INTRODUCTION TO STORMWATER ISSUES

2. The Hydrological Cycle

Figure 2.1 describes the effects of land development on streams and shows the connections between **quantity** and **quality**. Increased drainage efficiency changes the local **hydrological regime**, increasing run-off into streams, flow volumes and peak flows in streams, and the **time of concentration** (increasing the incidence of flash floods). Each of these changes affects the character of the stream, potentially degrading the stream **habitat**. Decisions relating to stormwater quantity need to consider the wider context and implications for the environment.

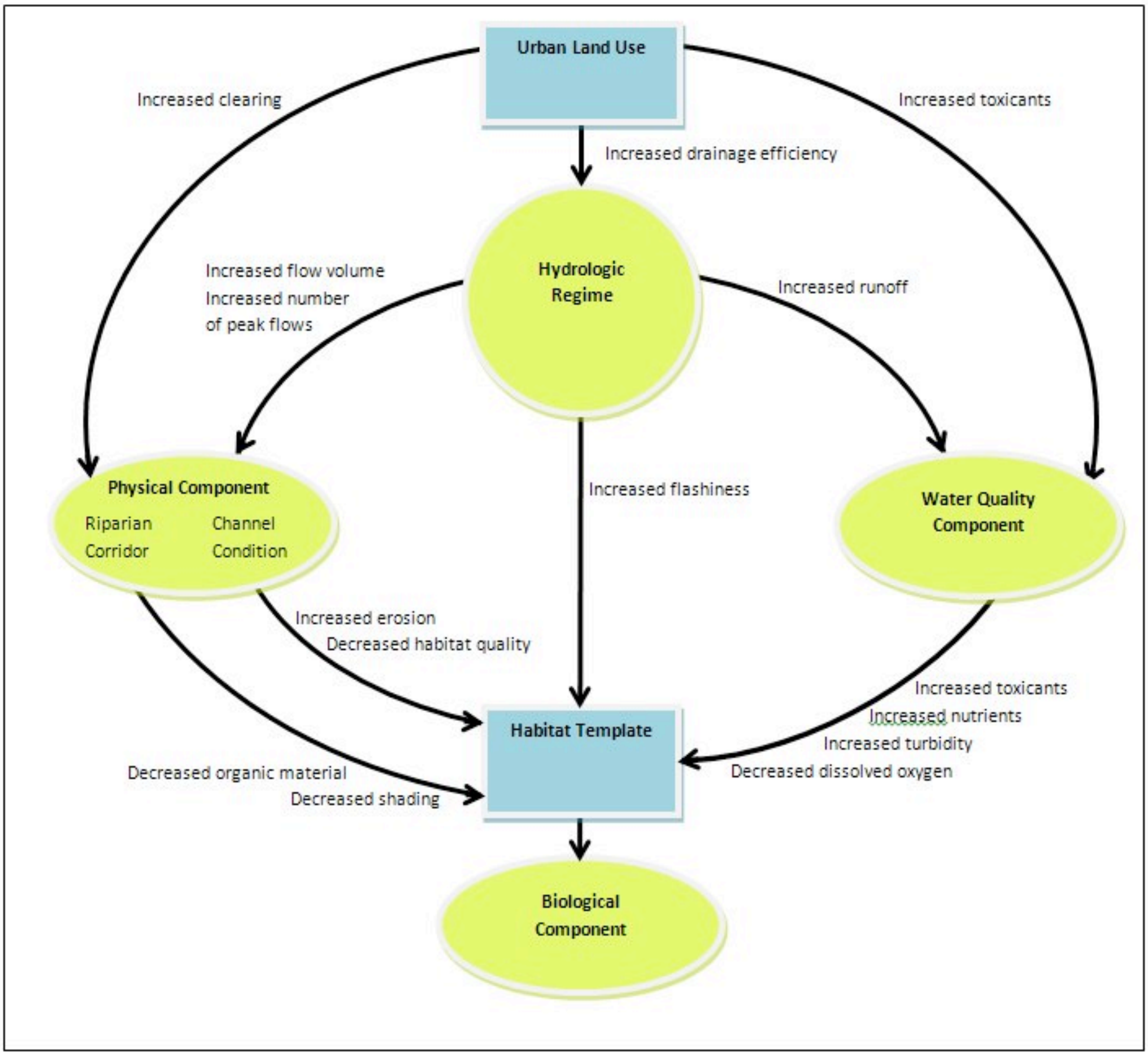


Figure 2.1: Interrelated effects of development on streams

Source: University of Maine, USA After: Measuring the Impact on Maine Surface Waters, 2003

The **hydrological cycle** describes the global circulation and conservation of water between the oceans (and other waterbodies), the atmosphere, and land (refer to Figure 2.2). Water circulates through mechanisms such as:

- **Evapotranspiration** (ground to atmosphere);
- **Precipitation** (atmosphere to ground and waterbodies); and
- **Infiltration** (waterbodies to ground).

