4. Protect Stream Health

Washington State and British Columbia are geographically similar, with a wet coast and a relatively dry interior separated by mountain ranges. On the coast, Washington State's Puget Sound and British Columbia's Georgia Basin together comprise the Salish Sea. In terms of how rainwater management in a watershed context has evolved, there is a history of cross-border sharing and collaboration.

A Road Map for Integrated Rainwater Management

In 1996, the Center For Urban Water Resources Management at the University of Washington (in Seattle) published a seminal paper by Richard Horner and Chris May. They synthesized a decade of Puget Sound research to identify the factors that degrade urban streams and negatively influence aquatic productivity and fish survival. They demonstrated that the four factors limiting stream health are, in order-of-priority:

1. **Changes in Hydrology –** Greater volume and rate of surface runoff caused by increased impervious area and road network densification.
2. **Disturbance and/or Loss of Integrity of the Riparian Corridor** – Clearing and removal of natural vegetation in riparian (streamside) areas.
3. **Degradation and/or Loss of Aquatic Habitat within the Stream** – Caused by erosion and sedimentation processes, bank hardening, and removal of large organic debris; aquatic habitat degradation is a direct result of 'changes in hydrology'.
4. **Deterioration of Water Quality -** Increased sediment load due to more runoff volume causing channel erosion. Pollutant wash-off from land uses, deliberate and accidental waste discharges.

The limiting factors and order-or-priority identified by Richard Horner and Chris May provided a 'road map' for integrated rainwater management. In BC, the Horner and May findings provided a springboard from which to reinvent urban hydrology and develop the Guidebook.

Changes to the Water Balance

Figures 11, 12 and 13 illustrate the progressive changes in hydrology and resulting impacts on stream health when land use change alters the Water Balance.

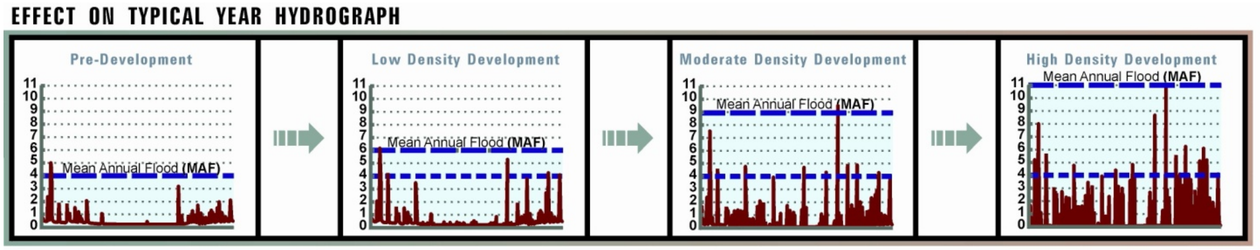
Same Rainfall, Different Runoff Pattern: Figure 12 illustrates 'changes in hydrology' as impervious area increases. A critical parameter for erosion is the number of runoff events per year that equal or exceed the magnitude and duration of the natural channel-forming event – before urbanization altered the Water Balance.

Impacts on Stream Corridor Ecology: Figure 12 is a schematic representation of the Horner and May findings, and illustrates how:

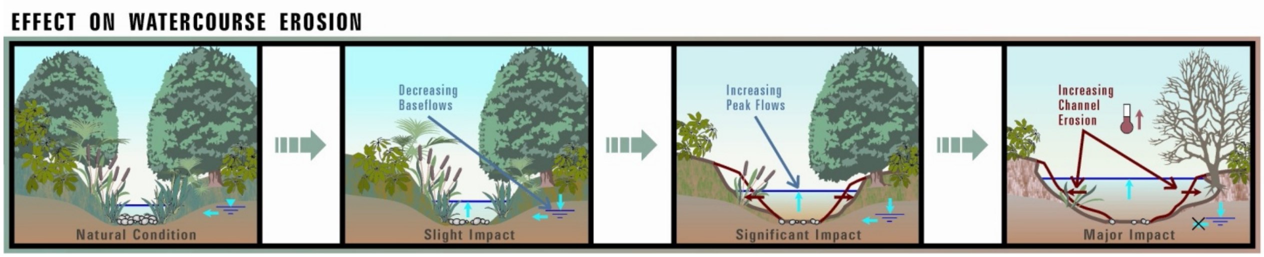
- The cumulative effects of increasing impervious area in a watershed combined with loss of riparian corridor integrity (as shown in the first two rows), alter the natural Water Balance and impact stream corridor ecology (as shown in the last two rows).
- The resulting increase in runoff volume causes watercourse erosion and progressive degradation of the channel cross-section (refer to middle row).
- The consequence of these cumulative changes is a progressive decline in stream corridor biodiversity and abundance for cold-water fish and clear water indicators, and a progressive transition to warm-water species and pollutant indicators (i.e. last two rows).

Eroded material creates turbidity, or dirty water, that can irritate fish gills and make it difficult for fish to find their food. Eroded sediments can cover spawning beds, smothering fish eggs in the gravel and possibly blocking access to spawning areas for the next generation.

The decrease in infiltration (due to replacement of soil and vegetation with hard surfaces) can also have impacts on fish because it reduces the slow, constant groundwater supply that keeps streams flowing in dry weather. This can lead to water levels that are inadequate to provide fish with access to their spawning areas, and can even cause streams to dry up in the summer.



Same Rainfall, Different Runoff Pattern



Increasing Volume + Longer Duration = More Stream Erosion + Loss of Stream Habitat

