and watercourse maintenance are all examples of source controls.

One example of public education source controls is stenciling programs. Storm drain stenciling programs remind residents not to dump pollutants on or in drains, sidewalks, and parking lots. More information on this program can be obtained through the Ministry of Environment or the Department of Fisheries and Oceans.

Street Sweeping is an operations & maintenance source control used increasingly to help minimize the migration of silt and sediment into the storm drainage system. Street sweeping is not to be confused with street flushing, which is often inappropriate as it uses water, often chlorinated, to convey sediment into storm drainage infrastructure and contributes to the water quality problems associated with construction projects.

[23] Source and On-Site Controls for Municipal Drainage Systems, Infraguide, March 2003

4.14.3 Erosion and Sediment Controls (ESC)

ESC is a very specific form of source control, and warrants extensive discussion. Construction is a primary factor negatively impacting aquatic habitats. Stormwater runoff from construction sites has been found to contain significantly higher contaminant concentrations than stormwater from development sites. This is particularly disconcerting since ESCs are frequently implemented incorrectly and poorly maintained, rendering them ineffective. Consequently, stormwater management plans must contain effective erosion and sediment controls.

Effective erosion and sediment control plans promote good water quality. The most popular ESCs are: silt fences, stabilized construction entrances, storm drain inlet protection, and vegetation stabilization; however, all four techniques rank high in installation and maintenance problems. Erosion and sediment control techniques are frequently unregulated and not integrated with other stream protection efforts.

In addition, ESC measures are not universally applicable to all sites. For example, certain measures, although effective for trapping sediment in granular soils, are ineffective with clay soils. Measures such as control ponds are ineffective unless sized appropriately. Designers often overestimate the effectiveness of certain controls, and generally undersize control facilities which results in inappropriate control measures on site.

“Critical elements to an effective ESC include:

- reduction of clearing and grading;
- phase construction to limit soil exposure at any one time;
- immediately stabilize exposed soils;
- protect slopes and cuts;
- install perimeter controls to filter sediments;
- use sediment settling controls;
- adjust ESC plan at construction site; and
- assess ESC practices after rain event.”[24]

[24] Brown, W. E., and D. S. Caraco. 1997. A critique of erosion and sediment control plans muddy water in – muddy water out? Watershed Protection Techniques 2:393-403.

Site management makes a huge difference in the effectiveness of ESC initiatives. If construction can be completed in the dry seasons, the risk of erosion and sedimentation are significantly reduced. ESC infrastructure must be installed at the very outset of any construction project, before any excavation or soils mobilization takes place. Construction entrance mud-mats should be constructed at the outset of construction. Soil stockpiles should be covered at all times. Site slopes must be controlled with interceptor swales. Catchbasins should be fitted with socks/sediment traps. Disturbance should be on an as-needed basis. These measures need to be maintained. Street sweeping is valuable: flushing is not. Filters w. flocculants are valuable. Through the implementation of a treatment train of ESCs, construction sites can become less of a burden upon the adjacent watercourses.

Cover Practices

As discussed above, soils should only be disturbed as necessary, and natural vegetation should be preserved wherever possible. Buffer zones should be included near all watercourses to reduce the impact upon the aquatic habitat.

On housing lots, straw mulch or polyethylene tarps in non-traffic areas are recommended. Compost is also emerging as a viable erosion control product although there are specific parameters that must be met in order for compost to function properly in this application.

On sites that require soil stockpiles, if the pile will be in place for durations greater than two days during the wet season, or seven days during the dry season, up to a maximum of 60 days, temporary measures such as temporary seeding, mulching & matting, or clear plastic covering should be implemented. Soil stockpiles should be surrounded by siltation control fence at all times.

Upon completion of a project, or if a soil pile is to be stockpiled for greater than 60 days, permanent cover practices, such as the establishment of grass cover, are to be implemented. Establishing grass cover is the second most effective method of erosion control behind limiting disturbance. Methods used to establish grass cover are sodding, broadcast seeding, hydroseeding, and drillseeding. Use soil tests to determine lime and fertilization requirements for suitable species selection.

Erosion Control Measures

There are a wide range of erosion control alternatives that should be selected based upon the specific conditions and requirements of each site. Initiatives bearing consideration include:

- Construction road stabilization;
- Pipe slope drains;

- Subsurface drains;
- Surface roughening;
- Gradient terraces;
- Bio-engineered protection of very steep slopes;
- Level spreader;
- Interceptor dikes and swales;
- Check dams;
- Outlet protection;
- Rip-rap;
- Vegetative streambank stabilization;
- Bio-engineered methods of streambank stabilization; and
- Structural streambank protection

Sediment Control Measures

- Silt/Filter fences are effective filters for sediment-laden runoff coarser than 0.02mm; however are commonly installed improperly and poorly maintained, rendering them ineffective. Design criteria include: stakes should be > 7.5cm in diameter and > 1.5m long and driven > 40cm into the ground; stakes should be < 2.4m apart unless wire backing is used; and bottom should be buried in a trench > 20cm.
- Stabilized construction entrances (Mud Mats) involve a minimum of 300mm of crushed stone, measuring at least 8m wide and 30m long into the site. The entrance should be flanked on both sides by silt fences.
- Storm drain inlet protection and catchbasin filters should be installed on all potentially affected inlets. The installation of catchbasin inserts or filter cloth protection over the catchbasin inlet are appropriate as temporary sediment control measures.
- Straw bale barrier, Brush barrier, and Gravel filter berms are all appropriate for installation in overland flow paths in order to slow runoff volumes and trap sediment. Caution must be used as these measures are primarily effective in trapping large sediment.

- Catchbasin sumps are similar to conventional catchbasin designs except that the sump provides a permanent pool for settling solids and sediment storage. They are designed for relatively small flows and typically located off-line. They are suitable for pretreatment to reduce sediment loading and trash and can be useful in high sediment loading areas such as gravel parking lots and residential areas. They require cleaning at least twice per year. General design criteria should include: each trap can service approximately 1.2ha; a sump depth between 1 to 1.5m > 1,500 mm diameter manhole; and sump volume = 20m3 per m3/s of design flow.
- Sediment traps are similar to sediment ponds, but designed for small sites. Fed by swales and ditches, this detention facility on the low-side of the site retains water and allows for settling of solids before discharge off-site.
- Sediment ponds (or basin) are appropriate for sites of 5 hectares or larger, are used to settle suspended sediments larger than 0.02mm in stormwater runoff in construction and development areas. Conventional basin designs such as simple risers do not provide enough detention time or proper conditions for settling. A floating skimmer or a perforated riser with gravel jacket should be incorporated for higher rates of sediment removal (Jarrett 1993). Wherever possible, outlets should be designed to draw from the surface, not the bottom of the facility. Standing water should be maintained at all times not merely during storm events. As a design guideline, ponds should be sized to accommodate 125m3/ha of site area. Of this volume, at least 20% should be dedicated to a forebay. The remainder, as a permanent pool, should measure 1.3-1.8m in average depth, and not exceed 2.4m.
- Dust control.
- Tire wash.

