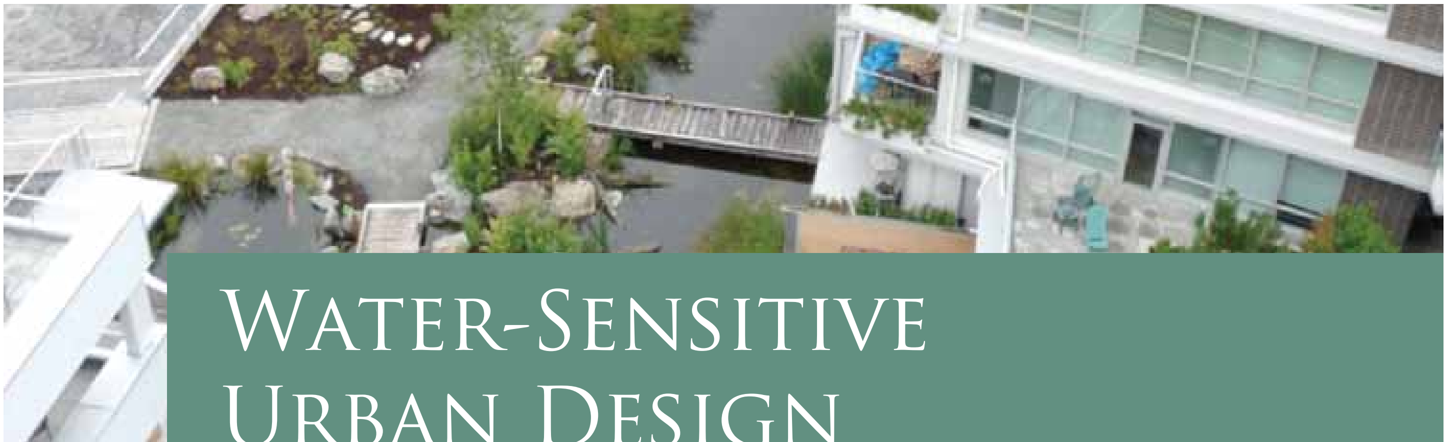

Water-Sensitive Urban Design

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Learning objectives

One of the greatest challenges facing architects and planners today is the urgent need to design sustainable neighbourhoods, communities and, on a larger scale, cities in order to lower operating costs and create more livable spaces. While there is no specific template to follow, design teams responding to the challenge have adopted a number of universal design principles. One of the key elements of sustainable design is effective water management that mimics the natural hydrological cycle. This typically results in more greenspace, higher property values and better return on investment for the client.[1] The tools and techniques that are used to achieve this goal are commonly referred to as Water-Sensitive Urban Design (WSUD).

This article focuses on the rationale for, and techniques to address, WSUD, with particular attention paid to case studies and real, working examples, and solutions. It also includes examples of how water and energy management can be better integrated, which can substantially enhance the value (for example, increased revenue, lower operating costs, reduced permitting time, reduced GHGs) and effectiveness of design compared to managing each aspect in isolation of the other. Sources of specific Best Management Practices (BMP*[2]) information can be found at the end of the article.

After studying this article, readers will be able to:

1) identify need for and benefits of WSUD;
2) identify the characteristics of a healthy watershed* vs. an unhealthy watershed;
3) identify key principles of Water-Sensitive Urban Design (WSUD);
4) identify characteristics of WSUD vs. traditional design;
5) understand the value of WSUD in protecting and regenerating watershed health and reducing infrastructure costs;
6) understand who needs to be involved in an integrated design team if water-related aspects of sustainable community design are to be well-managed;
7) identify ways that WSUD can help neighbourhoods, communities, towns and cities address reductions in GHGs*, and adapt to a changing climate;
8) demonstrate awareness of the legal and regulatory issues associated with WSUD and how to address them;
9) incorporate WSUD principles into their work; and
10) locate and access resources and tools to support Water-Sensitive Urban Design.

[1] Barraclough, C.L. and D.H. Hegg. 2008. Nature's Revenue Streams: Five Ecological Value Case Studies. Prepared for CMHC. Report 66590. http://www.cmhc.ca/en/inpr/su/waho/waho_004.cfm

[2] Refer to Glossary for terms marked with an asterix (*)

This article is organized in nine sections:

1) Introduction – what are the issues?
2) Water-Sensitive Urban Design – what is it and why should we do it?
3) Watershed health – what makes a watershed healthy?
4) Watershed health – the role of good planning and design
5) The principles of WSUD – case studies and examples
6) The value of WSUD to the owner and the community
7) Integrating water and energy management
8) Legal and regulatory issues and how to manage them
9) Checklist of WSUD principles – what have we missed?

Introduction – what are the issues?

Canada is blessed with nearly 25 per cent of the world's freshwater. Unfortunately, it is a resource that can be taken for granted, and, in some cases, badly undervalued. Faced with growing summer water shortages, drinking water quality concerns, flooding, dried up urban streams, loss of green space and decaying municipal infrastructure, many communities are being forced to rethink their approach to water.

The traditional engineering and public health water management approach considered only four types of water and categorized them as to whether they were beneficial or not: drinking water and rainwater (beneficial) vs. wastewater* and stormwater* (problems to be eliminated). For centuries, water has been managed using an open-ended approach where water is used only once and then disposed of. This is in contrast to nature, which uses closed-loop systems that are based upon microrecycling of water as the foundation of the hydrological cycle. As more and more people move into large urban centres, far removed from natural water supplies, the cost of providing water and treating water increases. At the same time, a changing climate is making the supply of water less reliable. It is therefore essential to manage water within cities as efficiently as possible and to reuse water many times before discharging it to be cleaned and used again. One of the most effective means of accomplishing this is to work with natural cycles and take advantage of natural ecological processes to capture, store, purify and release water.

Water-Sensitive Urban Design – what is it and why should we do it?

Water-Sensitive Urban Design (WSUD) is an approach to water management in urban areas, first made popular in Australia due to serious water problems there. It has since been adopted around the world and been expanded to include not just stormwater* management, but all aspects of the water cycle including rainwater, snowmelt, wastewater (including blackwater* and greywater*) and drinking water, in addition to natural freshwater systems. Its widespread adoption may be due, in part, to the value WSUD provides to both the developer and the community. For example, the costs of treating and delivering water are growing; by harvesting rainwater on site or reclaiming and reusing stormwater and wastewater for non-potable purposes, the amount of expensive drinking water required by a development is reduced. Similarly, in drought-prone or water-limited areas, planning to use water that is "fit for its purpose" (that is, drinking water for drinking and cooking, rainwater or reclaimed water for toilet flushing and irrigation) may be the only way to secure enough water to build the project in the first place.