Figure 11

Consequences of Changes to the Water Balance

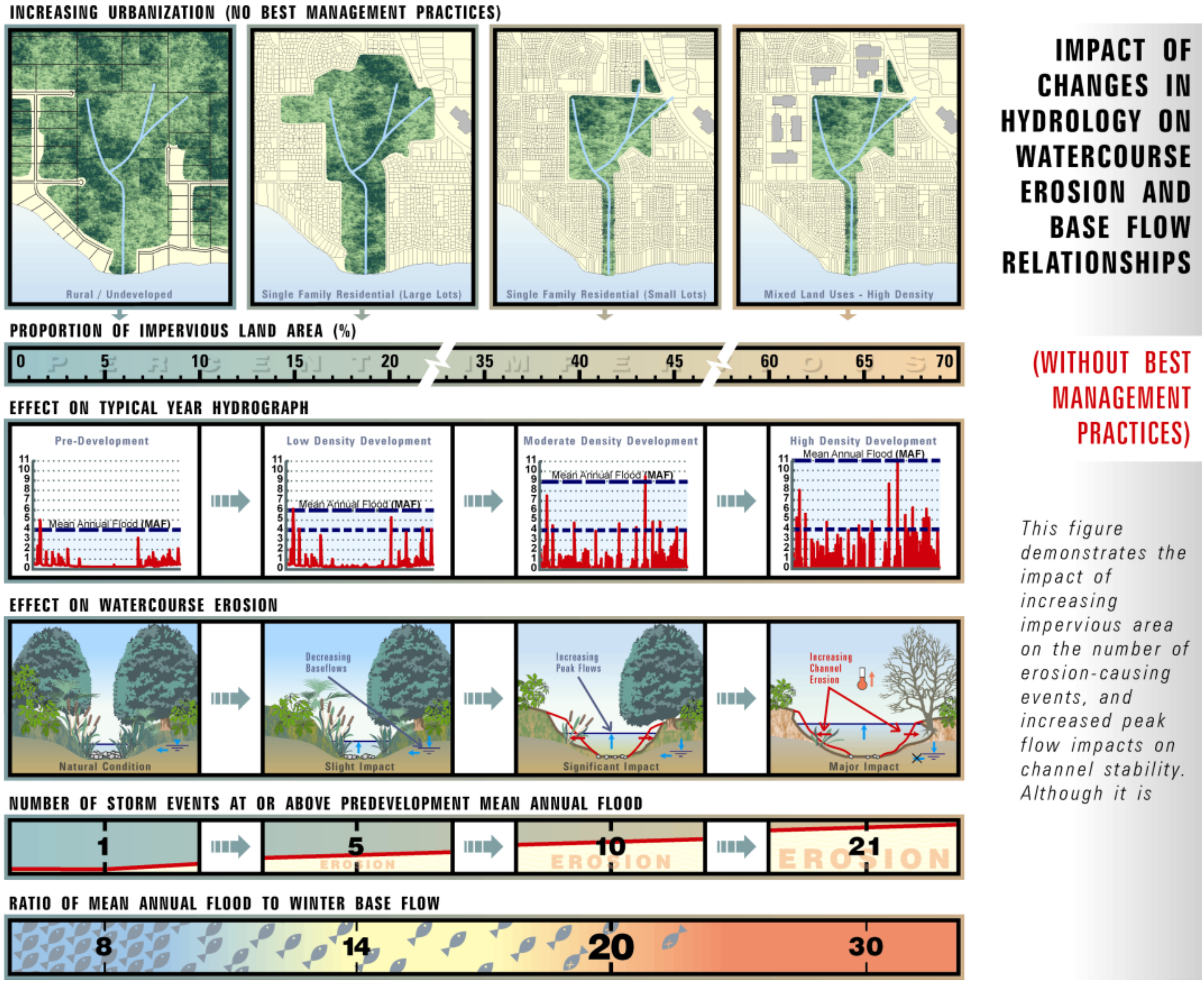


Figure 12

Source: *Stormwater Planning: A Guidebook for British Columbia*, 2002

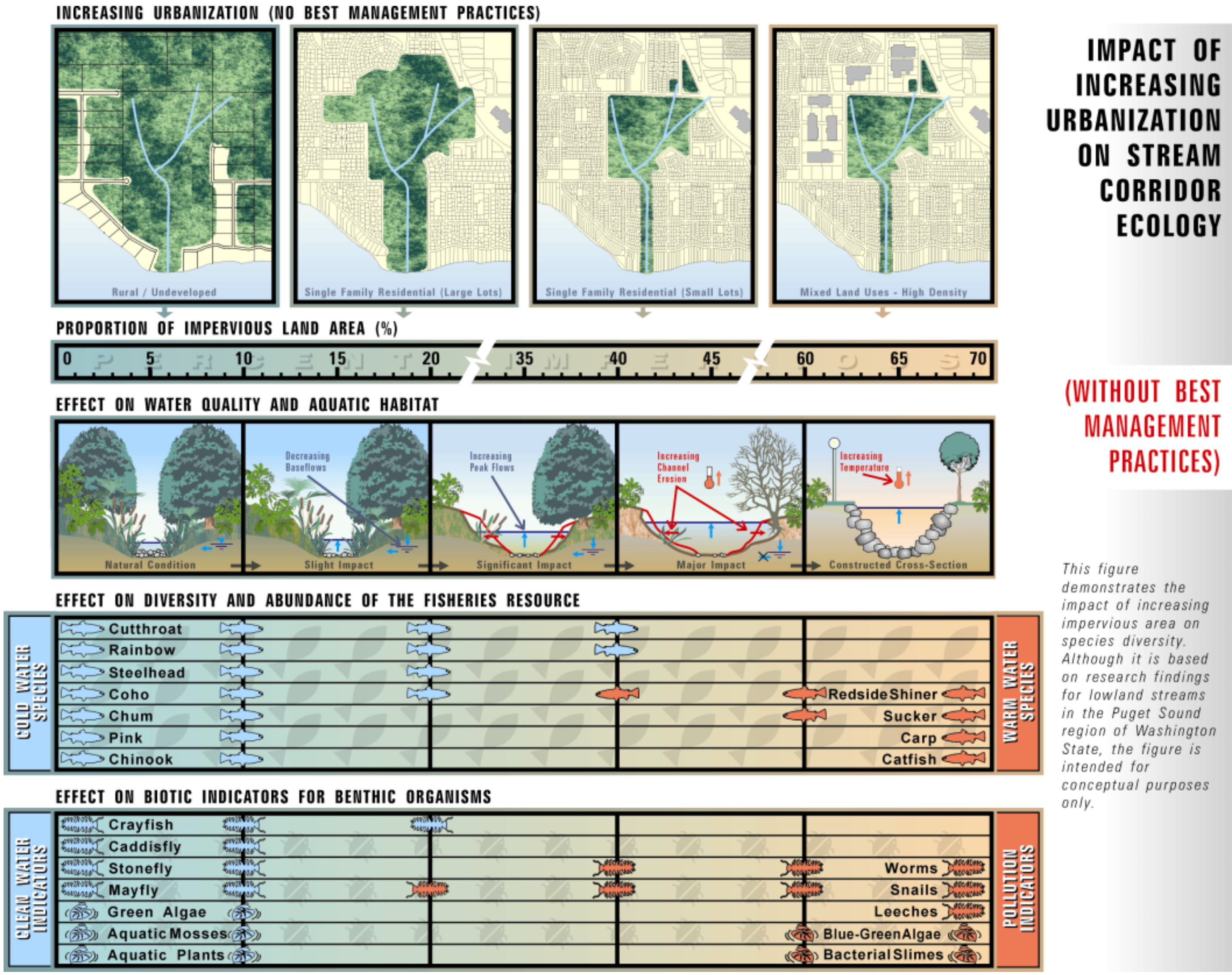


Figure 13

Source: *Stormwater Planning: A Guidebook for British Columbia*, 2002

Stream Health Methodology

Land development produces increased volumes of stream discharge combined with increased duration of discharge. The result is increased stream erosion following development. So, mitigation of the stream impacts must include controlling the combination of discharge rate and the time over which it occurs.

Integrating the site with the watershed and the stream requires integration and synthesis of hydrology, aquatic ecology and geomorphology. In Beyond the Guidebook, the outcome is called the *Stream Health Methodology*.

Many advances in science-based understanding occurred in the mid-1990s. Yet engineering practice generally did not incorporate this understanding. The water balance methodology driving the Beyond the Guidebook initiative addresses this historical oversight.

Understand What Causes Stream Erosion: In hindsight, what did not happen in the 1990s was a comprehensive bringing together or synthesis of engineering and biophysical understanding. At the time, neither discipline had a clear understanding of the processes involved or of the wide ranging impacts that they were trying to mitigate. Yet the way forward is foreshadowed in this quote from Larry Roesner (of Colorado State University), proceedings editor for a 1996 ASCE conference: "What is required is the development of soft engineering that simultaneously achieves the scientists' criteria for ecosystem protection or restoration, and looks and acts like a natural environment".

What Erosion Looks Like: Channel discharge and width increase as a consequence of urbanization. The photo included as Figure 14 is representative of conditions often experienced in urban streams. It illustrates the impact of down-cutting and/or bank-undermining over time. The cause-and-effect relationship boils down to this sound-bite: *more volume equals more erosion*.

Science of Stream Erosion

The Stream Health Methodology is based upon shear stress as applied to the stream bed and banks over time. This is a measure of the energy available to cause erosion in a stream. The methodology also relies on a ***continuous simulation*** of watershed response (i.e. stream discharge) to rainfall over a period of record, which would typically be several decades.

The quantitative indicators for stream erosion analysis are *Tractive Force* and *Total Impulse*.

Estimate the Tractive Force: "The methodology is founded on the concept of quantity of energy available to cause stream erosion. The approach also recognizes that some stream erosion is essential; and uses estimates of tractive force applied over time to establish the energy available to cause stream erosion and to provide a balance between pre- and post-development conditions," explains Jim Dumont.

"While the use of tractive force as a single measure is interesting, it only provides a snapshot of conditions within a stream and the energies associated with flow."