ESC Plans are becoming a mandatory component of all design submission. Design guidance can be obtained from:

- ***Best Management Practices Guide for Stormwater Appendix H: Construction Site Erosion and Sediment Control Guide***, Greater Vancouver Sewerage & Drainage District;
- ***Land Development Guidelines for the Protection of Fish Habitat,*** DFO/MOE
- *Filter Fence Design Aid for Sediment Control at Construction Sites,* USEPA
- *Stormwater Management For Construction Activities: Developing Pollution Prevention Plans and Best Management Practices,* USEPA

4.14.4 On-Site Controls

"On-site (or lot-level) controls are practices that reduce run-off volumes and/or treat stormwater before it reaches a municipal conveyance system."[25] These controls can generally be categorized as either infiltration controls, storage controls, or pretreatment controls. Guidance in the design of various infiltration controls can be obtained from the GVRD's *Stormwater Source Control Design Guidelines* and *Best Management Practices Guide for Stormwater* as well as the EPA's *The Use of Best Management Practices (BMPs) in Urban Watersheds.*

Low Impact Development (LID) is an innovative micro-scale runoff control strategy for wet-weather flow management issues based on the incorporation of distributed micro-scale Best Management Practices throughout the subcatchment to replicate pre-development conditions. They have been demonstrated to be very effective in achieving the objectives of stormwater management in a cost-effective manner.

That said, on-site controls can add significant cost to a project. They do not preclude the construction of major storm infrastructure, and should be carefully considered as communal facilities may be more efficient and effective in certain instances.

Infiltration Controls

Since infiltration BMPs rely heavily on the infiltration capabilities of the underlying soils, it is important to investigate the long-term effectiveness of these practices. Further, since these structures are constructed on private property, consideration must be given to the implications of failure due to lack of maintenance, or retrofit complications. In general, infiltration controls are not recommended in areas where the percolation rate of the native soils is less than 5mm/hr.

Controlled lot grading as discussed in section 4.8.

Buffer & Filter Strips are important infiltration controls as they physically separate potential contaminants from sensitive habitat, and provide infiltration and filtration.

Foundation drain sump pumping can be used to transport water to the surface for storage or to infiltration systems to reduce stormwater runoff. Foundation drainage is normally clean and is suitable for infiltration or for overland flow to storage ponds instead of direct conveyance to storm sewers. Design criteria include: sump pump discharges should be > 2.0m from foundations and be directed to back yards away from side walks to prevent icing conditions; and surface discharges should be > 0.5m above ground to prevent blockages from ice and snow.

[25] Source and On-Site Controls for Municipal Drainage Systems, Infraguide, March 2003

Downspout disconnection is encouraged as roof leaders leading to surface areas promote infiltration and reduce negative effects of high peak flows. Many local municipalities have implemented by-laws restricting the connection of downspouts to municipal storm sewers. Flows should be spread horizontally and energy should be dissipated to prevent erosion of the site surface.

Green Roofing implements functioning rooftop gardens (e.g., Vancouver Public Library) and potential benefits include: added property value, protection of roof membrane, decreased home energy expenditures due to heat loss, decreased urban heat island effect, and increased urban green space. The National Research Council of Canada (NRC) compared a conventional roofing system with a Green roof and documented reduced mean daily energy demand for space conditioning due to heat flow through roof membranes in summer by > 75%. In addition, stormwater runoff was reduced by 54% and peak runoff rate and volume were also reduced.[26]

Green roofing requires a specialized roof waterproofing membrane, drainage layer, filter membrane, growing medium and vegetation. Waterproofing membranes are standard components of conventional roofing. The drainage layer is installed on the waterproofing membrane to drain excess water from the growing medium. This layer can be made of various materials such as gravel, specialized polymer foam panels, or a porous polymeric mat. The drainage layer can also be used to retain water and serve as a reservoir for plant irrigation between rain events. The filter membrane is a geo-textile installed on the drainage layer to prevent clogging of the drainage layer with growing material. The growing material functions to support vegetation. Lightweight artificial medium can be used in place of soil to reduce stress on roof structure. Plants that are native to the area are typically successful; however, consideration should be given to extreme conditions of rooftops such as wide ranging temperatures and soil moisture levels and higher winds. Irrigation systems may be needed depending on plant species and local climatic conditions.

The design should begin simultaneously with the building or retrofitting project so the structural load can be balanced with the building design. Saturated weight of all materials should be used in structural load calculations. Access to the roof for maintenance and irrigation should be included in the design. Fire breaks of non-flammable material (e.g., gravel) should be located every 40m in all directions and at the roof perimeter. Use root resistant material such as thermoplastic and elastomer for waterproof membranes. Roofing materials containing bitumen or other organic materials are susceptible to root penetration and micro-organic activity. Prior to installing layers above the waterproof

[26] Liu, K. 2003. Engineering performance through rooftop gardens thorough field evaluation. National Research Council Canada.

membrane the roof should be flooded and inspected for leaks. Use high diversity plant mixes because they are more stable and self-sustaining than monocultures.

Infiltration/Soakaway Pits are filter-cloth-lined gravel-filled excavations which can detain and infiltrate runoff from roof leaders or surface swales. Compacted gravel exhibits void ratios up to 40%. Dependant upon the soils conditions, infiltration capacity, and depth to groundwater table, these can be very effective BMPs for groundwater recharge and runoff volume reduction.

Biofiltration Systems are constructed to simulate functions of natural landscapes for stormwater runoff treatment. Typical biofilters include grass filter strips, and vegetated swales. Natural vegetation is used on the structure surface. Pollutants are removed by adsorption, filtration, volatilization, ion exchange, and decomposition. These structures are alternatives to traditional curb and gutter storm conveyance systems and reduce volume and velocity of stormwater runoff. Design criteria include:

- size of biofilters should be < 61m in length; and
- longitudinal slopes should be < 1% (Koon and Arnold 1997);

Grass filter strips are uniformly graded and densely vegetated areas that intercept sheet runoff from impervious surfaces such as rooftops, highways and parking lots. They function to trap sediments, allow partial infiltration, and reduce velocity.

Vegetated swales are shallow broad channels lined with dense vegetation and commonly they are commonly associated with low-density development. Cost effective swales are intended to remove pollutants and allow infiltration of stormwater. Sodded lawn is typically used in swale planting; however, wetland vegetation can increase pollutant uptake and provide habitat for wildlife. Vegetated erosion control should be used along all sides of the weir and at drainage inlets. Swales should be properly maintained to prevent ponding. Design criteria include:

- a pool should be located at the top of the channel to prevent sediment buildup;
- vegetation should be > 7.5 cm in height;
- maximum current velocity should be 0.5m/s; and
- a minimum longitudinal slope of 1 to 2% to maintain conveyance.