The objective of WSUD is to *maintain or replicate the pre-development water cycle through the use of design techniques to create a functionally equivalent hydrological landscape.*[3] When urban development occurs, large surfaces (roads, rooftops, sidewalks) are made impermeable. Stormwater runoff from individual properties and roads intensifies, flows increase and potential contaminants from residential and commercial activity and vehicle use flow into the streams and watercourses. Traditionally, stormwater generated from urban areas is conveyed efficiently to piped drainage systems to reduce stormwater ponding and flooding

[3] Upper Parramatta River Catchment Trust. May 2004. Water Sensitive Urban Design. Technical Guidelines for Western Sydney. Australia. ISBN 0 7347 6114 7

risk to roads and properties. The effect of this type of water management approach on natural systems has included:

- the intensification of flows in watercourses potentially resulting in stream bank erosion and sedimentation;
- a reduction in groundwater recharge;
- contamination of streams with oil, grease, brake dust and toxic substances that have an adverse effect on water quality and aquatic ecosystems;
- an increase in the use of potable* water for domestic, commercial/industrial uses as well as outdoor irrigation of gardens and open space areas; and
- more severe flooding and increased areas of flooding due to the increased volume of runoff.

WSUD is the integration of various Best Management Practices (BMPs) for the sustainable management of the urban water cycle. WSUD is concerned with the design of urban environments to be more "sustainable" by limiting the negative impacts of urban development on the total urban water cycle (Figure 1). Therefore WSUD is about:[4]

- trying to more closely match the post-development runoff regime with the pre-development runoff regime, in both quality and quantity;
- reducing the amount of water transported between watersheds, both in water supply import and wastewater export by reducing consumption and reusing treated effluent;
- optimizing the use of rainwater that falls on urban areas;
- minimizing impacts on existing natural features and ecological processes;
- protecting water quality and quantity of surface and ground waters;
- improving the quality of, and minimizing, polluted water discharges to the natural environment;
- incorporating collection, treatment and/or reuse of runoff, including roof water and other rainwater;
- increasing social amenities in urban areas through multi-purpose green space;
- landscaping and integrating water into the landscape to enhance visual, social, cultural and ecological values;
- adding value while minimizing development costs (for example, drainage infrastructure costs);
- accounting for the intersection between water use and wider social and resource issues; and
- harmonizing water cycle practices across and within the institutions responsible for waterway health, flood management, pollution prevention and protection of social amenities.

The motivation behind WSUD is to integrate urban design with natural ecological processes to aid in the protection and conservation of water and add value to the development and community.

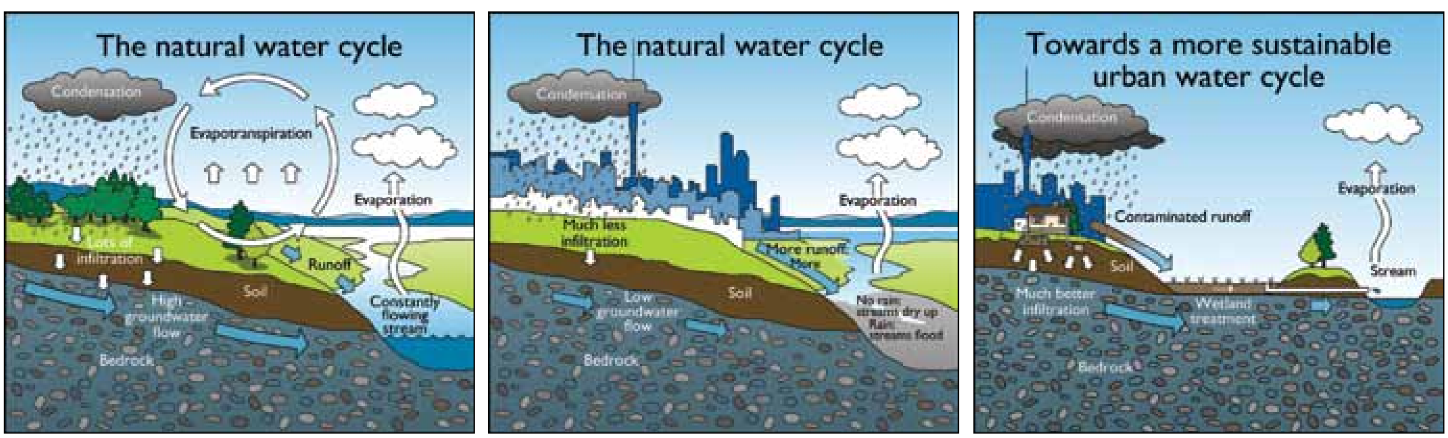

Figure 1 – The Natural Water Cycle, The Urban Water Cycle and a More Sustainable Urban Water Cycle © Auckland Council 2011 (http://www.aucklandcity.govt.nz/council/services/stormwater/about.asp). Used with permission.

[4] Australian Government National Water Commission. http://www.environment.gov.au/water/publications/urban/water-sensitive-design-national-guide.html

Watershed health – what makes a watershed healthy?

If the role of WSUD is to keep watersheds and watercourses healthy, one must first define watershed "health." We typically think of all the things we want from a watershed or stream, and if we can obtain those values or goods, then we believe the watershed to be healthy. For example, as long as we can draw clean water, catch edible fish, and swim in a creek, then it must be "healthy." Unfortunately, this type of value-driven thinking often causes us to forget about the processes and attributes that generate those values in the first place. Those processes include the ability of the stream to maintain adequate flows year-round, dissipate energy without undergoing undue erosion, have adequate riparian* vegetation to shade the stream, filter sediment, transpire water and stabilize stream banks, and be able to develop diverse channel characteristics to provide the water depth, duration and temperature necessary for fish production, waterfowl breeding and other habitat requirements. When a stream has all these characteristics, it is very resilient and is able to respond to extreme events without significant damage. This is called "proper functioning condition" or PFC.[5] A stream or watershed that is functional is then able to provide many goods and services that support people, including clean plentiful drinking water, attenuation of flood flows, attractive green spaces, clean air, forage for livestock, and healthy fish and wildlife populations. It is also more resilient to extreme weather events such as severe rainstorms and drought.

For architects, planners and other design professionals, the implications of this definition of stream health are significant. In order to dissipate energy, a stream needs room to move and should therefore not be channelized or confined; the stream's floodplain must be protected; the banks should be well-vegetated with native species and not reduced to grass or rip-rap; rainwater must be allowed to slowly soak into the ground and not quickly runoff and overload the stream; wetlands* must be preserved for both their hydrological attributes and their ability to filter and purify water; and groundwater must be recharged to allow streams and wells to flow year-round, even in dry summer months. Even on sites where no stream is present, the runoff from that site will ultimately enter a receiving stream or the ocean. In each case, preserving or mimicking the natural hydrological patterns is necessary to protect downstream receiving environments. This is not to say that development cannot take place. Indeed development can restore damaged ecosystems, but it must be undertaken with a view to working with nature, rather than against it.