Estimate the Total Impulse: "When we introduce the additional dimension of time and examine the tractive force applied to the stream cross section, we can then convert the measure of force into a measurement of the amount of energy being applied to a stream cross section," Jim Dumont further explains.

"Application of this formula is particularly simple because the continuous simulation of watershed response to rainfall will provide both the discharge and depth of flow at each hour of the simulation throughout the period of simulation."

"The flow conditions that would not result in movement of bed and bank material can be eliminated. This leaves only the ***Impulse***, or total energy that would result in stream erosion. The effect of development and different mitigation schemes can be tested numerically," concludes Jim Dumont.

Photo Credit: Richard Boase, District of North Vancouver

Tractive Force Equation	Impulse Equation
☐ Simple equation ✓ Applicable for a wide, open channels ✓ Product of unit weight of water, hydraulic radius of flow, and slope of channel ☐ Include banks for narrow channels ✓ Banks are often the critical part	☐ A measure of energy applied to the stream cross-section in the form of friction ☐ Use duration of flow to estimate total Impulse for a range of flow depths ☐ Can exclude non-erosive tractive force ☐ Easy to include in continuous modelling

Figure 14

Stream Erosion

Effects of Urbanization on Small Stream Health

The previous pages and figures have provided background on the evolution of an engineering methodology to protect stream health. Next, this Primer elaborates on the aquatic biology perspective. Examples of Parksville streams are also introduced to provide local context.

Commit to Water Stewardship: "Urbanization is a collective term describing a series of land and water uses which can dramatically affect small streams and their biological resources (Figure 15). In many cases, the effects of urbanization accumulate over time (sometimes decades), reflecting a continuum of decisions and actions that incrementally degrade streams and reduce their biological productivity and resilience," observes Craig Wightman.

"Historically, many small watercourses deemed to be 'in the way' of development have been ditched, straightened or placed in culverts, denuded of riparian vegetation, and impacted by more intense storm runoff and droughts (the latter a result of greatly increased impervious surfaces in the basins). They are also impacted by water-borne pollutants and changes in thermal regimes, typically becoming much warmer in summer following loss of riparian canopy."

"To attempt to reverse decades of impacts can be costly and high risk. Hence, it makes sense to commit to water stewardship at the outset of urban development, with early planning taking into account the environmental needs of watercourses, fish and wildlife species, and their intrinsic natural heritage values to a community's present and future generations."

"While initially protecting aquatic health is always a 'water smart' decision, several BC communities have also elected to restore damaged streams as demonstrations of hope and collective action. Burnaby's Guichon Creek in the City of Burnaby (Metro Vancouver) and Bowker Creek in Victoria-Saanich-Oak Bay (Capital Region) are two 'good news' stories attesting to the power of vision, partnership and innovation to reverse past effects of neglect and mistreatment."

What is a Healthy Urban Stream?

"There are many elements that, in total, shape the health of urban streams. These include natural stream flows, suitable water chemistry, energy (e.g., sunlight, organic matter) and physical structure (including riparian corridors) that generate diverse habitats for native species of flora and fauna (Figure 16)," continues Craig Wightman.

Protect Riparian Corridors: "The concept of water resource health, or integrity, is reflected by the 'ecological goods and services' commonly associated with healthy functioning watersheds. In terms of importance to humans, aquatic 'goods and services' are most commonly tied to clean and safe drinking water, safe consumption of fish, assimilation of wastewater and healthy and diverse communities of aquatic plants, fish and other wildlife."

"Functioning, intact riparian corridors along urban streams also provide greenways that directly enhance local conservation, recreation and property values. And, as we are now fully appreciating, surface and groundwater are rarely mutually exclusive; but are joined through complex hydro-geological pathways that are seasonally co-dependent for recharge."

"Riparian set-backs on salmonid-bearing streams in the Nanaimo Regional District (and in all member municipalities) were mandated by the provincial government through passage of the Fish Protection Act (1997), followed by enactment of the Riparian Area Regulation (RAR) in 2004," reports Craig Wightman.