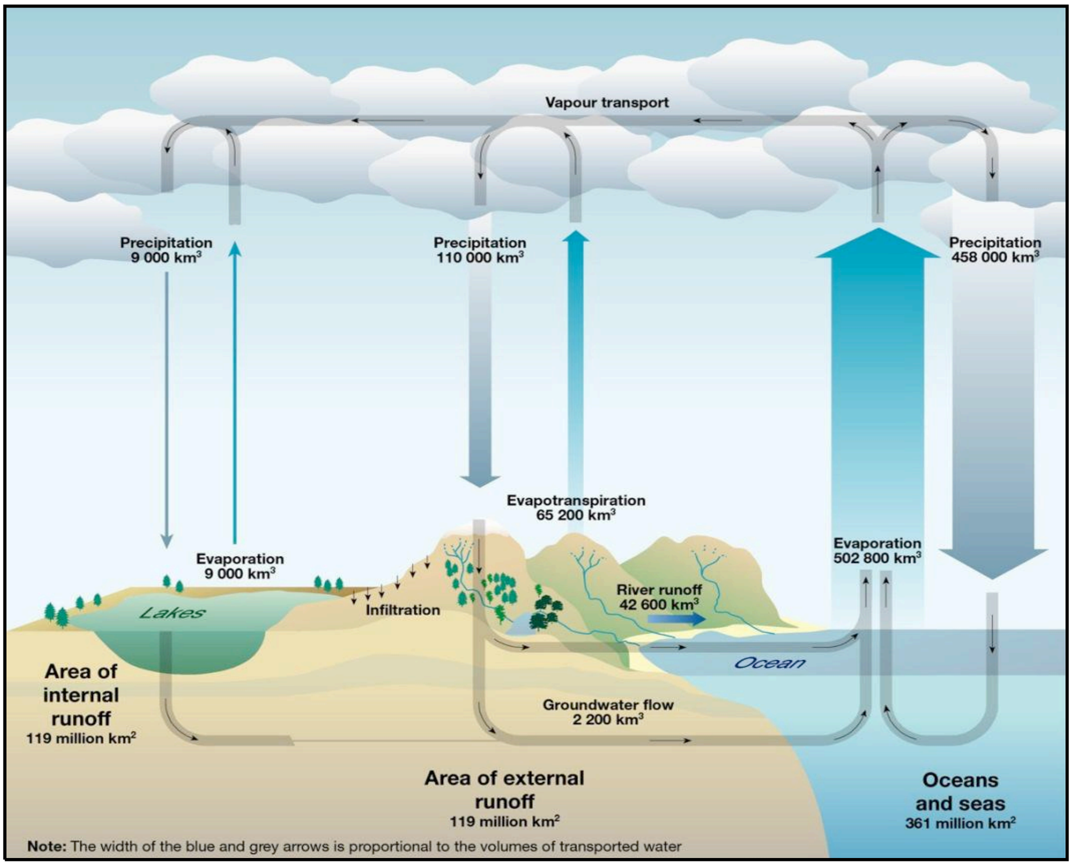
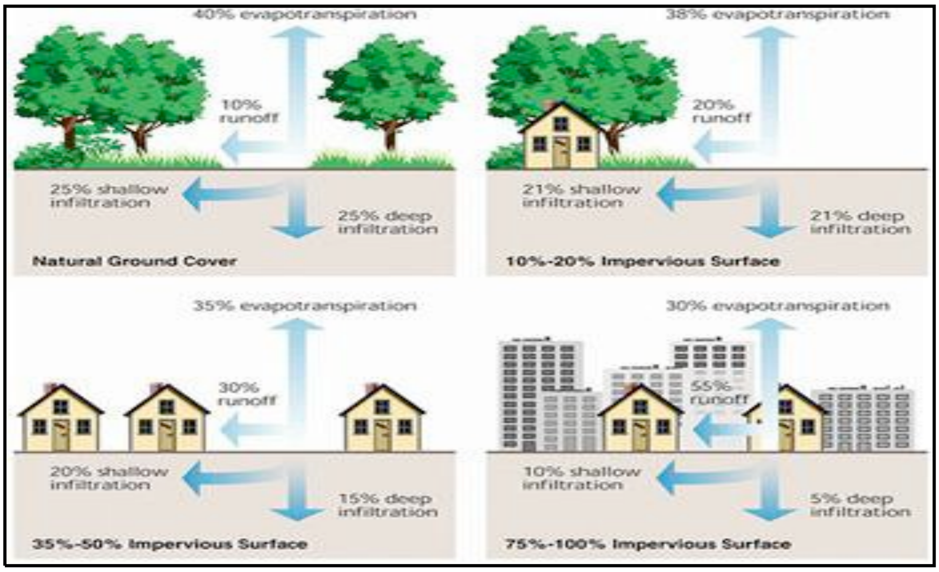