Paradoxically, the same conditions that give rise to low groundwater tables and dried up streams in urban environments, also give rise to flooding. Conventional engineering practice has been to straighten creeks and remove the riparian vegetation that slows water down in an attempt to get water off the land and alleviate flooding. This is exactly the opposite of what nature does, which is to keep water on the land as long as possible. Streambanks have a marvelous capacity to absorb and hold water, and to slowly release it during summer months. Those streambanks require the roots of healthy trees, shrubs and other vegetation to hold the soil together. At the same time, the vegetation takes up water and releases water vapour to the atmosphere, thus cooling the surrounding area. When a stream can access its floodplain, the flow slows, sediment drops out to rebuild soils, and water is cleansed as it percolates through the soil into the groundwater to reappear many months or years later as baseflow in a stream. The longer that water stays on the land, the more constant the flow, *the lower the risk of extreme flood events* and the cleaner the water in the stream.[6]

[5] Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, and J. Staats. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. TR 1737-15. Bureau of Land Management, BLM/RS/ST-98/001+1737, National Applied Resource Sciences Center, Denver, CO. 126 pp.

[6] Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, and J. Staats. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. TR 1737-15. Bureau of Land Management, BLM/RS/ST-98/001+1737, National Applied Resource Sciences Center, Denver, CO. 126 pp.

Watershed health – the role of good planning and design

Planners and designers (including architects, ecologists, engineers, landscape architects and others) have the ability to profoundly influence watershed health. Water is often seen as the domain of the "roads and drains" department of a municipality or as the pervue of stormwater engineers on a development project; rarely are architects or planners involved. Water supply and sewage disposal are also typically the exclusive domain of engineers. In fact, water touches every aspect of design, and the entire design team needs to be involved if water management is to be truly integrated.

Take the example of a medium-density, multi-family development in an urban setting. Let us assume that zoning, and therefore prescribed density, is already in place. Conventional design would see a civil engineering team design roads, utilities and "drainage" for the site. A water supply, likely piped municipal water, would often be assumed, as would connection to a sewer main. The source of the potable water and the fate of the wastewater would not be a significant consideration. Density would be pre-determined by zoning and other municipal regulations. Runoff from roads, sidewalks and buildings would be conveyed to the nearest waterbody via pipes and drains. The architectural team would design the buildings and the landscape architects would design the plantings to beautify the site. While an oversimplification, this design process is common.

By comparison, a WSUD approach would start by looking at the site in the context of the watershed and ask a series of questions:

- What was the historical ecological status of the site? Was it forested? Was it a wetland? How much water naturally ran off the site vs. infiltrated the soil? What can be done during the design process to keep the site as natural as possible and/or return the site to a similar hydrological condition?[7]
- How much water (rain and snow) falls on the site in a normal year? What are the predicted changes in rainfall or snowfall under the scenario of a changing climate? What measures need to be taken to account for this?
- Where does the potable water* come from? Is there adequate supply to support the development and also meet in-stream ecological needs of the watershed? Is the density appropriate in this context? Design teams must remember that the health of neighbouring watersheds (for example, water supply watersheds and wastewater receiving watersheds) can also be affected by their development.
- Where will stormwater runoff go? What can be done to reduce runoff, infiltrate rainwater and reduce downstream erosion? Are green roofs appropriate? Can bioswales or other Best Management Practices (BMPs) be used to treat and convey water? Can porous paving* be used to reduce runoff?
- Where will treated wastewater go? Can an opportunity be created to treat and reuse this water for non-potable purposes? Can this help reduce demand on the potable water system? Can this project be linked to neighbouring developments to obtain an economy of scale?
- Can rainwater be captured on site for non-potable uses such as toilet flushing and irrigation? Are there off-site uses for this water?
- What are all the ways water is being used or moved on site? Is water used for cooling (for example, in air conditioners)? Are wet soils needed to support pilings under buildings? What quality of water is needed for each use?
- What is the function of the landscaping? How can it help or hinder water management, including water quality?
- What is the overall value (economic, ecological, social) of implementing these measures?

Note that all of these questions need to be asked before any infrastructure is designed or built. The answers will directly affect the size of piping, layout and surfacing of the roads, design of buildings, elevation of buildings (flood risk), nature of the landscaping and even the density of the development. The role of the ecologist, as part of the integrated team, is to put the site in its watershed context and to keep the evolving site and building design consistent with that context. The following case studies provide examples of WSUD at different scales and at different stages of the planning and construction process.

[7] See the Water Balance Model, available on the Water Bucket website at www.waterbucket.ca.

The principles of WSUD – case studies and examples

Suburban

Willowbrook Subdivision Saanich, B.C.

Willowbrook Subdivision was developed by Cadillac Homes Ltd. and is an urban infill development of 31 single-family detached residences on former agricultural land (Figure 2). It is partially within the 200-year floodplain for Swan Creek, which had previously been ditched to drain the land and allow farming. As part of the development project, Swan Creek was upgraded from an agricultural drainage ditch, relocated and rehabilitated through the site (with 17 per cent of the property dedicated to Saanich as parkland), and added to a neighbouring linear park. Six wetland ponds were created to manage stormwater, extend wildlife corridors, connect local public walking trails and provide habitat. Approximately 750 metres of fish-bearing creek was restored to conditions similar to the 1930s before urban development. A sewer right-of-way was used as a space to provide additional wetland stormwater treatment and to construct a walking trail–thus adding functionality to otherwise unused space and retaining full access for repair and maintenance. In exchange for the dedication of 17 per cent of the land base to accommodate the creek restoration and wetland ponds, the municipality granted smaller lots and higher density on the site.

Hydrological requirements were established and the 200-year floodplain determined by hydrological modelling of the flows in Swan Creek. This approach was essential to address due diligence with regard to flooding both up and downstream. The design of the urban stormwater treatment ponds and wetlands was based on the Proper Functioning Condition (PFC) criteria, and used to define how the subdivision and road layout would be developed given the need to keep water on the land as long as possible and allow it to infiltrate into groundwater. The design also addressed public safety issues, wildlife habitat requirements plus aesthetic and recreational benefits to the new park.

