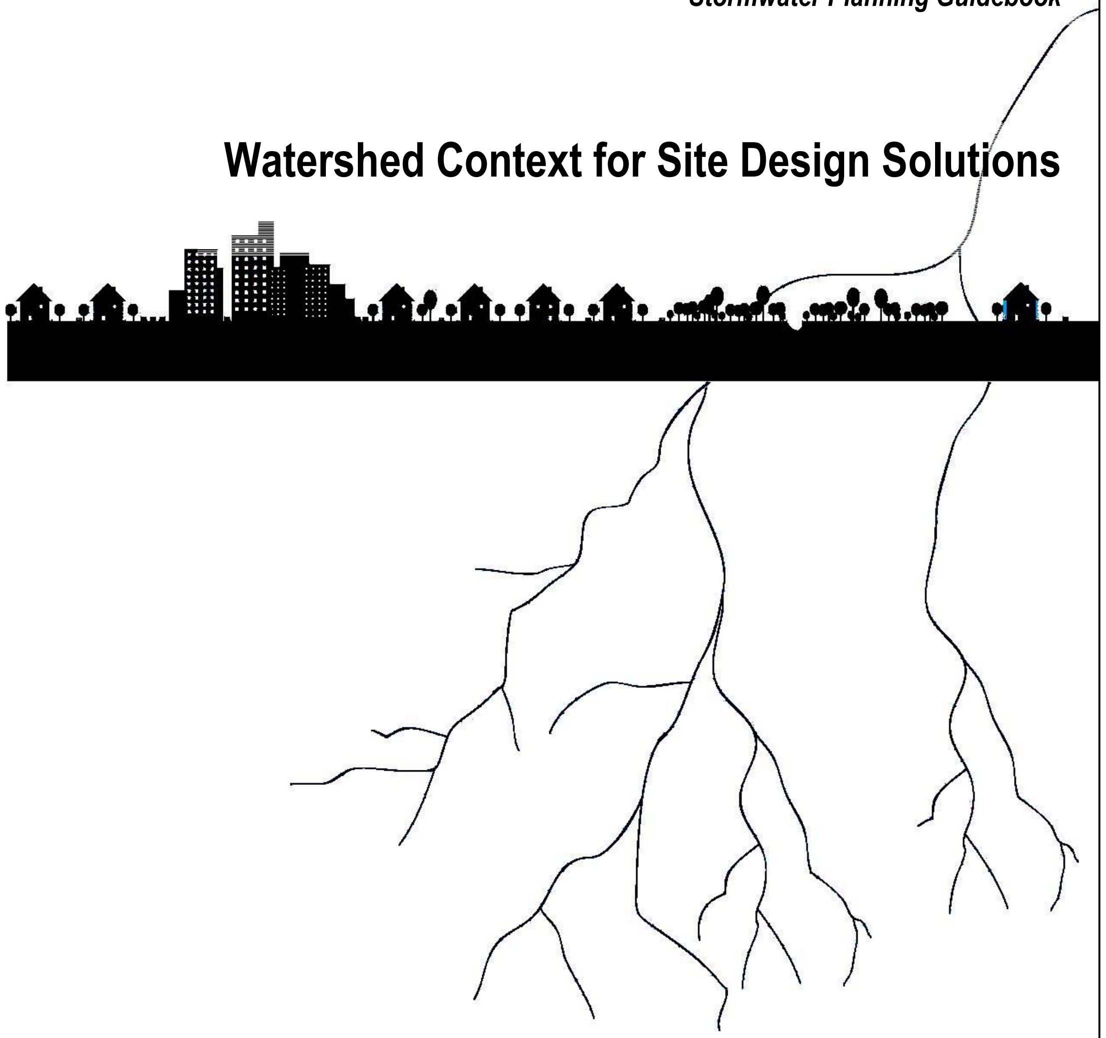
Watershed Context for Site Design Solutions



Chapter Eight

8.1 Determining What is Achievable at the Watershed Scale

The purpose of applying site design solutions is to ultimately achieve benefits (in terms of watershed health and/or flood risk management) at the watershed scale.

Determining what is achievable at the watershed scale is key to developing a shared long-term vision for a watershed. This long-term vision then provides a context for all planning, data collection, capital expenditures and regulatory changes.

Section 8.2 presents case studies that show what can be achieved at the watershed scale through the application of stormwater source controls.

Section 8.3 illustrates what is needed to achieve the widespread application of source controls that are required to achieve significant benefits at the watershed scale.

The Value of Watershed Retrofit Scenarios

Watershed retrofit scenarios were modeled using the Water Balance Model (see Chapter 7) for three developed watersheds in the Greater Vancouver Regional District (GVRD). The purpose of the watershed modeling was to answer the questions:

- ☐ How can implementation of stormwater source controls on all new developments and re-developments over a long time period, on a watershed-wide basis, benefit flood management and urban stream health?
- ☐ Are there specific stormwater source controls that work better in theory than others?

The modeling results from two of the GVRD case study watersheds are presented in Section 8.2. These results demonstrate that it is achievable to significantly improve and potentially restore watershed health over a 50-year timeline by applying stormwater source controls to re-development projects.