Absorbent Landscaping includes components such as vegetation, organic matter, and soils either soak up water or facilitate evaporation. Tree crowns can intercept up to 28% of annual rainfall.[27] Plants function in stormwater detention and promote evapotranspiration. Rainfall storage in soil is 7 to 18% of soil volume. Sand stores less water than loamy soils and infiltration rates are also affected by soil type. Soil compaction reduces infiltration rates. Deposition of fine sediments on soils also decreases infiltration and is avoided with erosion control BMPs. Applying surface mulches and organic material can maintain infiltration rates. Various soil type infiltration rates include: 0.6 to 6mm/hr for fine soils (e.g., silt and clay); approximately 13mm/hr for loam soils; and approximately 210mm/hr for sandy soils. Design considerations should include: maximizing absorbent landscape area, conserve natural forest land and undisturbed soil; minimizing impervious surfaces by using narrow roads; connecting run off from impervious areas to absorbent landscapes with an overflow to storm drainage; tilling and aerating soil that is compacted during construction; and use of effective erosion control to prevent sedimentation of absorbent landscapes.

"Runoff from pervious areas can be virtually eliminated by providing a 300mm layer of landscaped absorbent soil, even where the hydraulic conductivity of the underlying soil is low."[28]

Pervious Pavements include porous asphalt, porous concrete, perforated concrete blocks, and cobble stone with porous joints or reinforced turf. Another type combines a concrete matrix with large voids filled with permeable materials such as gravel or grass. These materials are suitable for use in low traffic areas without heavy vehicle use such as parking lots. Benefits of pervious pavement include storage and biodegradation of pollutants (e.g., oil and gasoline), reduction of peak flows, and groundwater recharge. Problems can arise from pavement clogging; therefore, proper planning and design should be considered to avoid misuse. During construction, proper BMPs such as grass filter strips should be used to prevent pavement clogging by sediments.

Design criteria include:

- total catchment area draining into pavement should be < 2ha;
- pavement should be downslope from building foundations, which should have piped drainage at footers;
- for designs relying on full infiltration from the reservoir into underlying soils the rate should be > 12.5mm/hr;
- sites with infiltration rates < 12.5mm/hr should require partial infiltration solutions with drain pipes;
- pavement surface slope should be > 1% to avoid flooding; and

[27] Ngan, G., 2004. *Stormwater Source Control Design Guidelines 2005*, GVRD.
[28] Report on Effectiveness of Stormwater Source Control, GVRD, December 2002

- designs for heavy loads should use reinforcing grids in the pavement sub-base.

Three common designs of pervious pavement are full infiltration, partial infiltration, and no infiltration. Full infiltration drains all inflow into underlying soil. Pipes are used to provide overflow and secondary drainage if the base becomes clogged. Partial infiltration drains allow partial infiltration of water into soils while the remainder is drained by perforated pipes. No infiltration is used in areas with low permeability soils or a high water table. The reservoir is lined with an impermeable membrane and water is removed at a controlled rate through a pipe system. Caution must be used to prevent infiltration into adjacent manholes.

Rain Gardens are landscaped basins that collect and allow infiltration of water to soils. They mitigate ground water depletion and improve aesthetics. Trees, shrubs, and grasses are typically used in rain garden plantings. Rain gardens often have a drain rock reservoir and perforated drain system to collect excess water. Design criteria include:

- rain garden size should be 10 to 20% of upstream impervious area and be sized by continuous flow modeling;
- biofiltration facilities should be a minimum of 3m downslope of building foundations;
- a 0.5 to 0.7mm thick organic mulch should line the garden to control erosion and maintain infiltration; and
- drain rock reservoir bottoms should be level and control methods should be implemented to prevent mixing with fill soils.

Storage Controls

Although stormwater storage was the primary component of stormwater management within the initiatives to attenuate post-development peak flows to pre-development rates, they will continue to be a valuable part of all stormwater management plans as part of the treatment train approach. Through the use of Inlet Control Devices (ICD's), Orifice Plates, Reducer Pipes, and overflow weirs, stormwater release rates can be restricted to pre-development levels and additional runoff can be detained on-site.

Surface Ponding/Parking Lot Storage is the most economical storage option, and is appropriate in non-essential areas or where access and travel are not required during major storm events. Storage up to 450mm is accepted in various locations across the country; however, maximum depths of 300mm are recommended, and maximums of 150mm are frequently used. Areas designed to detain stormwater on the surface must be designed with an overland flow route in order to convey flows safely off-site in major storm events, or should the system surcharge prematurely. Caution must be used to avoid the placement of sanitary manholes within the ponding limits, and where unavoidable, watertight sanitary manhole lids must be used to prevent excessive inflow.

Rooftop Detention can be utilized on flat roof buildings by fitting drains with a series of weirs to control the release rate and allow temporary storage of rain water on the roof. Recommended for industrial, commercial and institutional buildings, design criteria include: maximum ponding depth of 100mm; and roof supports must be adequate to support water weight. Coordination with the mechanical and structural engineers is required.

Underground Detention of stormwater is generally an expensive alternative but appropriate for sites where there is no space available for alternative detention infrastructure. Traditional alternatives include the use of oversized storm sewer pipes, corrugated metal Superpipes, HDPE pipes, Concrete Box Culverts, as well as Poured-in-Place tanks. Alternatively, compacted gravel provides void ratios up to 40%. However, although infiltration pits will provide some storage, most municipalities will not accept this as a form of detention. Consequently, there are a wide variety of proprietary detention products available throughout the province which provide substantial open space for detention while accommodating earth and traffic loads.

Cisterns are a popular and efficient way of retaining rooftop stormwater on-site for a variety of potential uses: reuse inside the building as greywater, irrigation of landscaped features, or infiltration into on-site infiltration pits. This is a very Green initiative that is gaining popularity and recommended as a component of most stormwater management plans. That said, analysis contained within the Capital Regional District *2004 Review of the Strategic Plan for Water Management* illustrates that the volumes of water retained onsite is supplementary but insufficient to replace potable water for irrigation, and not cost effective for greywater reuse.

Pre-Treatment Controls

Included as on-site stormwater management controls, these pre-treatment controls can also be considered as end-of-pipe measures depending on the application. However, Green and sustainable infrastructure promotes the implementation of BMPs that treat flows on-site.

Oil/Grit Separators are a very popular alternative on commercial and industrial sites for treating flows from paved parking areas where there is insufficient land available for treatment ponds. These facilities have been proven effective at removal of TSS and Oils and their use has become mandatory in many municipalities across the country. It is recommended that they become mandatory on all sites with parking for 50 or more vehicles. Issues include high capital cost and difficulty in enforcing ongoing maintenance.

Multi-Chambered Treatment Train Systems are effective at treating stormwater and reducing a broad range of runoff pollutants including TSS, petroleum hydrocarbons, bacteria, heavy metals, and nutrients.

4.14.5 Conveyance Controls

Conveyance controls are "practices that reduce runoff volumes and treat stormwater while the flow is being conveyed through the drainage system"[29] They are a valuable component of the treatment train and particularly relevant as they are the first municipally-maintained component.