Support for an ecological approach was so strong that permits from all the regulatory authorities were obtained in less than two months. During the period when this project was undertaken, the traditional permitting process on projects involving riparian and floodplain regulations was often in the order of two (2) years. Permit processes requiring Department of Fisheries and Oceans (DFO) approvals due to working in or around fish habitat or fish bearing streams could take up to three (3) years to obtain. According to the developer, the expedited approach saved him enough money in borrowing costs on the land to pay for the stream restoration program whose cost was in the order of $120,000. By choosing to develop the property in conjunction with the stream

Figure 2 – Willowbrook Subdivision shortly after completion in 2001 (left) and in 2008 (right). The stormwater wetlands and creek are at the left of the photos. The trail is very popular both for recreation and bicycle commuting. Photos courtesy of Aqua-Tex Scientific.

restoration and stormwater treatment, the developer was able to expedite approvals and start construction in 63 days.

Working closely with the regulatory agencies enabled a relaxation of building setback requirements. As portions of the site were within the 200-year floodplain, careful design allowed some mitigation of setback requirements for buildings by constructing the habitable floor areas of the homes above the level required by statute. Thus some foundations are within the 200-year floodplain boundary, but the "habitable space" is not, so the project complied with the building code. This permitted the retention of the allowable number of housing units to enhance viability of the project.

Due to the proximity to Swan Creek, municipal bylaws required a stormwater management system that would control discharge into the creek. A conventional solution would have been to construct a stormwater holding tank under the street with a pump system, at a cost estimated at $260,000 to $300,000. Although expensive, it would not have achieved the same degree of particulate and contaminant treatment achieved through the ecological method. It would also have failed to contribute to the habitat or visual amenity of the community, since the creek would not have been restored.

One of the important benefits of the project was the conversion of a single-purpose sewer line corridor into an upgraded proper functioning wetland and linked neighbourhood trail system, thus adding functionality to otherwise unused space and retaining full access for repair and maintenance. This added bird and wildlife habitat at developer cost, and improved a public right-of-way in a way that benefited the community and increased the value of the development. It also provided park space, recreation, and habitat, as well as stormwater management in a single corridor and treated runoff from both the new and existing subdivisions next door. This is an example of "stacking" functions, by using a single area of land to serve multiple purposes, in the same way that nature does.

Urban high density

Dockside Green (www.docksidegreen.com)

Dockside Green is a 15-acre master planned LEED™ platinum community on a former brownfield site in the heart of Victoria, B.C.[8] Dockside's design team rejected conventional water management practices by adopting a "fit-for-purpose" approach to water use. Water enters the site two ways: in pipes from the local drinking water reservoir, and directly through rainfall. Piped water is first used for potable purposes such as drinking, cooking and bathing. High-performance water fixtures and appliances including water-efficient dishwashers, washing machines, dual-flush toilets, and faucets and showers that save water, reduce potable water consumption by 65 per cent over traditional developments. Wastewater for the entire development is collected and treated on site using a membrane bioreactor to a level of treatment fit for unrestricted public access. The treated, reclaimed water is then reused as many times as possible for non-potable purposes including toilet flushing, landscape irrigation, irrigation of balcony planters, rooftop gardens, and water supply for a man-made stream channel. Annually, the volume of reclaimed water that is

Figure 3 – Dockside Green waterway and path is attractive even in the early winter. Photo courtesy of Aqua-Tex Scientific.

[8] www.docksidegreen.com

collected and reused is equivalent to one day's consumption for the entire Greater Victoria region (pop. 300,000) on the driest day of the year. Consequently, recycling water in this one development has created a benefit to the entire region.

The Dockside Green site was designed to mimic the natural hydrological cycle. Rainwater is intercepted, stored and used on site. Rainwater is captured and filtered by green roofs, bioswales and cisterns, and stored in the waterway for final polishing. Water is celebrated on the site through design. It is visible pouring from the open downspouts, splashing over mini-waterfalls instead of stormwater pipes, burbling down the man-made stream that runs the length of the site and soaking into raingardens that are landscaped with native plants. Making water infrastructure visible has proven to be very successful at Dockside Green. The man-made creek is the centre-piece of the development and acts as a barrier between public and private spaces, provides an educational opportunity, a play place for children, and habitat for local wildlife including ducks, crayfish, Great Blue Herons and river otters (Figure 4).

Information signs line the greenway and models of the reclaimed water system can be found inside the buildings. Most importantly, the wastewater treatment plant is not at the margins of the development or the city–it is located central to the development and adjacent to an outdoor public patio that is a popular year-round space. This provides an excellent educational opportunity against the typical "NIMBYism" that plagues many projects wishing to treat waste and reuse resources on site.

Figure 4 – An aerial view of the Dockside Green waterway and green roofs. Photo courtesy of Aqua-Tex Scientific.

Obtaining permission to treat wastewater on site was an arduous process for the Dockside project. The Liquid Waste Management Plan (LWMP) for the Capital Regional District prohibited it. In order for it to be approved, Dockside had to provide a backup system—in this case the backup is a permanent, but closed, connection to the city sewer system in the event that the treatment plant fails. Dockside was able to negotiate an exemption from the LWMP, and an exemption for its residents from the local sewer charge. While the residents bear the cost of the treatment plant, they benefit from lower water bills because they use reclaimed water for most non-potable purposes. When the Capital Regional District's member municipalities raise taxes to pay for the new proposed regional sewage treatment plan, Dockside's residents will be exempt from the increase. In the future, there is also the potential to sell reclaimed water to neighbouring users.

South East False Creek (www.thechallengeseries.ca)

The Vancouver 2010 Olympic Village at South East False Creek (SEFC) is an innovative development built on a brownfield site historically contaminated by heavy industry. Using sustainable planning practices, SEFC was designed to "acknowledge social, economic, and cultural values alongside a deep respect for the environment."[9] Managing both freshwater and marine water as a valuable resource and reducing potable water use were fundamental WSUD principles

[9] The Challenge Series. 2009. http://www.thechallengeseries.ca/wp/wp-content/uploads/2009/05/tcs01_booklet.pdf

incorporated into the design process. The private development portion of the project is named “Millennium Water,” underscoring the value of rainwater management, domestic water management, ecosystem function, and ecosystem regeneration (particularly on the marine foreshore). Some of the key WSUD features include:[10]

- Water is celebrated through design. Wherever possible water is made visible to the public rather than buried in pipes and infrastructure is designed as an amenity. For example, the Hinge Park Wetland serves a dual purpose as public green space and treatment for runoff before it enters the marine environment (False Creek).
- Rainwater is captured on roofs that are designed to collect water for rooftop gardening, while the overflow goes to cisterns. Fifty per cent of roofs are vegetated.
- Intensive green roofs with 20 cm of soil mitigate heat island effects, are energy efficient, create habitat and social benefits, and provide rainwater management.
- Rainwater is captured and stored in cisterns to be used for toilet flushing in the winter months, allowing drinking water to remain in the city reservoir (“water banking”*).
- Soil sensors and weather stations are integrated into the irrigation system to supply water based on plant needs.
- Heat recovery from sewage is used to preheat water for domestic use.
- One kilometre of formerly contaminated marine shoreline was rehabilitated, including a newly constructed habitat island that is not accessible to the public. After an 80-year absence, herring have returned to spawn. Waterfowl and eagles now nest in the perch trees on the new island (Figure 5).