"RAR requires local governments to protect riparian areas during residential, commercial, and industrial development. RAR is intended to protect 'features, functions and conditions that are vital in the natural maintenance of stream health and productivity'."

"These include sources of large organic debris; areas for stream channel migration; vegetative cover; provision of food, nutrients and organic matter; stream bank stabilization; and, buffers from excessive silt and surface runoff pollution."

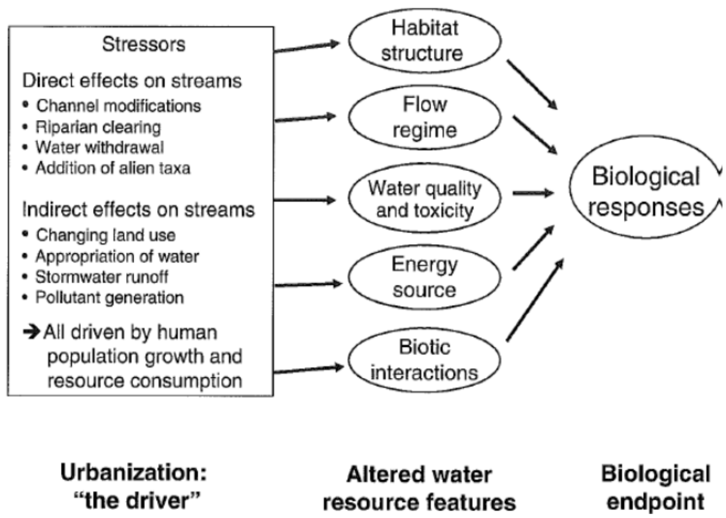


Figure 15

Five Stream Factors that are affected by Urban Development

(modified from Karr 1991 and Karr and Yoder 2004)

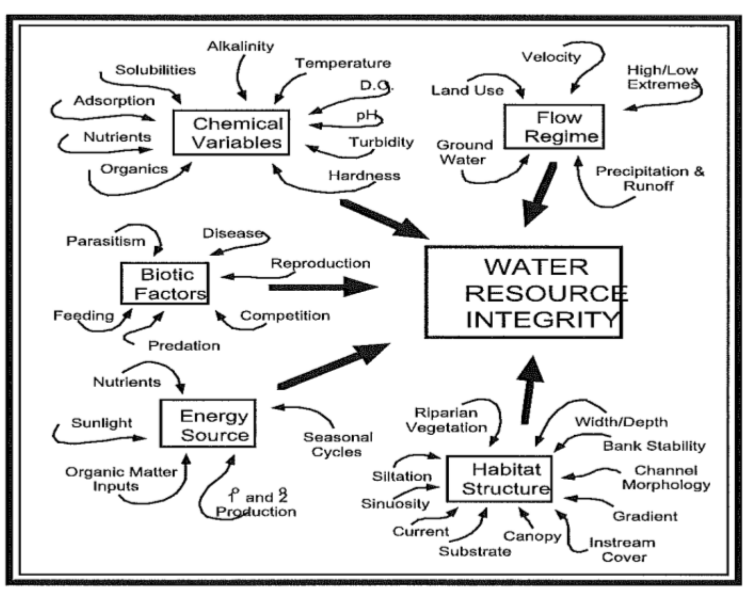


Figure 16

Five Major Factors which Collectively Shape Stream Integrity

(modified after Karr *et. al.* 1986)

What a Healthy Stream Looks Like

"In assessing the health of urban streams, the presence, condition and number of fish, insects, algae, plants and other aquatic life provide a reliable barometer. These are called biological indicators and, in aggregate, are the best and most accurate measures of health for streams, lakes and wetlands," explains Craig Wightman.

"Secondary measures, such as water quality and habitat – including spawning and rearing conditions for salmon and trout - are also informative. These metrics, and their underlying scientific methods, can be used by experienced practitioners in diagnosing stream conditions or limiting factors, and prescribing protection and remedial actions."