In general, restoring a degraded watershed is more challenging than preserving a healthy watershed. The GVRD case studies demonstrate that watershed restoration is achievable through source control (in one of the wettest parts of the province). This also demonstrates that watershed protection is achievable through stormwater source control.

Drivers for the Watershed Retrofit Evaluation

The Greater Vancouver Region is projected to experience significant population growth over the next 50 years (possible doubling). This will lead to densification of existing land uses and some development of existing natural areas, which will increase the volume and rate of stormwater runoff discharged into watercourses in the GVRD. The increased runoff is likely to result in:

- ☐ the need for upgrades and/or repairs to drainage infrastructure in many parts of the GVRD
- ☐ further degradation of aquatic ecosystems in urban watersheds
- ☐ further water quality deterioration (also a result of population increase)
- ☐ increased flooding risk to life and property

The effects of climate change are likely to exacerbate these impacts. The amount of fall and winter rainfall in the GVRD is anticipated to increase over the next 50 years due to climate change, which will further increase runoff. Climate change is also expected to increase the frequency of high-intensity rainfall events (cloudbursts), thus increasing the potential for flash flooding.

A key objective of the GVRD's *Effectiveness of Stormwater Source Control* report (2002) was to determine how:

- ☐ the impacts of increased runoff and more frequent cloudbursts could be avoided by applying stormwater source controls on future development and re-development projects within the GVRD
- ☐ the application of source controls on re-development projects could support restoration of aquatic ecosystems and decrease flooding risk over time, thus turning a potential problem (the combination of densification and climate change) into an opportunity (watershed restoration).

The Need for an ISMP Context

This chapter provides a broad overview of the potential benefits of source control (at a watershed scale), but does not evaluate source control options in the context of an Integrated Stormwater Management Plan (ISMP) – that is the next step (see Chapter 10). The ISMP process will determine what is achievable and affordable in the context of each individual watershed.

A key objective of any ISMP is to develop a source control strategy that is watershed-specific.

The ISMP process should identify where there is significant aquatic habitat to be protected or restored, and whether there are drainage problems, such as erosion of ravines or chronic flooding. A more detailed assessment of source control opportunities should focus on areas where land use change could cause or exacerbate stormwater-related problems. An ISMP should evaluate opportunities to mitigate potential negative impacts or to improve conditions through the application of source control.

An analysis of the land use in these catchments will provide an estimate of the expected time frame for new development or re-development over the next 50 years.

The costs and benefits of implementing source control options in these catchments must be evaluated based on more detailed information on soil conditions, hydrogeology, rainfall, streamflow, drainage infrastructure, land use and site design.

8.2 Watershed Retrofit Case Studies

This section summarizes the results of watershed retrofit modeling for two developed watersheds in the GVRD (see Figure 8-1), including:

- a watershed that is predominantly single family land use (McKinney Creek, Maple Ridge), and
- a watershed where re-development to higher density commercial and multiple family land uses is expected (Quibble Creek, Surrey)

The reference publication for these case study examples is the report *Effectiveness of Stormwater Source Control* (CH2M Hill Canada, 2002).

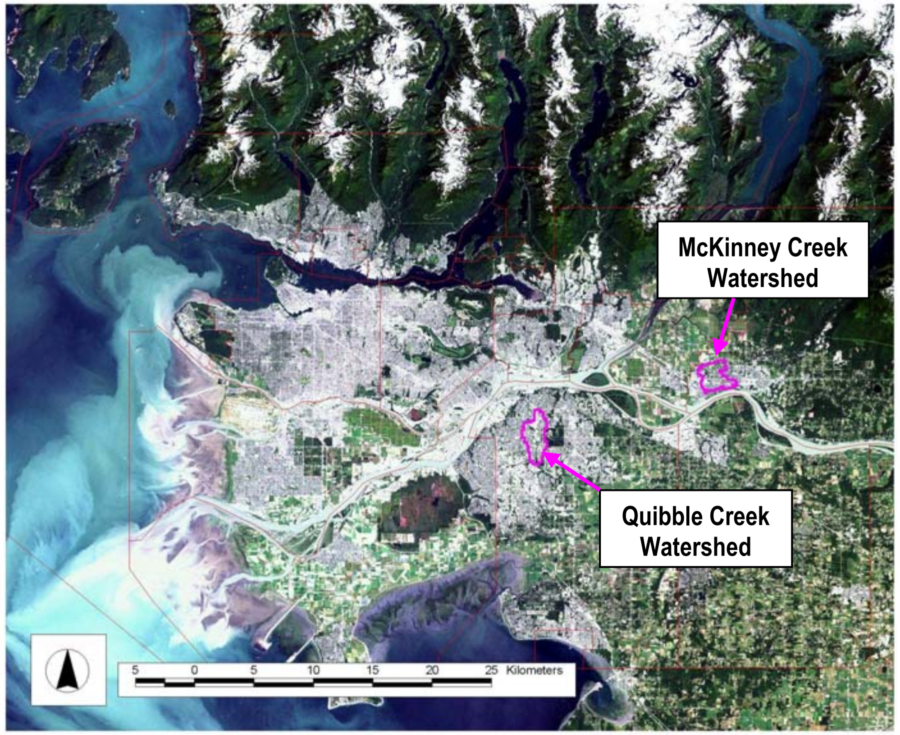


Figure 8-1 GVRD Case Study Watersheds

Indicators of Watershed Restoration

The watershed retrofit scenarios were evaluated based the following indicators of success:

- **Total runoff volume** - The primary watershed restoration target is to limit total runoff volume to 10% (or less) of total rainfall volume. This runoff volume target is based on the Water Balance of a healthy watershed (see Chapter 6).
- **Number of times the natural Mean Annual Flood (MAF) is exceeded** – The peak runoff rates from developed areas should only exceed the MAF that occurred under natural conditions about once per year, on average (more often during wet years). This runoff rate target is based on the hydrology of a healthy watershed (see Chapter 6).
- **Peak runoff rate from extreme rainfall events** – Reduction of peak runoff rates from extreme storms (e.g. from a 5-year storm) reduces watercourse erosion and flooding risk. Specific targets for flood risk management are highly watershed-specific.

The first two indicators show how well stream health is being restored, while the third provides an indication of how well flood risk is being managed over time.

Note that these are simply indicators of potential benefits. A more detailed evaluation of source control benefits for a particular watershed must consider the value of aquatic resources and the condition of drainage infrastructure throughout the watershed.

Without stormwater source control, land use densification, new development, and climate change will increase all of these indicators, resulting in watershed degradation.

Source Control Scenarios

The following source control scenarios were modeled using the Water Balance Model for each case study watershed, and evaluated relative to the three indicators of watershed restoration:

- ☐ **Scenario 1: Unmitigated** – Re-development is assumed to occur according to the standard practice of land development and stormwater management (i.e. no source controls applied).
- ☐ **Scenario 2: Unmitigated with Climate Change** – Same as Scenario 1, except that the anticipated effect of climate change on rainfall patterns is factored into the future scenarios.
- ☐ **Scenario 3: Absorbent Landscaping plus Infiltration Facilities** – For all future re-development projects, it is assumed that undeveloped areas are covered by absorbent landscaping (300 mm soil depth) and infiltration facilities are provided for all impervious surfaces (infiltration swales on all roads and bioretention facilities on all building lots). The size of infiltration facilities used for each land use type and road type were adjusted until the 10% runoff volume target was achieved or until the feasibility threshold was exceeded.
- ☐ **Scenario 4: Intensive Green Roofs plus Absorbent Landscaping plus Infiltration Facilities** – Same as Scenario 3, except that all re-developed multiple family and commercial buildings are designed with intensive green roofs (300 mm of soil depth). The runoff from green roofs is directed to infiltration facilities (sized as described in Scenario 3). All re-developed single family homes have impervious roofs connected to infiltration facilities. Intensive green roofs are not considered feasible for single family land uses.
- ☐ **Scenario 5: Rainwater Re-use plus Absorbent Landscaping plus Infiltration Facilities** – Same as Scenario 3, except that all re-developed buildings (including single family) incorporate rainwater re-use cisterns (300 m^3 of storage per hectare of rooftop, water re-used for toilets and washing machines). Overflow from the re-use cisterns is directed to infiltration facilities (sized as described in Scenario 3).

The cumulative hydrologic benefits (or impacts) associated with implementing these source control scenarios were modeled over a 50-year timeline.

Information and Assumptions Applied to Scenarios

The source control scenarios were modeled based on information and assumptions regarding:

- ☐ **Land use within the watersheds -** Local government staff (from the District of Maple Ridge and the City of Surrey) provided statistical data on the distribution of land use types within their respective watersheds. Surrey provided information on both existing zoning and future Official Community Plan zoning, which provided a basis for quantifying future land use change (densification). The site design characteristics for each land use type were estimated based on information on zoning bylaws and development standards (also provided by local government staff).
- ☐ **Expected timeframe for re-development –** For the McKinney Creek watershed, the age of existing development within the watershed was estimated based on discussion with the local government staff and field investigation. For the Quibble Creek watershed, the City of Surrey provided data showing the date of servicing for individual development parcels (a good approximation of building age). A 50-year re-development cycle was assumed for all watersheds.
- ☐ **Soil conditions –** There was limited soils information available for the case study watersheds. Conservative assumptions were made regarding the hydraulic conductivity of soils, which resulted in conservative findings regarding what is achievable using infiltration facilities.
- ☐ **Rainfall -** Rainfall data from the GVRD gauges closest to each case study watershed were used to simulate the performance of the source control scenarios. A year of continuous rainfall data from a very wet year (1999) was used to simulate the scenarios for each watershed.
- ☐ **Climate change -** Climate change scenarios were generated by applying climate change factors (developed by the Canadian Centre for Climate Modeling and Analysis) to the rainfall data for each watershed for a very wet year (1999).

Case Study #1: McKinney Creek Watershed, Maple Ridge

Land Use

The majority of land use in the 517 hectare McKinney Creek watershed (about 72%) is single family residential. With the exception of a small amount of housing in the northern portion of the watershed, most of this single family housing is relatively old (pre-1980s) with relatively low levels of lot coverage (around 30%). The remaining watershed area comprises some multi-family housing (about 8% of the watershed), some commercial land use along the highways (about 6%), and some other land uses (about 14%), including agriculture, schools and community parks.