One of the greatest design challenges to the project was an imperative from the City of Vancouver that did not allow for potable water to be used for irrigation. Vancouver’s rainfall pattern is very challenging when it comes to rainwater capture. Most of the rain falls in the winter when the water is not needed for irrigation, but in the summer months the rainfall is extremely low. That meant that in order to use captured rainwater for irrigation, the cisterns would need to be huge because all the water would need to be captured in winter and then stored until needed in the spring. Both the cost and the space required were prohibitive. Furthermore, in the event of an extreme drought, there would not be adequate rainwater to sustain the landscape plants unless potable water could be used for irrigation. In order to solve the problem the ecology team looked beyond the site and developed the concept of “water banking.”*

In a water banking approach, rainwater is captured in basement cisterns and used for toilet flushing and irrigation. The continual collection and use of rainwater throughout the year provides a 40-per-cent reduction in total water demand that the Village places on the municipal reservoir—a far superior

Figure 5 – The new habitat island at South East False Creek. Herring have returned to spawn in this marine environment after an 80-year absence. Photo courtesy of Roger Bayley Inc.

[10] The Challenge Series 2009. http://www.thechallengeseries.ca/wp/wp-content/uploads/2009/11/tcs06_booklet.pdf

conservation performance than if the rainwater were used solely for irrigation (Figure 6). For every cubic metre of water captured, an equivalent volume is "banked" in the city's drinking water reservoir. When summer rains end and the cistern is dry, the drinking water can be withdrawn from the "bank" in the reservoir, because the development has not put a strain on the reservoir during the rest of the year like everyone else has.

College of the Desert Palm Springs, CA

The College of the Desert (CoD) in Palm Springs, California, is developing a brand new 119-acre college campus in one of the driest places in the country. It broke new ground in planning by first developing a set of Integrated Sustainability Guidelines for the development of the West Valley Campus, long before any site planning was completed or buildings were designed.[12] Since water is in such short supply, it was a key focus of the Guidelines. The Guidelines reveal the connections between community, campus, and buildings over a broad range of themes. Furthermore, they provide a framework and serve as a manual for campus planners, administrators, architects, engineers, ecologists, and stakeholders to develop, implement, and measure sustainability as the campus is built out over many years.

The overarching goals of the Integrated Sustainability Guidelines are zero waste, sustainable hydrology, net-zero energy, carbon-neutral campus, and ecological restoration. Green buildings and green infrastructure must fit into the local and site-specific context. Principles of sustainability are arranged by thirteen themes over the community, campus, and building scales. All themes are addressed in the Integrated Sustainability Guidelines at the appropriate level of detail at each scale. The thirteen themes are education, policy and governance, social, economics, ecology, water, energy, waste, transportation, greenhouse gases, health and wellness, agriculture and food, and materials (Figure 7).

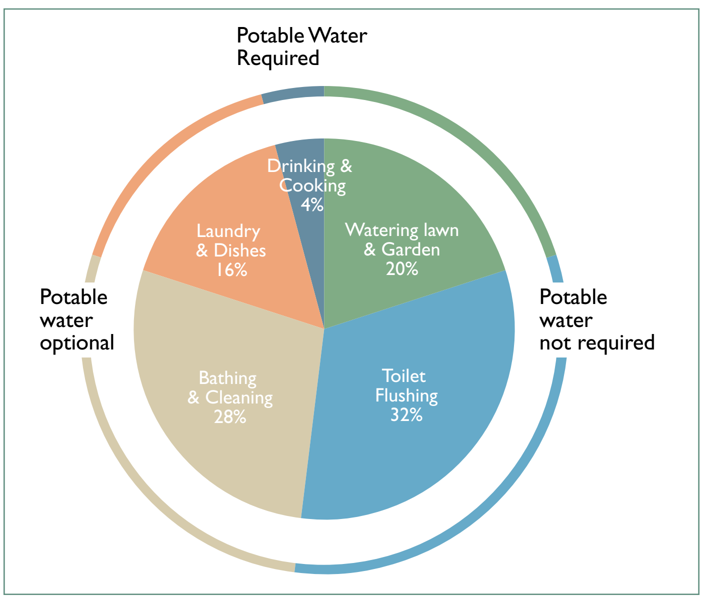

Figure 6 – Water use by residents of Greater Vancouver. Toilet flushing and irrigation are two of the heaviest demands on municipal water supplies. Using rainwater for these activities contributes to the Olympic Village's 40-per-cent reduction in standard potable water use (figure from The Challenge Series, 2009, with permission of Roger Bayley Inc.)[11]

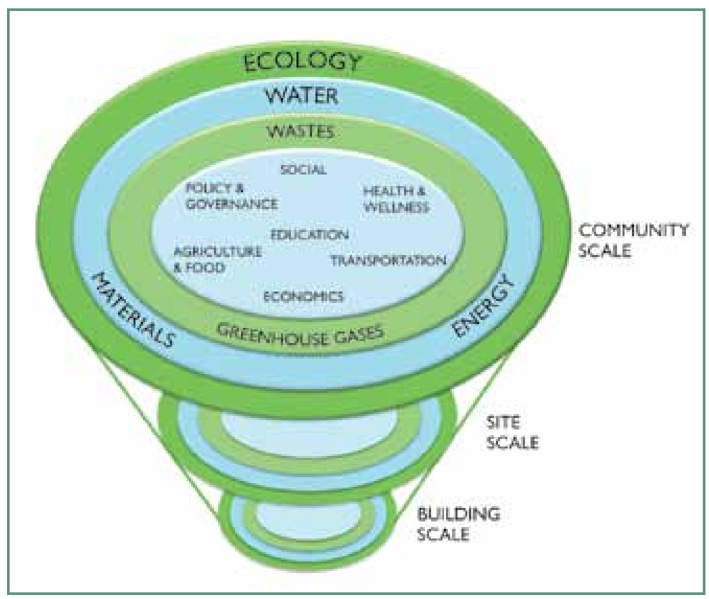

Figure 7 – Representation of the thirteen themes at three scales as set out in the College of the Desert's Integrated Sustainability Guidelines with permission of Stone Environmental, © 2010.

[11] The Challenge Series. 2009. http://www.thechallengeseries.ca/wp/wp-content/uploads/2009/05/tcs01_booklet.pdf

[12] Stone Environmental Inc., Aqua-Tex Scientific Consulting Ltd., Farallon Consultants, Cobalt Engineering LLP and Terence Williams Architect. 2010. Integrated Sustainability Guidelines for the West Valley Campus, College of the Desert, Palm Springs, CA.