Figure 2.2: Hydrological cycle
Source: UNEP, 2008

Whilst the distribution of water within the hydrological cycle may differ from location to location and at each stage of the cycle (due to factors such as climate or landform), the total volume of water remains unchanged. Broadly however, it is estimated that less than 1% of freshwater is accessible to land-dwelling plants and animals (including humans) and more than 97% of water is locked within oceans (Shiklomanov, 1993).

Changes in land use, including urban development and road building, interact with the hydrological cycle by modifying the local circulation of the water between natural reservoirs; sometimes with negative consequences (refer to Figures 2.1 and 2.3). Adverse effects of such modification can include a reduction of groundwater levels and resources, and changes to waterbody characteristics that result in reduced physical condition, reduced water quality and reduced biological quality.

Unlike a natural catchment, urban areas typically lack the vegetation that intercepts and absorbs rainfall. Urban catchments also have a high proportion of impervious surfaces such as concrete, asphalt, pavement, and rooves; all of which increase stormwater runoff (NURP, 1983; refer also to Figures 2.3 and 2.4). The compaction of soils and / or simply the removal of top soils can also contribute to catchment changes.



If over 10% of a catchment is covered by impervious surfaces, stream quality may be moderately impacted.

Catchments with over 25% impervious surfaces are likely to have severely impacted streams.