Rainfall

Hourly rainfall data from GVRD rainfall gauge DM44 in Maple Ridge was used to simulate the performance of the source control scenarios. Rainfall data from a wet year was used (total annual rainfall = 1811 mm).

Soils Information

The available soils information included Geologic Survey of Canada mapping, and some soils mapping that was done in conjunction with a sub-surface drainage assessment (at a fairly coarse level). Based on this information, a conservative assumption was made that soils in the watershed have poor to medium hydraulic conductivity (around 6 mm/hr). There was little basis for estimating the variability of soil conditions throughout the watershed.

The District of Maple Ridge has reports that indicate the potential for fairly high water table conditions in a localized region of the watershed. The depth of all infiltration facilities was reduced to reflect this information.

Results

The primary form of re-development that is likely to occur over the 50-year time horizon in the McKinney Creek watershed is re-development of older (relatively low coverage) single family lots to higher coverage single family lots. This will likely be the result of larger homes and driveways being placed on existing lots and/or existing large lots being subdivided into smaller lots.

Figure 8-2 shows the difference in impervious coverage between a typical older single family development (on the left) and a typical newer single family development (on the right).

Without source control (Scenarios 1 and 2), this re-development is expected to increase total runoff volume, peak runoff rates, and the number of times the natural MAF is exceeded (see Figures 8-3a, 8-3b and 8-3c). The effects of climate change are likely to exacerbate the increase in runoff volume and rate.

Based on the stated assumptions, the 10% runoff volume target could be achieved with infiltration facilities and absorbent landscaping (source control Scenario 3) for all residential land uses, though not for commercial land uses. However, since commercial land uses represent a relatively small portion of the total watershed area, the application of infiltration facilities and absorbent landscaping could come very close to achieving the 10% runoff volume target at a watershed scale over the 50-year re-development cycle.

At the watershed scale, there would be little additional benefit gained by adding rainwater re-use or green roofs. The addition of green roofs could significantly improve the reduction in peak runoff rates from multiple family and commercial land uses. However, since most of the watershed is single family, this translates into a relatively small benefit at the watershed scale. Similarly, rainwater re-use would improve the reduction in runoff volume from commercial land uses, but this translates into a small benefit at the watershed scale.

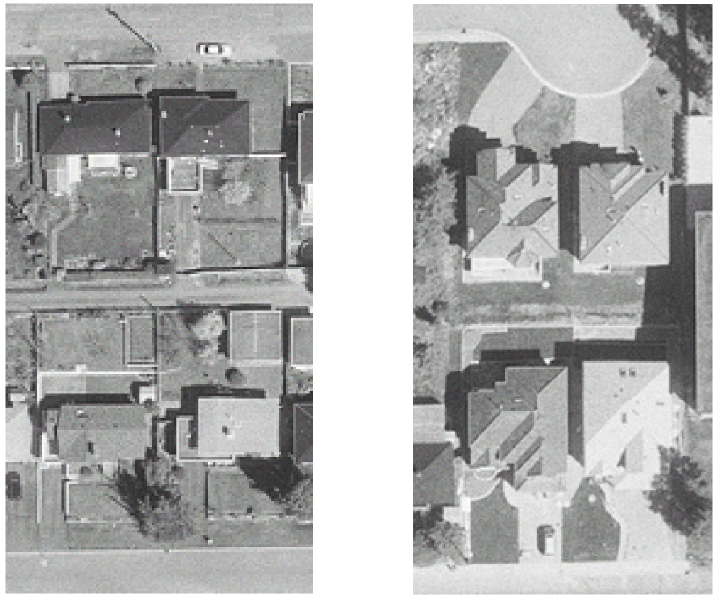


Figure 8-2:

Re-development impacts in the McKinney Creek watershed

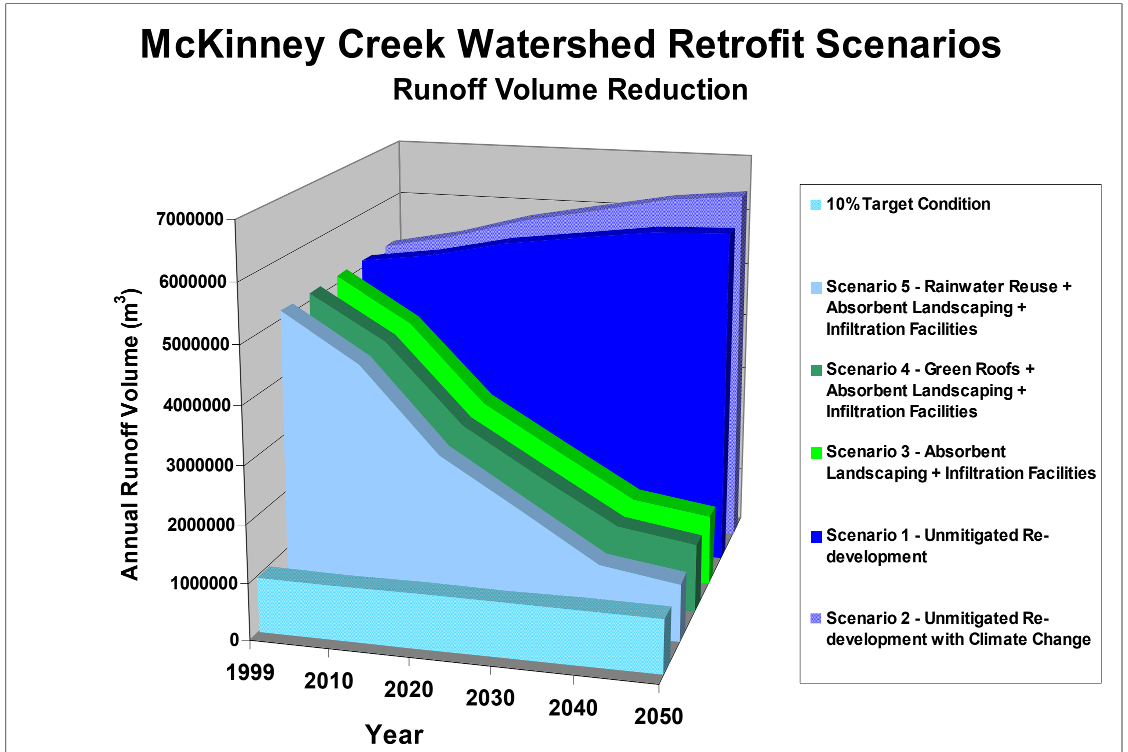


Figure 8-3a

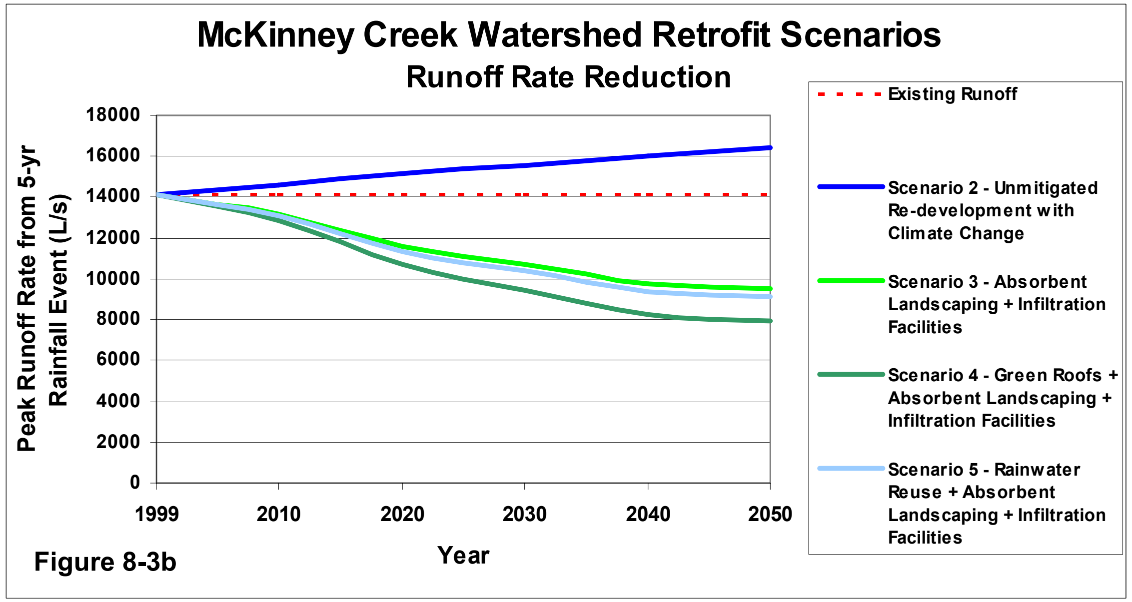


Figure 8-3b

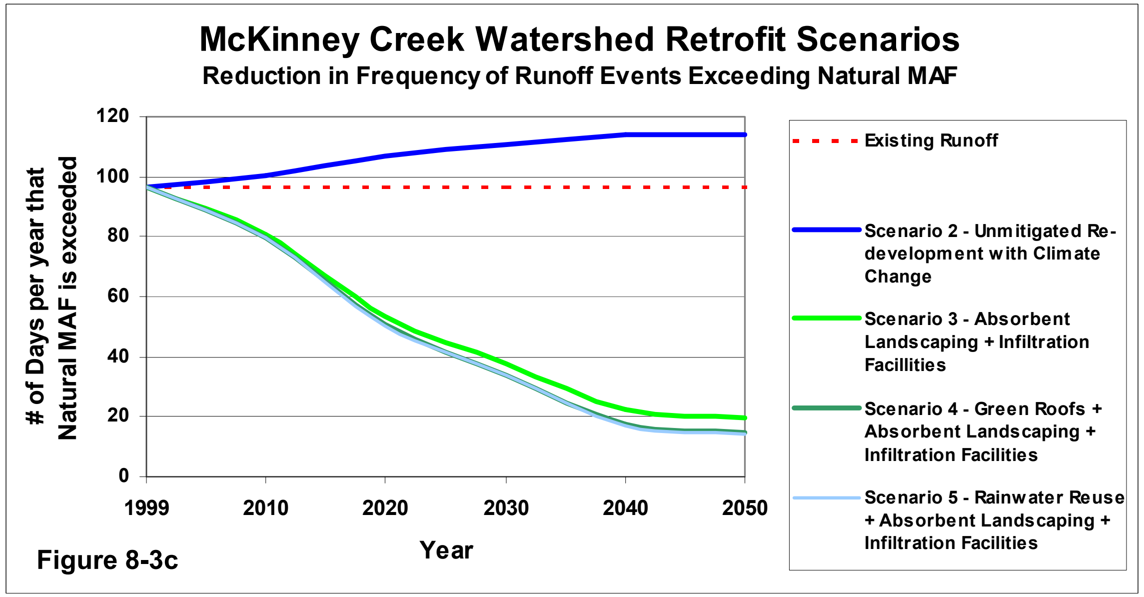


Figure 8-3c

Case Study #2: Quibble Creek Watershed, Surrey

Land Use

A substantial portion of land use in the 622 hectare Quibble Creek watershed (about 54%) is currently single family. A significant portion of the single family homes are relatively new (post-1980). The remaining watershed area comprises commercial land uses (about 20% of the watershed area), some multi-family housing (about 8%), and conservation areas (about 18%) that are not likely to develop in the future.

The City of Surrey's Official Community Plan calls for significant densification in the Quibble Creek watershed. About two-thirds of the existing single family housing in the watershed is expected to re-develop into multiple family land uses (a range of densities). The amount of commercial land is not likely to increase substantially, but existing local and community commercial land uses are expected to re-develop as higher-density town centre commercial.

Rainfall

Hourly rainfall data from GVRD rainfall gauge SU56 in North Surrey was used to simulate the performance of the source control scenarios. Rainfall data from a wet year was used (total rainfall = 1733 mm).

Soils Information

The only soils information available for the watershed was the Geologic Survey of Canada soils mapping (1:50,000 scale). This mapping shows about half of the watershed to be high conductivity soils and the other half to be low conductivity soils. Based on this information, a conservative assumption was made that soils have poor hydraulic conductivity (around 2.5 mm/hr). Aside from the coarse level GSC mapping, there was no basis for estimating the variability of soil conditions throughout the watershed.

Results