Pervious Pipe Systems are designed to exfiltrate stormwater and convey flows downstream when necessary. Although not recommended for soil conditions with infiltration rates of less than 15mm/hr or areas of high groundwater, these systems have been shown to reduce the volume of runoff by as much as 91% and in one case infiltrate all of the runoff from rainfalls up to 40mm. Designs vary, but one successful design includes a grassed swale underlain by an infiltration trench which contains the perforated pipe wrapped in filter cloth lying on a bed of clean aggregate. Catchbasins direct stormwater to this pipe, but are also connected to a main sewer line via an overflow approximately 1m above the perforated pipe.

Pervious Catchbasins can describe one of two different designs: typical catchbasins atop a granular bed with a perforated bottom; or a traditional catchbasin with a large sump that is interconnected with exfiltration storage media. Both systems have been effective; however, consideration should be given to the application in areas unlikely to be subject to high contaminant loadings as they can reduce the infiltration capability of the surrounding soils.

Pervious Curb and Gutter Systems are relatively new in Canada but used throughout Japan where they have been rather successful. Ultimately, these systems utilize an L-shaped gutter atop a U-shaped drain. The drain is constructed of pervious pavements surrounded by gravel, which allows for exfiltration of stormwater. Caution must be used in areas where freezing will render them ineffective and can heave adjacent pavement.

Grassed Swales/Ditches symbolize the shift from the curb-and-gutter closed conveyance systems and the return of sustainable infrastructure. Grasses swales and ditches promote infiltration and treatment while providing flood control. Although occupying more space within the right-of-way, these conveyance controls are Green initiatives and should be promoted in new residential areas.

[29] Conveyance and End-of-Pipe Measures for Stormwater Control, Infraguide, January 25, 2005

Infiltration Swales store runoff from paved surfaces in surface soil and drain rock reservoirs and allow groundwater recharge while adding green space. They are designed to treat and convey large flows and are suitable for residential areas, municipal office complexes, and rooftop and parking lot runoff.

4.14.6 End-of-Pipe Measures

End-of-Pipe Controls are "practices that reduce runoff volumes and treat stormwater at the outlet of drainage systems, just before it reaches the receiving streams or waters. These controls are usually implemented to manage the runoff from larger drainage areas."[30]

It is important to note that even though source, on-site, and conveyance controls are proven to be effective in most circumstances, they do not eliminate the need for end-of-pipe quantity and quality control. As many of the BMPs are on private property, their long-term effectiveness cannot be guaranteed. Many require proper maintenance to be effective. In the event of failure of the upstream BMPs, end-of-pipe measures become a very important component of the treatment train.

There are several considerations in the design of end-of-pipe measures. First, detention facilities must hold stormwater for longer than 24 hours to be effective water quality control device. Second, these facilities must be maintained in order to remain effective. Third, end-of-pipe measures are significantly more effective and require less maintenance if pre-treatment is provided as above. Finally, off-line facilities are preferred to on-line facilities as on-line facilities can have detrimental impacts upon aquatic habitat. Reference to specific design parameters can be made to DFO's *Land Development Guidelines for the Protection of Aquatic Habitat.*

Dry Detention Ponds are designed to attenuate peak flow rates by temporarily storing stormwater and releasing it at a controlled flow rate generally based on a 24-hour drawdown time. Due to gravitational settling some suspended solids are removed from the runoff and remain in the basin. However, if they are not removed with regular cleaning, they will likely become resuspended in later storm events. This efficiency can be increased by including and maintaining a pre-settling chamber for coarse sediment accumulation. Detention ponds can improve water quality; however, their efficiency is a function of pond draw down time. They are suitable for drainage areas > 5ha in low density residential areas where nutrient runoff from fertilizers are a concern. They are frequently used in areas where wet ponds are impractical, and advantageous for multi-use areas like playing fields, parking lots, and natural depressions. However, dry ponds are often less effective than wet ponds due to the potential for re-suspension of sediment. They are most often used primarily as a quantity control.

[30] Conveyance and End-of-Pipe Measures for Stormwater Control, Infraguide, January 25, 2005

Wet Detention Ponds intercept a volume of stormwater and provide storage and treatment. Water above the permanent pool level is displaced by runoff. They provide water quality improvements, reduce peak flow rates and add aesthetic value and create aquatic and terrestrial habitat for wildlife. Basins should be lined with aquatic vegetation around the perimeter to increase pollutant removal efficiency and provide a barrier to entry. They are typically constructed as a dual purpose facility; the flood fringe area is used to store runoff from large infrequent storms and the extended detention area is for storage of frequent small storm event runoff. Suspended pollutants and sediments settle and are stored in the detention area. Wet ponds are suitable for residential, commercial, and industrial areas > 5ha. Their ability to reduce soluble pollutants is high; hence, they are efficient in areas which contribute nutrient-rich runoff. Water quality control performance can be improved by providing a forebay and backup water supply to maintain minimum storage volume in the extended detention area. Design criteria include:

- water surface should be >2ha;
- sides should have a maximum slope above active storage zone of 5:1;
- maximum interior side slope is 7:1;
- maximum depth should be 3.0m;
- forebay area should not be >1/3 of permanent pool surface area; and
- in cold climates additional storage should be added to compensate for loss due to ice build-up by increasing pond surface area.

Constructed Wetlands use natural functions of wetlands to aid in pollutant removal from stormwater. In addition, they provide storage for stormwater. A water balance check must be performed to ensure an availability of water to sustain aquatic vegetation between runoff events and dry periods. They are similar to wet detention ponds; however, a large portion of the permanent pool surface area is covered by emergent wetland vegetation. Constructed wetlands are appropriate where ground water is close to the surface. They provide excellent water quality buffering and sediment removal and are suitable for large detention volumes. Biological uptake of nutrients and water are benefits of wetlands to improve water quality and reduce water runoff. Constructed wetlands also facilitate ground water recharge and control peak flow rates. Additionally, they provide recreational opportunities, contribute to urban green space, and provide habitat for fish and wildlife. Stormwater runoff should be pretreated due to potentially damaging effects on wetlands. This is typically achieved by installing an adjacent wet pond approximately 10% of the wetland area and 1.5 to 2.0m deep for settling solid wastes. Creating the longest possible flow path through the wetland increases contact time and increases settling of solids. Design criteria include:

- > 50% of permanent pool surface should be covered with emergent vegetation;
- a minimum surface area ≥ 1.5% of the catchment area;

- incorporate as much edge habitat as possible;
- approximately 10% of the surface should be 1.5-2.0 m deep; and
- an adjacent wet pond 10% of the wetland area and 1.5 to 2.0m deep should be installed for settling solid wastes.

4.15 EVALUATION OF STORM DRAINAGE ALTERNATIVES

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Integrated SWM Plan	↑↑↑	↓↓	↑↑↑↑	↓↓↓	↑
Run Off Modelling	↑↑		↑↑↑	↓↓	↑↑
Rainfall Data	↑↑↑↑		↑	↓	
Reduced Site/ Lot Grading			↑↑	↓	↑↑
Pollution Prevention	↑		↑	↓	
Source Controls	↑	↑	↑↑	↓	
On-Site Controls	↑↑	↑↑	↓	↓	↑↑
Conveyance Controls	↑	↑	↑↑↑	↓↓↓	↑↑
End of Pipe Measures	↑↑	↓↓	↑↑	↓↓	

5.0 ROADS

5.1 GENERAL

Some of the Green road design alternatives addressed in this section include:

- cross-section road designs with narrow pavement widths, increased landscaping, and rain gardens;
- sidewalks, walkways, and bikeways;
- driveways and laneways; and
- pavement structures that utilize recycled materials while minimizing the need for excessive ongoing maintenance and repair.