Illustrative Examples: The contrast between 'degraded' and 'healthy' stream conditions is illustrated by Figure 17 (photos of Romney Creek near the Parksville Springwood Pump Station) and Figure 18. The latter is the cover photo from the District of North Vancouver's "Quick Guide" to Streamside Protection Development Permit Areas.

"Sections of Romney Creek have been ditched; and its original riparian cover largely removed and replaced by grass and ornamental shrubs along the pump station's perimeter fence. Three-spined stickleback is reportedly the only native fish species still occupying the stream at this location," reports Craig Wightman.

"Sticklebacks often display environmental plasticity in the face of conditions too harsh to support cold water species, like Coastal Cutthroat trout. Hence, if trout were once present in upper Romney Creek, they may have been lost as a product of expanding urbanization over time."

"In contrast, the small North Vancouver stream (Figure 18) remains in its original course, well-shaded by riparian tree and shrubs, and with a predominant substrate of mixed boulders, cobbles and gravels. Coarse substrates provide high quality habitat for larval forms of aquatic insects and safe hiding and foraging sites for juvenile salmon and trout. From a fish habitat perspective, the photo conveys an impression of stream stability, diversity and values worth preserving! The District of North Vancouver has ensured preservation of these natural amenities through its Streamside Protection requirements, passed as a bylaw in 2008."

"In other small basins, the City of Parksville has recognized stream values and provided riparian set-backs, including upper Shelly Creek in vicinity of Hamilton Avenue (Figure 19). This setback has succeeded in preserving some stream habitats, although erosion and sedimentation are persistent in the same reach. This may be partially due to subdivision construction practices of the past, and also to headwater private land logging beyond the municipal boundary. In spite of less than ideal habitat conditions, stream-resident Coastal Cutthroat trout were captured here in September 2011."

ROMNEY CREEK: *Note ditch-like appearance and concrete sill near where it "disappears" under Despard Avenue and a neighbouring sub-division.*

Figure 17

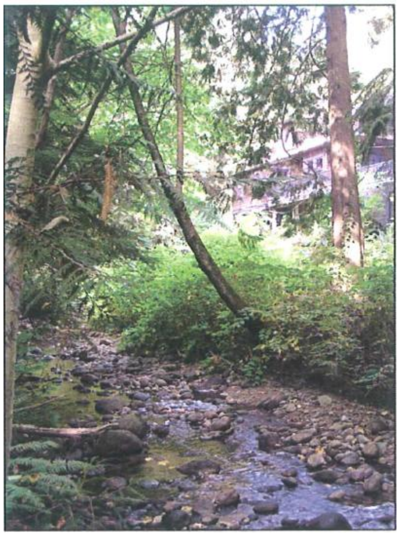


Figure 18

"Other positive signs in the upper Shelly catchment include installation of fish passage baffles in a new culvert under Wildgreen Way, and a sediment retention pond adjacent to the same road (Figure 20)."

"These collective measures represent a milestone in the City's development planning around small fish-bearing streams. They are an important step in accepting responsibility for the impacts of urban development at spatial scales ranging from backyards to entire drainage basins. To demonstrate commitment and ensure this progressive approach is sustained, it would help if Parksville formally endorsed the tenets of BC's Living Water Smart Plan (2008), which pledges to educate all land and water managers about the fundamental requirements of stream health. In turn, this will help promote a more holistic approach to conserving surface and groundwater resources for the community's future," concludes Craig Wightman.

SHELLY CREEK: *Adjacent to Hamilton Avenue subdivision - alder dominated riparian zone, rip-rapped left bank and riffle habitat; resident Coastal Cutthroat trout sampled in September 2011*

Figure 19

SHELLY CREEK: *Baffled culvert and sediment retention pond installed under and adjacent to Wildgreen Way, respectively. Important steps in preserving healthy streams and fish populations.*

Figure 20