The primary impact of densification in the Quibble Creek watershed is likely to result from the re-development of single family land uses to multi-family land uses with higher impervious coverage (see Figure 8-4). Commercial densification also increases impervious coverage but to a lesser extent (even local commercial land uses have relatively high levels of impervious coverage).

Without source control (Scenarios 1 and 2), densification and the effects of climate change are expected to increase total runoff volume, peak runoff rates, and the number of times the natural MAF is exceeded (as shown in Figures 8-5a, 8-5b and 8-5c on the following page).

The 10% runoff volume target could be achieved with infiltration facilities and absorbent landscaping for all land uses except those with greater than about 80% impervious coverage (includes the highest density multi-family land uses and nearly all commercial land uses). At the watershed scale, the application of absorbent landscaping and infiltration facilities (i.e. Scenario 3) could reduce runoff volume to about 20% of total rainfall. In order to achieve the 10% target, it would be necessary to apply rainwater re-use to the high coverage land uses (i.e. Scenario 5).

Green roofs and rainwater re-use would have more significant runoff reduction benefits for the Quibble Creek watershed than for the McKinney Creek watershed (Case Study #1) because high coverage land uses (high density multi-family and commercial) represent a larger portion of the total watershed area. The benefits of rainwater re-use are most significant in terms of reducing runoff volume. The benefit of green roofs are most significant in terms of reducing peak runoff rates from extreme rainfall events.

Since much of the development in the Quibble Creek watershed is relatively new, the opportunity to apply source control to re-development projects is likely limited in the short term (over the next 10 years).

Figure 8-4:

Projected densification in Quibble Creek watershed

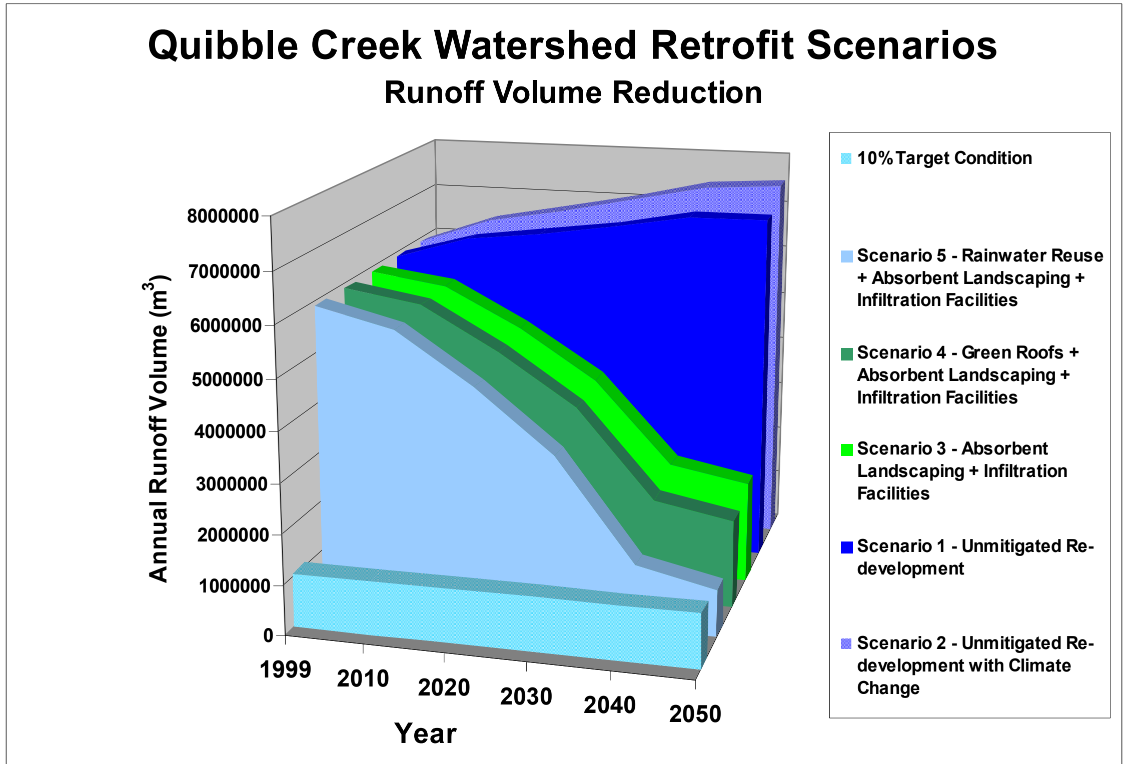


Figure 8-5a

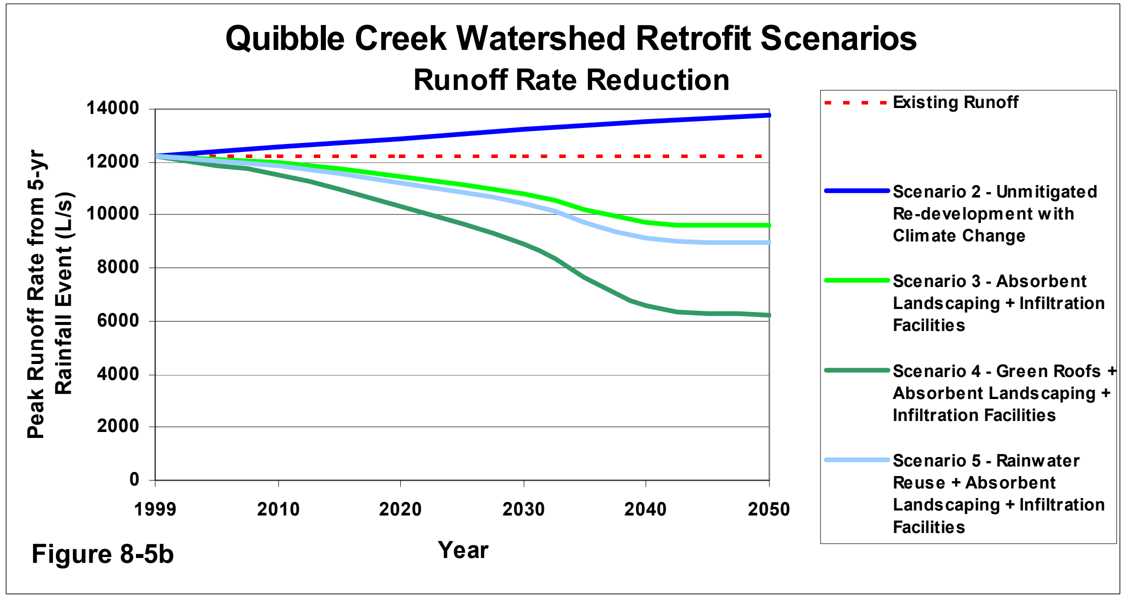


Figure 8-5b

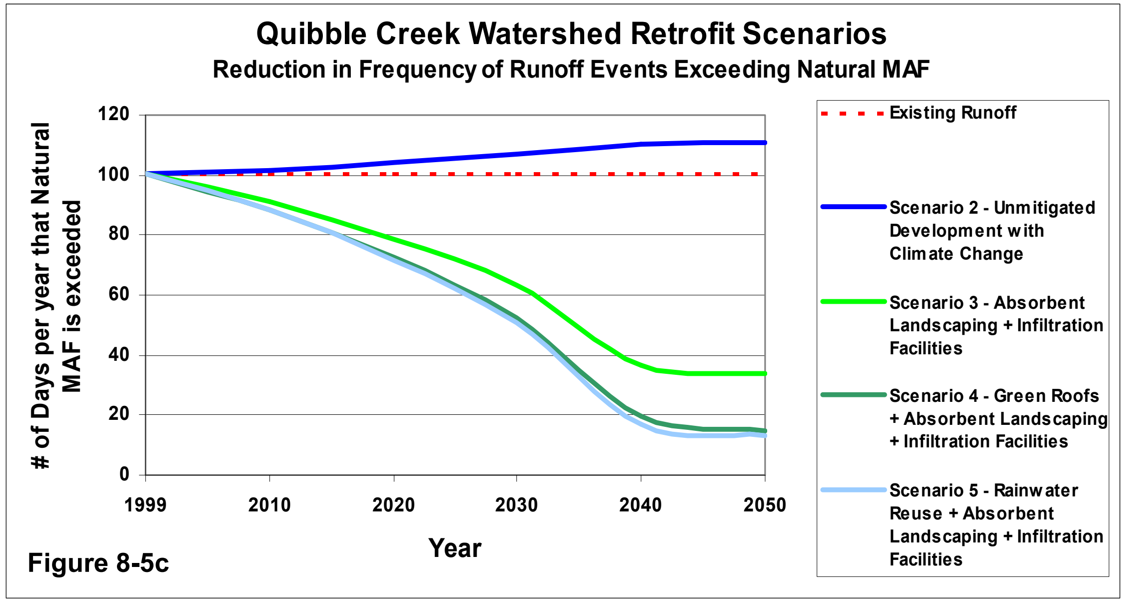


Figure 8-5c

8.3 Achieving Watershed Protection or Restoration

Widespread application of stormwater source control is needed to protect or restore watershed health. This will require changes to the standard practice of land development and stormwater management.

The details of these changes will vary from one watershed to the next. Watershed-specific source control strategies should be developed through the ISMP process (see Chapter 10) based on an assessment of watershed-specific opportunities and constraints.

The core objective is to identify options to change the way that land is developed and re-developed, so that people, property and natural systems can be better protected; and over time, stormwater infrastructure can be managed more efficiently and watersheds can be protected or restored.

Changing Development Standards

An ISMP may identify the need for changes to development standards and regulations in order to implement a watershed-specific source control strategy. The level of support from the public and from all levels of government, as well as the ability of the development community to adapt to new standards, will set the pace of change and influence the pace of ISMP implementation.

This support can only happen if there is a broad understanding among all players, the development community in particular and public in general, about the changes in standard practices - why they are needed, what they are, and how they can be practically accomplished.

Facilitating Stormwater Source Control Applications

The first large-scale applications of stormwater source controls and supporting policies may be implemented as demonstration projects. Local governments (independently or collectively) will need to take the lead in implementing and monitoring these initial demonstration projects (e.g. public works projects, neighbourhood concept plans, progressive ISMPs).

Local government leadership is important for demonstrating to developers, the community and senior government regulators that proposed actions at the site level are both effective and affordable. This will build support for the regulatory, professional and industry changes that will enable the realization of long-term stormwater infrastructure planning and management.

Monitoring demonstration projects provides the foundation for adaptive management. The goal is to learn from experience and constantly improve land development and stormwater management practices. Hydrologic monitoring is fundamental to adaptive management, since it is the hydrologic indicators that provide the information needed to improve the way we develop land and manage stormwater at the site level.