Green initiatives with respect to roads are often confused with those included in the Storm Drainage Systems section, particularly those in Stormwater Management. Practices such as sediment and erosion control, pervious paving, biofiltration swales, even road cleaning are all more closely related to Stormwater Management than road design and will not be discussed again in this section.

Life-cycle costs, particularly those as a result of long-term maintenance, must be recorded and analyzed to effectively assess the impact of these new initiatives.

5.2 ROAD CLASSIFICATIONS - PLANNING CONSIDERATIONS

The design of roadways must be an integral part of the conceptual planning of new developments. The layout of the road network and classifications of these roads is a major factor in choosing cross-section elements. The Canadian Mortgage and Housing Corporation, (CMHC), continues to spearhead significant research into various street design patterns and their implications on the communities they service. Clearly the intent of all road networks should be to allow for efficient vehicular, pedestrian, and public transportation without adversely affecting adjacent habitat. However, there are varying degrees of efficiency in the road patterns employed to date.

The loop and cul-de-sac layout has been determined to be a relatively inefficient design. Although it creates quiet streets, it uses more land than other alternatives, and generally creates a labyrinth that impedes pedestrian traffic, increasing dependency on vehicular traffic. Alternatively, grid networks allow for direct access in all directions and to public transportation, but attention must be paid to creating a hierarchy of arterial, collector, and local roads as well as continuous walkways and bikeways to avoid superfluous intersections and reduce the dependence upon vehicular transportation. Another concept promoted by CMHC is the use of rear laneways for parking. This allows local roads to be much narrower, promoting safer streets, social interaction, pedestrian traffic, and additional visible green space.

Road networks have as immense an impact on terrestrial animals as they do on the traveling public. Roads can intercept and fragment wildlife migration patterns and established corridors. Consequently, road sighting, design, and planning of wildlife movement need to be integrated to create roads with pathways and greenways that avoid confrontation of wildlife with vehicles and people and allow wildlife safe passage. *Second Nature: Improving Transportation Without Putting Nature Second* is a valuable reference on this topic.

5.3 CROSS-SECTION ELEMENTS

Upon design of a road layout and preferably the creation of low-traffic local roads, alternative cross-sectional elements can be implemented to incorporate Green design initiatives. Green design elements include additional traditional landscaping, reduced pavement widths, permeable on-street parking, bicycle lanes, alternative intersections, and traffic calming measures.

For example, the width of pavement directly correlates to the volume of stormwater runoff, the Urban Heat Island Effect, (UHIE), and the speed of traffic. Wider pavement creates more impervious area, hence more runoff. UHIE is a result of impervious pavements absorbing significant amounts of solar energy and impacting the local temperatures. Design speeds are a function of road size, as wider roads are generally more likely to convey traffic at higher speeds.[31]

Therefore, where possible throughout low-use local roads, reduced pavement width is recommended. This reduction inherently reduces stormwater runoff and the UHIE, while additional room is available for tree planting and landscaping, which further reduces the UHIE through shade creation. On-street parking can be created with structural soils and grasses instead of pavements to increase the permeable surface. Additional space within the right-of-way can also be used to allow for sidewalks and/or bike lanes removed from the roadway, and ditches as required.

5.4 ALIGNMENTS

Although a component of the overall road layout, variations in a road alignment can have significant impact upon its aesthetics and overall perception. A long straight road is often perceived as a commuter thoroughfare, where speeding is common. Narrow, winding roads help to discourage speeding.

[31] High Performance Infrastructure Guidelines: Best Practices for the Public Right-of-Way, Design Trust for Public Space

5.5 INTERSECTIONS

There is a fine balance between traffic calming to create steady, efficient transportation, and excess delays caused by superfluous or poorly designed intersections. The use of roundabouts, for instance, is a potential Green design alternative to create a landscaped island in the centre of the circle, while there may be efficiency gained through the smooth conveyance of traffic and reduction of conflict points. Although more space and paved areas are required versus traditional intersections, roundabouts are gaining in popularity and are increasingly popular.
Allowing traffic to flow continuously while allowing for changes of direction should be considered for all new intersections. Specific design criteria for such intersections are still in development; however, guidance can be obtained from the Ministry of Transportation Technical Bulletin entitled *Planning and Design of Modern Roundabouts* dated January 2003.

5.6 RAILWAY GRADE CROSSINGS

Refer to MMCD Design Guideline Manual

5.7 TRAFFIC CONTROL DEVICES

Traffic signs and pavement markings should be in accordance with the Transportation Association of Canada, (TAC), *Manual of Uniform Traffic Control Devices for Canada*, 1998, and its updates. Sign design shall conform to the TAC *Sign Pattern Manual*, 2001, and the corresponding *Supplemental Guide for Guide and Information Signage in Canada*, 2003.

Bikeways warrant special consideration as their design and integration into roadways is rapidly evolving. TAC's *Bikeway Traffic Control Guidelines for Canada* 1999 is a valuable resource. In addition, various municipalities, such as the City of Nanaimo and City of Abbotsford have produced *Bicycle Facility Design Guidelines* that should be consulted within those areas.

There are a couple of important Green principles to be applied to signs and markings. For example, there are new coatings being applied to signage that causes it to effectively light-up as traffic passes, reducing or eliminating the need for illumination. In addition, suppliers are producing markings that are increasingly environmentally-friendly and VOC free. Consideration should be given to these two issues upon design of signs and markings.

Traffic calming measures include initiatives beyond signs and markings. The TAC *Canadian Guide to Neighbourhood Traffic Calming*, 1998, outlines many effective methods for creating safe roadways by controlling traffic without unnecessarily delaying traffic. Measures including raised crosswalks, sidewalk extensions, speed humps, curb extensions (bulges), curb radius reduction, on-street parking, raised medians, and signage have all been demonstrated to effectively control traffic. Many offer the opportunity for additional landscaping. Consideration should be given to the implementation of these measures in new and retrofit roadworks projects.

5.8 CUL-DE-SACS

Cul-de-sacs discourage alternative modes of travel to the automobile because they tend to obstruct continuous pathways for pedestrians and cyclists and are harder to service with public transit. Alternative road patterns are recommended.

5.9 TRAFFIC BARRIERS

Traffic barriers control and direct traffic flow, and should follow the recommendations within the TAC *Canadian Guide to Neighbourhood Traffic Calming*. Initiatives such as directional closures, diverters, intersection channelization, raised medians, and right-in/right-out islands can all be effective in blocking or directing flow to create desired traffic patterns. There are potential trade-offs between increased travel distances and increased vehicle emissions in some cases.