Figure 2.3: The hydrological effects of development

Source: Planning with power from FISRWG, 1996

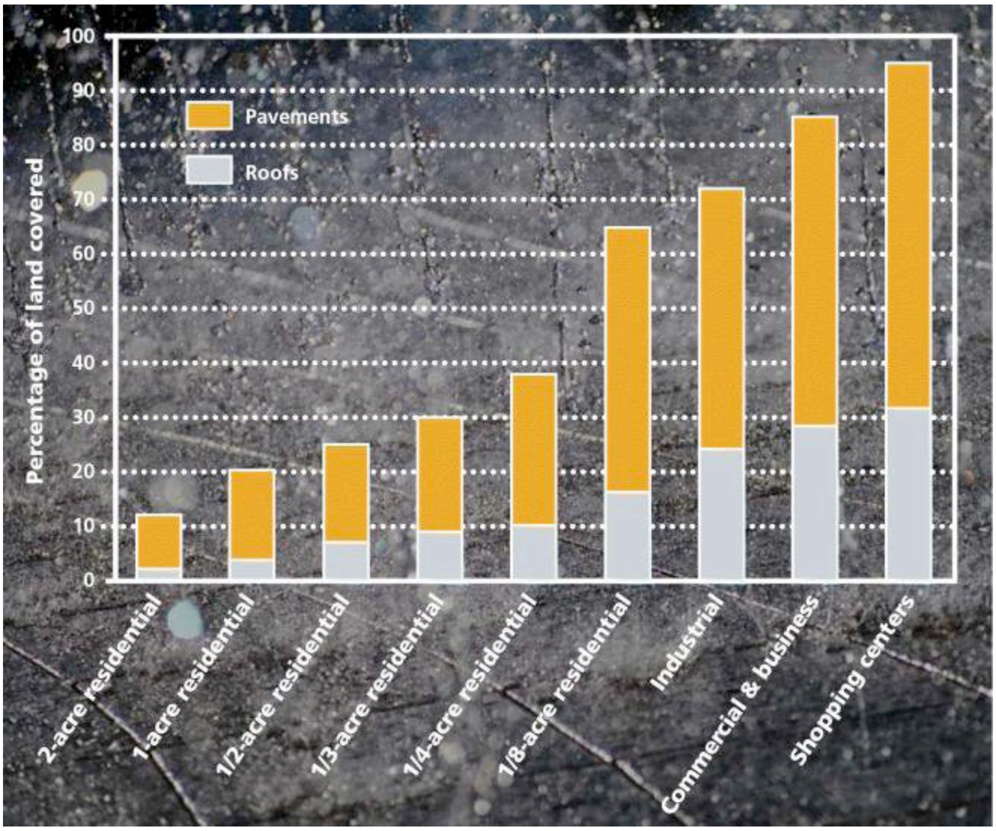


Figure 2.4: Developed Land Use Levels of Imperviousness

Source: L Frazer, 2005 (after B Ferguson , 2005)

The relationship between imperviousness and runoff has been explored by a number of researchers (e.g. Schueler, 1987; American Society of Civil Engineers, and the Water Environment Federation, 1998), and found to be closely correlated (refer to Figure 2.5) except at very low levels where other factors such as soils nature or slopes become important (Schueler, 1987).

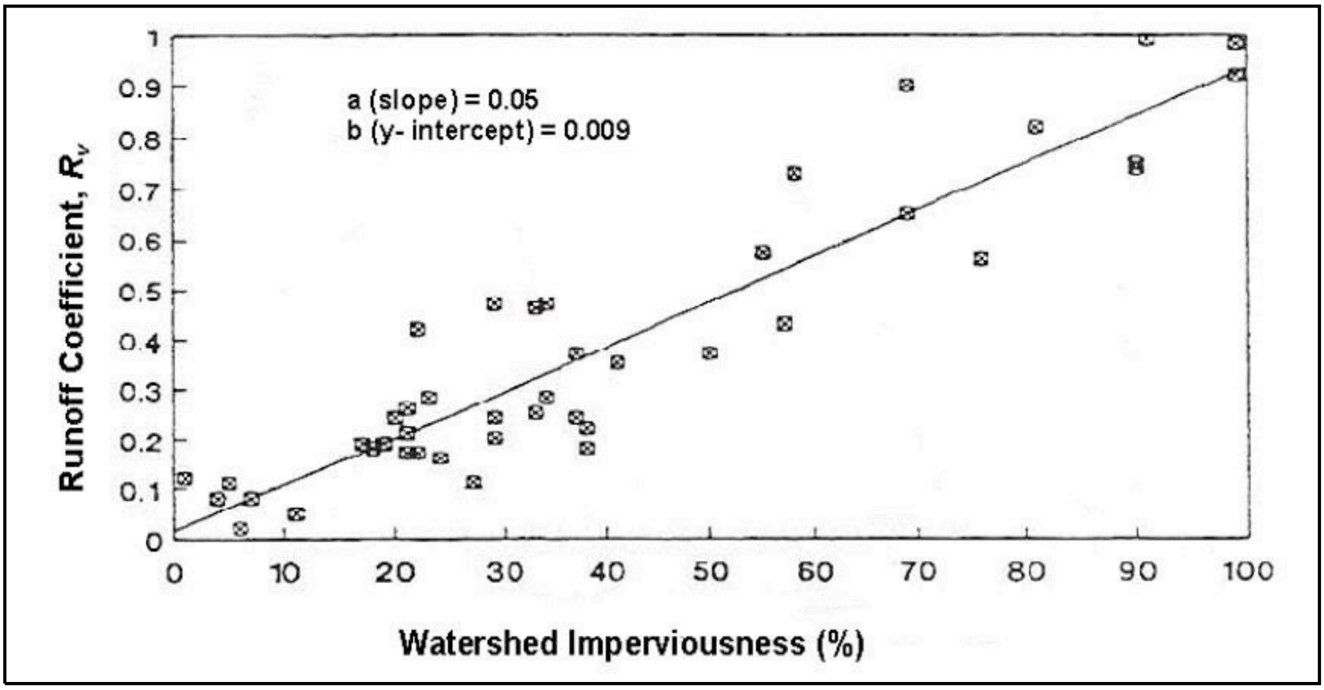


Figure 2.5: Relationships between impervious cover and the volumetric runoff coefficient
Source: Source USEPA after Schueler, 1987

Information on runoff coefficients suggested for general New Zealand conditions can be found in the *New Zealand Building Code Clause E1 Surface Water* (2010):