The Integrated Sustainability Guidelines were further refined into a set of Performance Targets.[13] These targets are now being used in the design of two buildings representing the first phase of development.

This project is an example of how WSUD can be incorporated into the earliest planning stages of a project. By setting standards and targets in advance, the design team can use its creative abilities to achieve those targets without having to adhere to rigid, prescriptive design directives.

The value of WSUD to the owner and the community

WSUD has direct economic and social benefits in addition to the ecological ones. For example, the value of managing rainwater using ecological, rather than engineered, methods has been extensively documented in the CMHC publications "Ecologically Engineered Stormwater Management—Five Case Studies" and "Assessment of Ecologically Engineered Stormwater Management" published in 2009 (product no. 66599). The five case studies examined were all located within the Colquitz River watershed in Saanich, British Columbia: 1) the relocation and restoration of Blenkinsop Creek on the Galey Farm 2) Swan Creek restoration

The Performance Targets that relate directly to WSUD are:
Reduce potable water use by 50% over baseline campus conditions (per capita).
Use recycled water for non-potable uses.
Incorporate a greywater reuse system in campus design.
Incorporate vegetated roofs in campus design (appropriate to a desert climate).
Include rainwater harvesting and utilization of rainwater on campus.
Conserve outdoor water use through use of native vegetation and xeriscaping.
Utilize excess non-potable water for aquifer recharge.
Ensure >80% of wastewater generated on campus receives tertiary treatment.
Effective impervious area is a maximum of 10% of campus footprint.

The Performance Targets also suggested strategies and technologies that the design team could use to meet the Targets at the building, campus and community scales. Some selected examples of those suggestions are:
Dual plumb the water supply to all toilets.
Dual plumb the building sewers to separate wash basins, showers, drinking fountains, and laundry washers for greywater reuse.
Install extremely low water use composting and/or incinerator toilets (easiest to maintain and use). Begin at maintenance building or targeted building for worker/targeted feedback and social acceptance. Provide worker training.
Prohibit pre-rinse at dishwashers. Use installed vacuum plate scraper instead of pre-rinse for dishwashers.
Prohibit meat thawing under running water. Provide space for meat thawing in refrigerator.
Use high water-efficiency commercial dishwashers and sanitizers.
Provide a Best Management Practices manual for the kitchens. Institute a new-employee training that includes why each of the water reduction practices is necessary.
Use water brooms instead of hoses and nozzles to clean kitchen facilities.
Provide one or more greywater reuse treatment systems.
Install a purple pipe network to take advantage of future recycled water use.
Design locations for future onsite wastewater reclamation and reuse possibilities.
Develop a water budget for landscape irrigation.
Reduce/eliminate long-life pesticides. Use such pesticides during dry weather only. (Avoids polluting stormwater and limiting its reuse value, allowing safe use of rainwater).
Where larger flows are anticipated, install underground cisterns for rainwater capture. Integrate this water supply into the irrigation system. Accommodate run-on from other neighbouring properties into this scheme.
Sell reusable water bottles (non-plastic). Provide filling stations (drinking water fountains with water filtered on campus). Connect drainage from filling stations to greywater recycling system.

[13] Stone Environmental Inc., Aqua-Tex Scientific Consulting Ltd., Farallon Consultants, and Cobalt Engineering LLP. 2010. Performance Targets for an Integrated Design Campus Plan. College of the Desert, Palm Springs, CA.

and wetland construction within the Willowbrook Subdivision 3) stream restoration within the South Valley Subdivision 4) wetland construction adjacent to the Rogers Farm Subdivision and 5) permeable paving and swale/wetland construction at the Vancouver Island Technology Park. In every case, it was found that ecological stormwater systems could offset infrastructure costs, reduce the environmental impact of the development and lessen the chances of downstream flooding. Other benefits included faster regulatory approvals and reduced carrying costs, faster home sales, more attractive neighbourhoods, reduced operation and maintenance costs for the municipality, significant increases in bird populations and other wildlife, and improved water quality.

Analysis for Willowbrook Subdivision, discussed in the case studies above, shows a net benefit of $965,000 to the developer and $60,832 to the municipality from using green infrastructure for water management rather than conventional tanks and pipes (Table 1).[14]

While not immediately obvious, there are also secondary benefits to WSUD. When developments are designed with the natural hydrological cycle in mind, they tend to have more green space and more vegetation. This reduces the urban heat island effect, reduces cooling costs, improves air quality, and improves human health and mental well-being. This in turn translates into higher worker productivity, better learning in schools, and faster healing amongst patients in hospital. Current research shows that green space reduces stress and benefits people with coronary heart disease, depression and anxiety, diabetes, migraine, and many other illnesses.[15] In recent years, researchers have attempted to quantify the economic value of nature (often called natural capital). A recent study of the Greater Vancouver area showed that the top three benefit values from the area's ecosystems were climate regulation ($1.7 billion per year), water supply ($1.6 billion) and flood protection/water regulation ($1.2 billion).[16] A similar study for Ontario's Greenbelt showed that the Greenbelt provides $2.7 billion worth of ecological services including water filtration, flood control, climate stabilization, waste treatment, wildlife habitat and recreation.[17]

Integrating water and energy management

When we turn on the tap, few people stop to consider the energy required to obtain clean water, or the cost of treating the water once it becomes wastewater. Before water reaches the tap, it must be captured in a reservoir, often filtered, certainly disinfected and then pumped to its final point of consumption where it is stored, and often heated before use. Once wastewater leaves the building it is

Willowbrook (Traditional)	Municipality	Developer
Cost of the Traditional Stormwater System		($260,000.00)
Present Value* (PV) of Ditch Maintenance	($7,651.95)	
PV of Costs for Future Capital Replacement of Stormwater Infrastructure	($9,908.03)	
Total Present Value	($17,559.97)	($260,000.00)
Willowbrook (Sustainable)	**Municipality**	**Developer**
Cost of Restoration		($120,000.00)
Increased Lot Yield		$825,000.00
PV of Wetland Maintenance	($4,057.28)	
PV of Educational Value	$34,344.83	
PV of Ecological Benefit	$12,470.09	
PV of Value of Carbon Stored	$515.30	
Total Present Value	$43,272.94	$705,000.00
Net BENEFIT	$60,832.91	$965,000.00

Table 1 – Willowbrook Financial Summary
Note: numbers in red in parentheses are negative.