In order to build and maintain trust between local governments, landowners, developers and senior government agencies, the rules of adaptive management must be established at the ISMP stage. These rules must define requirements and consequences of monitoring. In many instances, either prior to or concurrent with the first demonstration projects, there will be a need to change current standards and administrative processes to accommodate these new standards. The following steps will facilitate this process of change:

- ☐ **Step 1 - Establish an enabling regulatory framework** – Make regulatory changes that will facilitate the approval process for development and re-development projects that capture rainfall at the source for infiltration, evapotranspiration and/or re-use.
- ☐ **Step 2 - Ensure that new design standards reflect local conditions -** Through the implementation and monitoring of demonstration projects, establish the design options for source control that will be most effective in the context of site-specific conditions (i.e. soils, precipitation, planned land use, etc).
- ☐ **Step 3 - Adopt a collaborative approach to change** – Consult with citizens and the development industry to determine:
  - preferred design options for stormwater source control
  - appropriate implementation strategies for regulatory change
  - appropriate financing strategies for rainfall capture and runoff control

- ☐ **Step 4 - Incorporate the most effective and acceptable design options into engineering standards -** Revisions to engineering standards should reflect local conditions as well as the preferences of the community and the development industry. Although new engineering standards for source controls can be incorporated into the relevant development regulations (Subdivision Bylaws, Building Bylaws, Zoning Bylaws, Development Permit Guidelines), it is also possible that standards could be performance-based, leaving the determination of appropriate source control strategies to the proponent as part of their development application.

- ☐ **Step 5 - Make the details of new design standards readily available -** Create a technical manual of options for on-lot stormwater source control, including details and specifications of design standards, and make it available on-line.

- ☐ **Step 6 - Facilitate procurement of materials needed to implement new design standards -** Implement a bulk purchase/re-sale program that makes it easy and affordable for developers to obtain the specialty products needed to implement stormwater source control. Also, provide a cheap source of material for absorbent soils through a local government composting program.

- ☐ **Step 7 - Build support through education -** Implement education programs to inform city staff, the development community and the general public about the need for changes in development practices and how to implement them.

In summary, these seven initiatives form the basis for a developing an action plan (see Chapter 9) which provides a framework for removing barriers and reaching the target condition for a watershed over a period of years.