5.10 SIDEWALKS AND WALKWAYS

In section 5.3 above, the reduction of pavement widths and overall impervious area can involve the construction of additional sidewalks and walkways, which can increase the impervious area within a development. Neither consideration automatically garners priority. This tradeoff must be assessed on a development-by-development basis. Boulevards are Green and provide a better environment for pedestrians.

Considerations include location, whether adjacent or removed from the roadway, numbers, whether necessary on both sides or just one, function, whether they can be operate as multi-use pathways, and material, whether impervious surfaces can be replaced with structural soils, wood-chip, or other naturalized covers. It is also important to remember that of the community population "over 50% regularly hike or use foot paths through natural 'greenways' where they exist."[32]

The Infraguide *Sidewalk Design, Construction and Maintenance* Best Management Practice has identified a sidewalk infrastructure deficit of $1.5-2.4 billion in Canada. Proper design and construction can more than double the current service life of a sidewalk up to approximately 80 years. Consideration must be given to the use of materials, width, location within the right-of-way, and proximity of trees. Rehabilitation methodologies such as grinding and mud-jacking may present viable and cost effective alternatives to replacement. Reference should be made to the Infraguide practice for more information.

5.11 BIKEWAYS

Creating useable bikeways extends past merely constructing a 3m wide path. Bicycle transportation needs to convey travellers from destination to destination, and include a

[32] Access Near Aquatic Areas: A Guide to Sensitive Planning, Design and Management, MOE/DFO

combination of on-street, off-street, and end-of-trip facilities, all with the appropriate signage and pavement markings. On-street bicycle facilities include shared bicycle routes, marked wide curb lanes, bicycle lanes, and paved shoulders. Off-street facilities include multi-use pathways. End of trip facilities including bicycle parking and shower facilities. Reference should be made to the TAC *Bikeway Traffic Control Guidelines for Canada* 1999, or local guidelines where available. The TAC *Bicycle Traffic Pavement Markings Manual* is anticipated as early as January 2006.

5.12 TRANSIT FACILITIES

Refer to MMCD Design Guideline Manual

5.13 DRIVEWAYS & LANEWAYS

The use of rear laneways instead of traditional front driveways moves traffic off the street, and encourages moving houses forward on the lot. These laneways allow the designer to consider additional Green alternatives. By removing the driveways, reductions in impervious area can be made if the laneway is designed as more pervious than regular asphalt. Recent experience in the City of Vancouver with the Country Lanes project suggests that laneways can be constructed with the use of structural grass: a rigid plastic grid that supports vehicular traffic but allows for the growth of natural grass within the grid. By constructing a road base of aggregate material with a sand/soil mixture, filling driving strips with small gravel, and utilizing permeable pavers at the land entrances, the structural soil is an alternative to traditional asphalt paving.[33]

5.14 CLEARANCES FROM ENVIRONMENTAL FEATURES

Setbacks within Fisheries Sensitive Zones (FSZ) from features such as wetlands, watercourses, ponds, riparian areas, or other environmental amenities can mitigate the effects of roadways on the natural environment. "Leave strips should be provided on all watercourses that flow into other intermittently wetted areas, small streams, side channels and ditches which may not flow throughout the entire year"[34]

5.15 UNDERGROUND UTILITY LOCATIONS

Infraguide's research outlines the wide range of failures identified in surrounding pavement as a result of utility access boxes. Settlement, concentric cracking, differential heave, and transverse cracking are all prevalent types of distress attributable to utilities. Further, it attributes these issues to the presence of compressible, frost-susceptible soils, which ultimately suggest poor workmanship. Adjustable frames have been effective compared to "25 percent of catchbasins

[33] City of Vancouver Country Lanes Project Summary
[34] Land Development Guidelines for the Protection of Aquatic Habitat, DFO/MOE 1993

and maintenance access holes (manholes) and 10 percent of valve boxes exhibit the distress types identified."[35] These failures can be avoided, and this becomes a Green infrastructure alternative.

Research recommends that manholes and valve boxes should ideally be located behind the sidewalk or curb, in the middle of the roadway/driving lane, or in the sidewalk. Wherever possible, they should be placed away from the tire path. Further, the use of proper backfill, compaction techniques, frost tapers, and geotextile wrapping as a frost heave mitigation technique may all prove useful in protecting the utility access and the surrounding pavement.

5.16 PAVEMENT STRUCTURE

Perhaps the must substantial and visible Green road design is occurring within the area of pavement structure. With regular advances in asset management, life-cycle costing, and preventative maintenance, the initial construction and ongoing maintenance of roads have undergone intense scrutiny in recent years. It is now understood that designers must look past the initial construction cost and quantify the long-term implications of their design decisions. They must understand that the choices of resource material, construction methodology, and construction by-products including pollution, have significant impacts upon the road's performance. In addition, public tolerance for lengthy traffic delays, noise, dust and other construction-related nuisances is waning. It is important to employ the industry's best practices in the design and construction of all roadways.

It is expected that all pavement structure design will be conducted in accordance with the: *Standard Specifications for Highway Construction*, 2004, Ministry of Transportation; *Pavement Design and Management Guide*, 1997, TAC; and the *Management of Road Construction and Maintenance Wastes*, 1994, TAC.

5.16.1 Pavement Alternatives

There is currently a long list of alternatives to conventional asphalt or Portland cement concrete pavements. In terms of impervious area and the UHIE as discussed above, traditional pavements can be replaced with interlocking pavers, porous/permeable concrete or asphalt. In low-traffic areas where contaminants are limited, these options promote infiltration and groundwater recharge, while preventing the heating and conveyance of stormwater into the storm drainage system. Other alternatives include the elimination of paved shoulders in favour of structural soil which is crushed gravel with soil stabilizer or reinforced grass as a means of allowing for vehicular traffic while reducing the impervious area of the roadway.

Designers might consider light-coloured aggregate in order to increase the albedo or reflectivity of paved surfaces, ultimately reducing their absorption of solar energy.

[35] The Construction of Utility Boxes in Pavement, Infraguide, December 2002

In terms of long term durability and performance, there are a variety of new techniques that are effective in producing better pavement surfaces. "Rutting (permanent deformation) is a prime potential failure mode of hot-mix asphalt."[36] Fortunately there are a wide variety of rut mitigation techniques appropriate for use throughout the province. Alternatives such as Rut-Resistant Hot-Mix Asphalt, Superpave Mixes, Whitetopping, and Roller Compacted Concrete have all been utilized with success.

5.16.2 Reduce, Reuse, Recycle

The pressure to reuse and recycle almost all construction materials is growing. Coupled with the need to preserve non-renewable resources by reducing aggregate mining and the increasing cost of transporting and disposing of spent materials, there may be significant savings to be realized in the recycling of construction materials.

For instance, road projects may utilize recycled asphalt or concrete. Coal fly ash or blast furnace slag can be used as additives. Recycled tire rubber can be used as an asphalt binder. This recycling of waste has tangible environmental benefits, but these additives have also been found to improve the durability and strength of the pavements they create.