[14] Barraclough, C.L. and D.H. Hegg. 2008. Nature's Revenue Streams: Five Ecological Value Case Studies. Prepared for CMHC. Report 66590. http://www.cmhc.ca/en/inpr/su/waho/waho_004.cfm

[15] http://news.bbc.co.uk/2/hi/8307024.stm

[16] http://www.davidsuzuki.org/publications/downloads/2010/DSF_lower_mainland_natural_capital.pdf

[17] http://www.davidsuzuki.org/publications/downloads/2008/DSF-Greenbelt-web.pdf

pumped to a treatment plant, screened, aerated, often filtered, disinfected and then pumped to a point of disposal. If that point of disposal is upstream of someone else's drinking water intake, the water often receives another more intense round of treatment before it can be reused. While small cities and rural areas still have the luxury of largely unfiltered and often gravity-fed water supplies, this is rarely the case in cities. In California, water-related energy use consumes 19 per cent of the state's electricity, 30 per cent of its natural gas, and 88 billion gallons of diesel fuel every year—and this demand is growing.[18] "The state water plan concludes that the largest single new supply available for meeting this expected growth in water demand over the next 25 years is water use efficiency. The remainder must be provided by the development of new water supplies including water recycling, and desalination of both brackish and seawater, all of which will increase energy demand over current levels."[19]

Municipalities are beginning to recognize that sustainable water management is also smart energy management. The Province of B.C. has recently published a guide entitled "Resources From Waste: Integrated Resource Recovery (IRR)."[20] In this guide the authors outline how IRR can:

- reduce greenhouse gas (GHG) emissions;
- reduce pollution and divert waste from municipal, industrial, and resource sectors to beneficial uses;
- reduce demand for new resources and infrastructure by providing local sources of clean energy, nutrients, and water;
- delay or offset the purchase or expansion of infrastructure; and
- generate new economic opportunities and new sources of revenue.

Metro Vancouver, formerly the Greater Vancouver Regional District, recently undertook a study to examine the opportunity to integrate water, energy, liquid and solid waste management for three member municipalities on the North Shore (West Vancouver, North Vancouver and the City of North Vancouver).[21] Faced with the need to build a new wastewater treatment plant at an estimated cost of $1.2 billion, Metro sought a way to offset this cost and reduce the taxpayer burden. Six scenarios of IRR were modelled, and compared to the cost of stand-alone wastewater treatment.

The study concluded that energy recovered from treated wastewater and organic solid waste could be distributed through a district energy system serving the main population centres of the North Shore. Electricity could also be generated from a gasifier and sold to BC Hydro; treated wastewater could be reused to enhance the ecological health of creeks and wetlands and reused for non-potable industrial purposes, nutrients could be recovered, and the water recycled. Other resource benefits include the potential to displace fossil fuels, reduce greenhouse gas emissions, and reduce NOX emissions. A 50-year life cycle valuation was assessed. In total, the preferred IRR scenarios were projected to generate between $2.8 and $3.2 billion in new revenues, but required additional capital and operating expenditures. The revenue for the best performing scenarios has the potential to exceed the additional cost, resulting in no net cost to the taxpayer and a significant improvement in waste diversion and recovery of resources. While the details of this study are beyond the scope of this article, further information can be obtained from Metro Vancouver.

Legal and regulatory issues and how to manage them

In many regions, design teams are leading the way toward WSUD and regulations have yet to catch up. For example, if reclaimed water is to be used inside a building for toilet flushing, Health Canada's draft guidelines state that it must be disinfected to the same standard as if it were to be used for swimming.[22] This can be costly and makes it challenging to meet green building standards such as LEED™ and the Living Building Challenge. One potential solution to avoiding over-treatment is to implement a testing program within the building to demonstrate the ability to meet safe bacterial and pathogenic standards and to periodically retest the system

[18] California's Water-Energy Relationship—Final Staff Report 2005. http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

[19] Ibid.

[20] http://www.cscd.gov.bc.ca/lgd/infra/resources_from_waste.htm

[21] http://www.fidelisresourcegroup.com/North.Shore.IRR.FINAL29Mar2011web.pdf

[22] http://www.hc-sc.gc.ca/ewh-semt/consult/_2007/reclaim-recycle/index-eng.php

to demonstrate continued compliance. Another option is to use captured rainwater for indoor uses and restrict reclaimed water use to outdoor irrigation. It is often possible to get approvals to test pilot projects in a region if the owner is willing to test the system and provide the results to the permitting authority with an agreement to install further treatment if it is warranted. This technique was approved in December 2010, by the Coastal Health Authority responsible for permitting the new VanDusen Botanical Garden Visitor Centre, in Vancouver. Under this scenario, untreated captured rainwater will be used for toilet flushing, and a regular testing program will monitor water quality. The building is Canada's first "living building."

Outdoor use of reclaimed water requires attention to the generation of aerosols. In general, reclaimed water is usually drip-irrigated, rather than sprayed, in order to avoid accidental inhalation of pathogens that may not have been adequately removed. There is no such restriction on rainwater. Drip irrigation, or subsurface irrigation, has the dual benefit of eliminated aerosols and reducing evaporative losses.

With respect to stream and floodplain management, many regions have predetermined riparian setbacks or buffers (for example, B.C.'s Riparian Areas Regulation). While buffers are desirable, streams do not come in standards widths and nor should buffers. The desire should be to create a net ecological benefit to the site. For example, if the setback being prescribed is on a channelized stream, a municipality may relax the setback in exchange for restoring that portion of the channel that is on the development site. This in turn adds value to the development and creates a win-win situation. Similarly, if the site is a redevelopment site, "credit" may be given for reducing the amount of impervious surface if progressive design practices are employed.

One must still pay close attention to flood construction levels, but in many cases those can be managed by elevating the buildings rather than moving further upslope. When planning development, consideration should be given to more frequent and extreme rainfall events. Historical rainfall models may no longer be accurate, and updated modelling should be undertaken to determine flood construction levels.

Perhaps one of the most commonly overlooked pieces of legislation related to water is the federal *Fisheries Act*. It applies to all fishing zones, territorial seas and inland waters of Canada and is binding to federal, provincial and territorial governments. Section 35 is a general prohibition of harmful alteration, disruption or destruction (HADD) of fish habitat. Any work in or around streams or wetlands must not negatively alter fish habitat, unless authorized by the Department of Fisheries and Oceans. It is important to note that "fish habitat" does not need to contain fish and that "fish" includes shellfish, crustaceans, marine animals including the larvae and juvenile stages. Subsection 36(3) prohibits the deposit of deleterious substances. A deleterious substance is defined by the *Fisheries Act* as any substance that, if added to water, makes the water deleterious to fish or fish habitat or any water containing a substance in such quantity or concentration or has been changed by heat or other means, that if added to water makes that water deleterious to fish or fish habitat. Deleterious substances include sediment.