Description of surface	C	Description of surface	C
Natural surface types		**Developed surface types**	
Bare impermeable clay with no interception channels or run-off control	0.70	Fully roofed and/or sealed developments	0.90
Bare uncultivated soil of medium soakage	0.60	Steel and non-absorbent roof surfaces	0.90
Heavy clay soil types:		Asphalt and concrete paved surfaces	0.85
– pasture and grass cover	0.40	Near flat and slightly absorbent roof surfaces	0.80
– bush and scrub cover	0.35	Stone, brick and precast concrete paving panels	
– cultivated	0.30	– with sealed joints	0.80
Medium soakage soil types:		– with open joints	0.60
– pasture and scrub cover	0.30	Unsealed roads	0.50
– bush and scrub cover	0.25	Railway and unsealed yards and similar surfaces	0.35
– cultivated	0.20	**Land use types**	
High soakage gravel, sandy and volcanic soil types:		Industrial, commercial, shopping areas and town house developments	0.65
– pasture and scrub cover	0.20	Residential areas in which the impervious area is less than 36% of gross area	0.45
– bush and scrub cover	0.15	Residential areas in which impervious area is 36% to 50% of gross area	0.55
– cultivated	0.10		
Parks, playgrounds and reserves:			
– mainly grassed	0.30		
– predominantly bush	0.25		
Gardens, lawns, etc.	0.25		

This change in **imperviousness** and thence **runoff** impacts on the **time of concentration** or speed at which any runoff is delivered to **a receiving environment** (refer to Figure 2.6). The time of concentration is influenced by catchment characteristics such as shape and surface area, slope length and gradient, orientation, nature of soil, vegetal cover or morphology of the waterbodies of the **catchment** area, and the effects arising from changes to imperviousness can be both indirect and direct:

- **Indirect effects** include those visible during dry weather periods when urban streams tend to have less flow because of decreased groundwater recharge from stormwater **infiltration** (refer to Figure 2.7). Where groundwater contributions to a watercourse are not adequate, then urban streams may start to lack the base flow necessary to sustain healthy habitats during extended periods of dry weather. In an analysis of stream flow in three Waitakere catchments, Trowsdale (2005) reported an overall reduction in base flow with increased urbanisation to the extent that stream flow can be suspended completely. This mirrors research undertaken by numerous other overseas as well as other New Zealand examples where increased imperviousness is resulting in reduced groundwater levels and resources which manifest as the drying of wetlands, loss of springs, and reduced base flows to lakes and rivers (Bannerman, 1994; Schueler, 1994; L Frazer, 2005).