Road rehabilitation projects also generate spoil, which can be reused as it contains gravels previously used as backfill. Further, the use of River Sand is also slowly gaining acceptance throughout the Lower Mainland. Due to its abundant supply, and subsequently its lower cost, River Sand is recommended for use in lieu of virgin aggregate materials where deemed acceptable by the geotechnical engineer.

Although the recycling of asphalt or concrete is now commonplace, there are preferred uses for this recycled material. Although the use of grindings/millings can be mixed with aggregate to form the road subbase, it is preferred that asphalt materials be reused in paving mixtures in order to recover the energy invested in its original production.[37]

One such process is the use of Foamed Asphalt. This in-place base recycling process introduces cold water and pressurized air into a hot-mix asphalt and combines the resulting froth with a recycled aggregate mix allowing for excellent bonding of the asphalt to the fines. This process eliminates the need for cutback solvents. The mixture requires no curing and the surface is immediately ready for the application of a wearing course. The process can be conducted as part of a single pass train. This method has been found to restore the strength of failing roadways while providing a fast, cost-effective roadway stabilization solution. Discretion must be used however, as research has suggested this process is not appropriate for wet-weather construction.

[36] Rut Mitigation Techniques at Intersections, Infraguide, September 2003
[37] Reuse and Recycling of Road Construction and Maintenance Materials, InfraGuide, 18 Jan. 2005

5.16.3 Maintenance Methodology

Pavements require maintenance. Poorly designed and constructed pavements require an excessive commitment to maintenance and reconstruction. Preventative maintenance involves assessing pavement performance and identifying maintenance problems while they can be addressed on a small scale before they become larger problems. Preventative maintenance is a core component of the Green guidelines because through early identification of maintenance problems, the cost, energy, and disruption are reduced.

The British Columbia Ministry of Transportation publication *Pavement Surface Condition Rating Manual* is a valuable tool in the quantification of pavement surface distress. By assessing various distress types and categorizing them as cracking, surface deformation, or surface defects, a pavement condition rating can be produced to guide maintenance programs in performing priority repairs.

Preventative maintenance of pavement can include one or all of the following: waterproofing; drainage; strengthening; resurfacing; and sealing of joints/cracks. This maintenance can be conducted through any of: spray patching, thin overlays, micro-surfacing; grinding; precision milling; or hot/warm/cold-mix asphalt recycling. A proper Asset Management program will quantify the cost savings of this type of maintenance relative to the full replacement of a failing section. Infraguide's *Timely Preventative Maintenance For Municipal Roads – A Primer* contains additional research on these methodologies.

5.17 EVALUATION OF ROAD, SIDEWALK, AND PAVEMENT ALTERNATIVES

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Cross Section Elements	↑	↓	↑↑↑	↑	↑↑↑
Roundabouts	↑	↑	↑↑↑	↑	↑
Traffic Control Measures	↑↑	↑↑	↑	↑↑	↑
Bikeways	↑	↑			↑↑
Driveways & Laneways	↓	↓	↑↑	↓	
Environmental Clearances	↑	↑	↑↑↑	↓↓	
Pavement Alternatives	↓↓	↓	↑↑↑	↓↓	

6.0 LIGHTING AND SIGNALIZATION

6.1 GENERAL

The Green design alternatives for street lighting and traffic signalization focus primarily on energy conservation, the appropriate application of lighting, and the efficient design of signalization. With every new development that comes on-line, the load placed upon the power distribution network increases, and the impact of signalization upon the traveling public multiplies. Since both streetlights and traffic signals are generally non-metered users of electricity, this results in a constant increase in cost for the local municipalities. However, by investing in energy-efficient lighting and signalization solutions, the rate of increase can be curbed, and lighting and signalization can be part of the solution in creating more sustainable infrastructure.

Lighting is essential to the safe conduct of vehicles and pedestrians in the dark. Studies have confirmed the intuitive assumption that there are a higher proportion of accidents at night, the results of which, including loss of life, damage to person and property, and loss of productivity comes at a huge cost to society. Consequently, the benefits to well-lit throughways are enormous. By providing well-lit roads, intersections, walkways and bikeways, users are afforded a sense of comfort and security in night-time travel.[38]

However, society has reached in impasse between these obvious benefits, and the costs, both financial and environmental, of sustaining enormous lighting infrastructure. With the advent of the Kyoto Protocol, requiring reductions in emissions from polluters such as coal-fired power plants, energy efficiency is now of critical importance. Societies such as International Dark Skies have emerged touting the damage caused by light pollution. The impact on nocturnal environments, reduced visibility of the night sky, and light trespass from neighbouring developments and properties are all emerging issues.

Davit arms and full cut-off fixtures are Green as they direct light to the roadway and reduce spillover and light pollution. This allows for more efficient lighting design, with fewer poles and fixtures required, and minimizes the impact upon the surrounding environment.

In the area of energy efficiency, new materials and techniques are available for energy conservation. However, gaining recognition in the applicable regulations and guidelines and the setting of new standards has not widely occurred yet.

Signalization is undergoing rapid change with the implementation of Intelligent Transportation Systems (ITS) using a wide array of computers, sensors, controls, communications, and

[38] Guide for the Design of Roadway Lighting, TAC, 2005 Edition

electronic devices to save lives, transit time, money, energy, and reduce the environment impact of traffic activities.

6.2 CODES, RULES, STANDARDS AND PERMITS

Although the traditional manuals for lighting and signalization include:

- *Guide for the Design of Roadway Lighting*, 1983, TAC;
- *Illumination of Isolated Rural Intersections*, 2001; and
- *Manual of Uniform Traffic Control Devices for Canada*, TAC, 1998;

The Transportation Association of Canada, (TAC), is currently preparing the *Roadway Lighting Guide*, anticipated for release in August 2005. This manual is widely anticipated to incorporate many Green initiatives for lighting and signalization.

6.3 ROADWAY CLASSIFICATIONS

The requirement for street lighting is significantly impacted by the classification of the roadway it serves. The important variables include the design speed of the road, and the interaction of vehicles with pedestrians using the road.

For example, freeways and expressways do not allow pedestrians and generally not cyclists either. The automobiles using them have headlights. Although their design speeds are higher, requiring a longer sight distances, the lighting requirements are significantly different from areas where pedestrians are likely to be crossing the road with regular frequency. Consideration must be given to the actual lighting requirements of each roadway.

6.4 DESIGN METHODS

In the utilization of any of the appropriate design methods, care must be taken to prevent the over-lighting of roadways. Ultimately, the value of watts/square meter will quantify the amount of light on an area.

6.5 VERIFICATION

Refer to MMCD Design Guideline Manual

6.6 LIGHT SOURCES

As per the Design Guideline Manual, it is noted that High Pressure Sodium lamps are accepted as giving the best lumen/watt ratio. It is also noted that Metal Halide lamps of others may be used on a case-by-case basis. Aside from the environmental issues associated with light pollution, it is important to evaluate the light source decision on a life-cycle costing basis in order to determine the best solution in the long-term.

For example, it is feasible to implement motion sensors on fluorescent lights. It is reasonable that under certain circumstances, particularly in low-use areas, this feature will be the best alternative.