The ramifications of the *Fisheries Act* are that stormwater cannot be discharged untreated into streams, wetlands or the ocean. Wastewater must also be treated to an acceptable standard. Fish habitat cannot be used as part of the treatment train for stormwater or wastewater. It is simple to comply with the Act as long as aquatic habitat is not altered and all stormwater and wastewater is treated in advance of discharge.

Checklist of WSUD principles – what have we missed?

When striving for WSUD, there are several key questions to ask. These questions are not all-inclusive but rather provide a starting point for design teams to consider when beginning a new project:

- Does the team have the necessary expertise to address water issues in an integrated fashion? Who is missing (ecologist, hydrologist, municipal infrastructure engineer, valuation professional)?

- What is the natural hydrologic regime of the site and is the water-use profile of the project consistent with that regime (for example, coastal rainforest vs. arid prairie)?
- What is the ecological function of the development site within the context of the watershed?
- Is water always treated as a valuable resource in each design decision?
- Is water kept on the land as long as possible to permit infiltration and groundwater recharge?
- Has every effort been made to prevent alteration to the natural drainage patterns on the site?
- Has water-related energy demand (both for supply and treatment) been minimized to the greatest extent possible?
- How would the project be designed given no regulatory barriers (that is, what is the potential of the project)? Working back from that point, what barriers can be eliminated or negotiated and how does that affect the design (project capability)?

Conclusions

Water-Sensitive Urban Design can seem daunting to design teams that have never attempted it, but once its value to a project is recognized, it can become routine practice. The key is to have the right people on the team, including ecologists, who can place the project in its watershed context, and help guide the team in its technical decisions. By asking the right questions from the very start of a project, significant cost savings can be achieved and greater value can be derived from the project, to the benefit of the owner and the community. Water touches all aspects of our lives, and thus should touch all aspects of our design.

Additional WSUD Resources

Canada Mortgage and Housing Corporation

Water and Housing: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/

Alternative Stormwater Management: http://www.cmhc schl.gc.ca/en/inpr/su/waho/waho_004.cfm

Vegetative Practices: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_011.cfm

Constructed Wetlands: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_008.cfm

Rain Gardens: http://www.cmhc-schl.gc.ca/en/co/maho/la/la_005.cfm

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Water Reuse: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_001.cfm

Water Efficiency: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_003.cfm

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Rainwater Harvesting: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_002.cfm

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Onsite Wastewater Management: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_005.cfm

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Additional References Related to Water-Sensitive Urban Design

BC's Water Plan: "Living Water Smart" http://www.livingwatersmart.ca

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Evaluating Options for Water Sensitive Urban Design, A National Guide (Australia). http://www.environment.gov.au/water/publications/urban/water-sensitive-design-national-guide.html

Low Impact Development Stormwater Management Planning and Design Guide. 2010. Toronto and Region Conservation Authority and Credit Valley Conservation Authority. http://www.sustainabletechnologies.ca/Portals/_Rainbow/Documents/LID%20SWM%20Guide%20-%20v1.0_2010_1_no%20appendices.pdf

Low Impact Development. Technical Guidance Manual for Puget Sound. http://your.kingcounty.gov/solidwaste/greenbuilding/documents/Low_Impact_Development-manual.pdf

Ontario Ministry of Environment Stormwater Management http://www.ene.gov.on.ca/environment/en/subject/stormwater_management/index.htm

Richmond Valley DCP No. 9 – Water Sensitive Urban Design. http://www.richmondvalley.nsw.gov.au/page/reports/NEW_Planning_Scheme/Richmond_Valley/RV_DCP_No_9/

The Waterbucket http://www.waterbucket.ca/

WSUD Technical Guidelines for Western Sydney (Australia). http://www.richmondvalley.nsw.gov.au/icms_docs/30005_Water_Sensitive_Urban_Design.pdf

Water Sensitive Road Design. Design options for improving stormwater quality of road runoff. http://www.catchment.crc.org.au/pdfs/technical200001.pdf

WSUD Case Studies: http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp

Glossary

Blackwater: Sewage.

BMP: A Best Management Practice (BMP) as defined by the U.S. *Clean Water Act* is a technique, process, activity, or structure used to reduce the pollutant content of a storm water discharge. BMPs include simple nonstructural methods, such as good housekeeping and preventive maintenance. BMPs may also include structural modifications, such as the installation of bioretention measures.

Evapotranspiration: The process by which water vapour is transferred from the land to the atmosphere by evaporation from soil and other surfaces and by transpiration* of plants.

GHGs: Greenhouse gases.

Greywater: Water from sinks, showers, washing machines and dishwashers; all household wastewater except sewage.

Porous (permeable) paving: Permeable paving is a range of materials and techniques for paving roads, paths, and parking lots that allow the movement of water and air around the paving material. Whether pervious concrete, porous asphalt, paving stones or bricks, all these pervious materials allow precipitation to percolate through areas that would traditionally be impervious and infiltrates the stormwater through to the soil below.

Potable water: Water fit to drink.

Present value: Present value is the value on a given date of a future payment or series of future payments, discounted to reflect the time value of money and other factors such as investment risk.

Riparian: The interface between land and water; riparian plants are found along the water's edge. Riparian zones are found along streams, rivers, lakes and wetlands* and provide critical habitat for many species.

Stormwater: Rainwater that has become contaminated with pollutants.

Transpiration: The process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapour and is released to the atmosphere.

Wastewater: Any water that has been adversely affected by anthropogenic influences. Sewage (containing human feces and urine) is a subset of wastewater, but the two terms are often used interchangeably.

Water banking: The practice whereby captured rainwater or reclaimed wastewater is used in place of potable water in order to allow water to remain in a reservoir for withdrawal at a later date.

Watershed (or catchment): A watershed or catchment is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point, usually the exit of the basin, where the waters join another waterbody, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.

Wetland: A wetland is an area of land where the soils is saturated with moisture, either permanently or seasonally, and which supports plant species that are tolerant of saturated soil moisture conditions. Some specific types of wetlands include swamps, bogs, fens, and sloughs. Wetlands can contain freshwater, saltwater or brackish water and sustain more life than any other ecosystem on earth including tropical jungles.

Questions

1. What is the main objective of WSUD?
2. List four ways that conventional urban development alters aquatic systems.
3. Name four ways that WSUD can restore or protect the natural drainage patterns and hydrological cycles.
4. What attributes does a stream need to be healthy? List five of them.
5. What expertise is critical to include on a design team in order to effectively address WSUD?
6. You need to convince your client of the value of WSUD. List three arguments that support your case.
7. Explain how WSUD can reduce the total energy demand of buildings and communities (life cycle).
8. What regulatory issues does a design team need to be aware of when planning a water-sensitive design?
9. A changing climate may bring with it more extreme weather events. Explain how WSUD can buffer a community against such challenges.