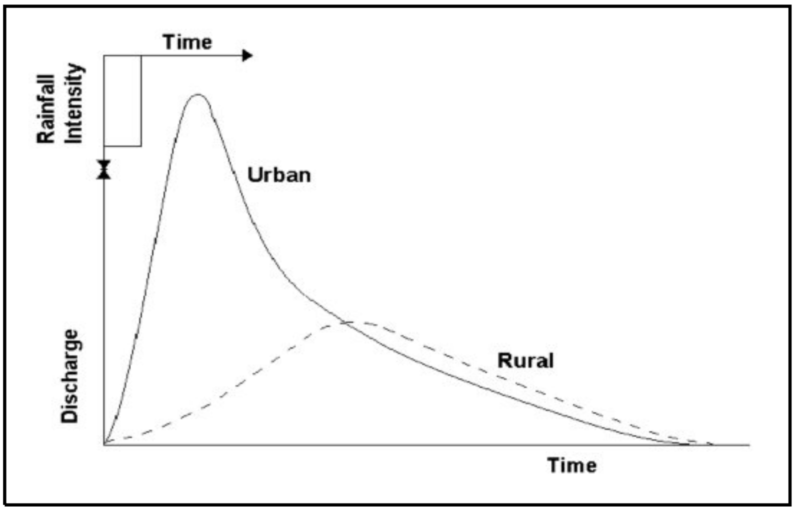


Figure 2.6: Flood hydrographs for urbanised and natural drainage basins

Source Canadian Ministry of Environment from Watt et al., 2000

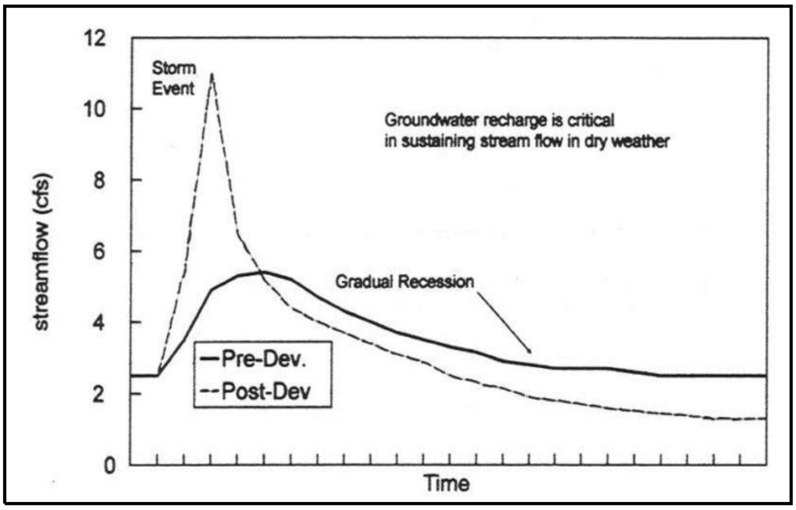


Figure 2.7: Decline in stream flow due to development

Source USEPA from MDE, 2000

Until fairly recently it has commonly been perceived that there is a relative abundance of water in New Zealand. However New Zealand's water resources as a whole are increasingly coming under pressure and a combination of factors is resulting in the need to critically address and manage the resource. Whilst surface waters have predominantly been used to source and supply water needs, the impact of groundwater and other aspects or systems on these resources is now being recognised:

> *"Once used, water can take many years to re-enter the water cycle …. The slow recovery of natural water resources has become more of an issue in recent years as farmers increasingly irrigate areas of land that were previously used for low-intensity purposes. Deforestation and conversion to pasture is also reducing forest cover and increasing direct runoff, rather than retaining and storing water in the forest undergrowth and soil mantle."* (IPENZ, 2008).

Although roads are a source of contaminants, provided pretreatment occurs, the management of stormwater from the roading network can play its part in managing recharge and effects on catchment hydrology; particularly where permeable soils and / or groundwater resources either facilitate or necessitate this.

Another significant indirect effect arises as a consequence of the use of measures and engineering controls which are put in place to manage the effects of increased imperviousness. This "collateral damage" as it were, can arise as a consequence of the installation of rip rap, "hydraulic improvement works", or similar structural controls and is therefore addressed after the range of direct effects have been discussed.

- In contrast to the indirect effects outlined above, **direct effects** can include:
  - Decreased **time of concentration**;
  - Increased runoff velocity; and
  - Increased magnitude and frequency of runoff events of all sizes.

This essentially results in a change to flood levels and timing (refer to Figure 2.8); with more stormwater reaching a watercourse more quickly, flood levels increase and watercourses respond more quickly to rainfall (Booth, 2002 from Hollis, 1975).

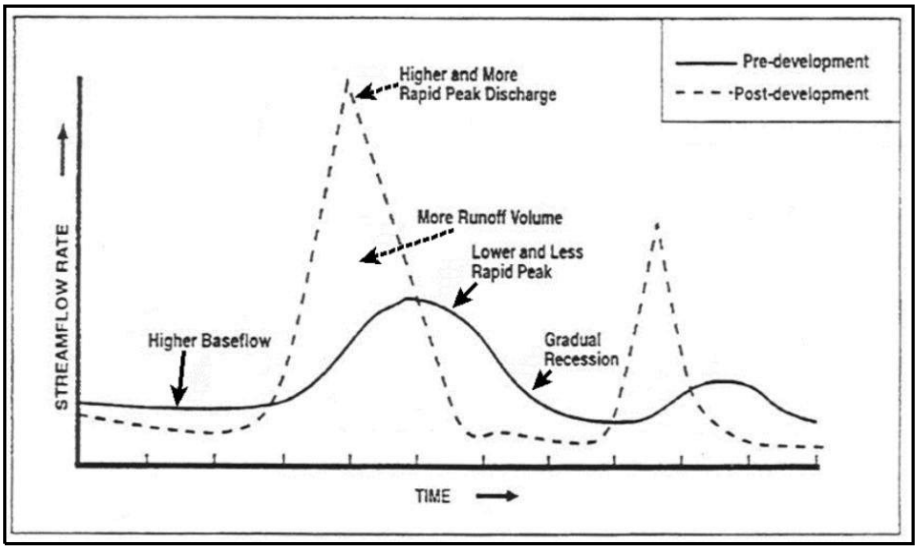


Figure 2.8: Changes to the receiving water hydrograph following development
Source USEPA from MDE, 2000