Similarly, Light Emitting Diode, (LED), Edge-Lit Illuminated Signage enhance road safety while reducing energy use by 90%. They also provide a design life of up to 15 years with minimal maintenance, and a high level of clarity and uniform brightness. Many traffic agencies are very receptive to LED technology, having recently benefited from the widespread conversion to LED traffic signals. This new technology is already saving them up to $1,000 annually per intersection, through reduced electricity costs and bulb replacements[39]

6.7 LIGHT LOSS FACTOR

Refer to MMCD Design Guideline Manual

6.8 PAVEMENT SURFACE CLASSIFICATIONS

As discussed in section 5.16.1, the choice of aggregate can have an impact upon the overall colour of the pavement, which impacts its absorption of solar energy resulting in an urban heat island effect. However, colour may also impact the surface reflectance of pavements. Lighter pavements may require less light, hence less electricity.

Further, road lighting is generally required in order to illuminate the pavement markings. With the improvement of pavement markings, through raised pavement marking, post-mounted delineators, and retro-reflective markings, pavement markings can now be illuminated by headlights reducing the need for overhead illumination.

6.9 INTERSECTION LIGHTING

Naturally intersections are the areas where visibility is of paramount importance. The interaction of pedestrians and vehicles necessitates clear sight lines and appropriate stopping distances. Although roundabouts are gaining popularity, their lighting requirements are higher than traditional intersections. In addition, "An unlit roundabout with one or more illuminated approaches can be hazardous. This is because a driver approaching on an unlit approach will be attracted to the illuminated area(s) and may not see the roundabout."[40]

6.10 CALCULATIONS

Refer to MMCD Design Guideline Manual

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[39] A "Good Sign" For Drivers – Carmanah Improves Illuminated Road Signs, Press Release, Carmanah Technologies Corporation, February 1, 2005

[40] Ministry of Transportation and Highways Technical Bulletin, January 2003

6.11 POLES

Refer to MMCD Design Guideline Manual

6.12 LUMINAIRES

Refer to MMCD Design Guideline Manual

6.13 POWER SUPPLY AND DISTRIBUTION

With the rising cost of electricity, the push to phase out greenhouse gas-emitting coal-fired power plants, and limited municipal financial resources, there is an increased push to "reduce electric power usage by providing photovoltaic power for street lighting & signaling"[41] The use of solar-powered LED beacons and other similar technologies is becoming a more viable alternative as the cost and size of solar-power generating tools is reduced. Designers should consider the integration of alternative and Green power supplies for lighting and signalization initiatives.

[41] High Performance Infrastructure Guidelines: Best Practices for the Public Right-of-Way, Design Trust for Public Space

7.0 EVALUATION & IMPLEMENTATION STRATEGIES

7.1 GENERAL

The Green design alternatives are intended for the Design Professional to consider in the context of proven, effective and economical design guidelines. In many circumstances, a specific issue for concern will promote consideration of innovative infrastructure strategies

The following tabulation is ordered in terms of ease of implementation. It is intended as a starting point for the Design Professional who wants to address Sustainable Development issues within the design of infrastructure, but with minimum risk to safety and economics. Many Green alternatives have negligible risks and low implementation costs. However, other techniques remain at the "pilot project" stage. Insufficient data is available to forecast long term effects. As a result, as experience is accumulated with these Green design alternatives, more substantial evaluation will be introduced, based on the input of local governments actually employing such measures over a period of time.

7.2 CLASSIFICATION

Table 7.1 contains Green design alternatives with negligible risk, as indicated by

- Favourable experience in the field
- Scope of potential effects
- No obvious maintenance or replacement factors

Table 7.2 contains Green design alternatives with moderate risk, as indicated by

- Significant initial cost implications
- Limited or no experience in the field to date
- Scope of potential effects include reliability and maintainability concerns
- Unknown life cycle costs

Table 7.3 contains Green design alternatives with significant risk, as indicated by

- Significant initial cost implications
- Limited or no experience in the field
- Scope of potential effects affects public safety and/or private property
- Significant maintenance or replacement issues
- Unknown life cycle costs

Table 7.1 GREEN DESIGN ALTERNATIVES WITH NEGLIGABLE RISK

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Reduced Site Disturbance	↑	↓↓		↓↓	
Site Material Re-cycling	↑	↓↓	↓	↑	
Subsurface Utility Engineering	↓	↓↓↓		↓↓	
Common Trenching	↑	↓↓	↓		
Promote Utility Coordination	↑	↓↓↓		↓↓	
Employ Trenchless Technology	↓↓		↓		
Backflow Prevention	↑		↑	↓↓	
Reduced Site/ Lot Grading			↑↑	↓	↑↑
Pollution Prevention	↑		↑	↓	
Source Controls	↑	↑	↑↑	↓	
On-Site Controls	↑↑	↑↑	↓	↓	↑↑
Conveyance Controls	↑	↑	↑↑↑	↓↓↓	↑↑
End of Pipe Measures	↑↑	↓↓	↑↑	↓↓	
Cross Section Elements	↑	↓	↑↑↑	↑	↑↑↑
Traffic Control	↑↑	↑↑	↑	↑↑	↑

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Measures					
Bikeways	↑	↑			↑↑
Driveways & Laneways	↓	↓	↑↑	↓	
Environmental Clearances	↑	↑	↑↑↑	↓↓	
Pavement Alternatives	↓↓	↓	↑↑↑	↓↓	

Table 7.2 GREEN DESIGN ALTERNATIVES WITH MODERATE RISK

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Adjust San. Peaking Factor			↑↑	↓	
Infiltration & Inflow Control	↑	↓↓↓	↑↑	↓↓	
Adjusting Per Capita Water Demand			↑↑	↓↓↓	
Non-Residential Demand			↑↑	↓↓↓	
Fire Flows			↑↑↑		
Water Pressure	↑↑	↑	↑↑↑↑	↓↓↓↓	
Maintenance Practices	↑↑		↑↑↑↑	↓↓	
Adjust San. Per Capita Flow			↑↑	↓	

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Odour Control	↑↑	↑	↑↑	↓↓	
Run Off Modelling	↑↑		↑↑↑	↓↓	↑↑
Rainfall Data	↑↑↑↑		↑	↓	
Roundabouts	↑	↑	↑↑↑	↑	↑

Table 7.3 GREEN DESIGN ALTERNATIVES WITH SIGNIFICANT RISK

Green Practice	Initial Cost	Life Cycle Cost	Performance Reliability	Risk Of Failure	Scalability & Integration
Life Cycle Costing	↑↑	↓↓↓↓	↑↑↑↑	↓↓↓	↑↑↑
Universal Metering	↑↑↑	↑↑	↓	↓↓↓	↑
Greywater Systems	↑↑	↓↓↓↓		↑	↑
Alternative Collection Systems	↓↓	↓↓	↑↑	↓	↑↑↑
De-Centralized Treatment Facilities	↓↓	↑	↓	↑↑	↑
Wastewater By-products	↑↑↑	↓↓↓↓	↑↑	↑	↑
Integrated SWM Plan	↑↑↑	↓↓	↑↑↑↑	↓↓↓	↑