



How Urbanization Affects the Water Cycle



An educational program for land use decision makers that addresses the relationship between land use and natural resource protection.

Why is the Water Cycle Important?

The water cycle, also known as the hydrological cycle, is the continuous exchange of water between land, waterbodies, and the atmosphere. Approximately 97% of the earth's water is stored in the oceans, and only a fraction of the remaining portion is usable freshwater. When precipitation falls over the land, it follows various routes. Some of it

Impervious Cover (IC):
all hard surfaces that do not allow water to penetrate the soil, such as rooftops, driveways, streets, swimming pools, and patios

evaporates, returning to the atmosphere, some seeps into the ground, and the remainder becomes surface water, traveling to oceans and lakes by way of rivers and streams. Impervious surfaces associated with urbanization alter the natural amount of water that takes each route. The consequences of this change are a decrease in the volume of water that percolates into the ground, and a resulting increase in volume and decrease in quality of surface water. These hydrological changes have significant implications for the quantity of fresh, clean water that is available for use by humans, fish and wildlife ¹.

MORE WATER FASTER

DEVELOPED LANDS
Rain pours more quickly off of city and suburban landscapes, which have high levels of impervious cover

NATURAL LANDS
Trees, brush, and soil help soak up rain and slow runoff in undeveloped landscapes

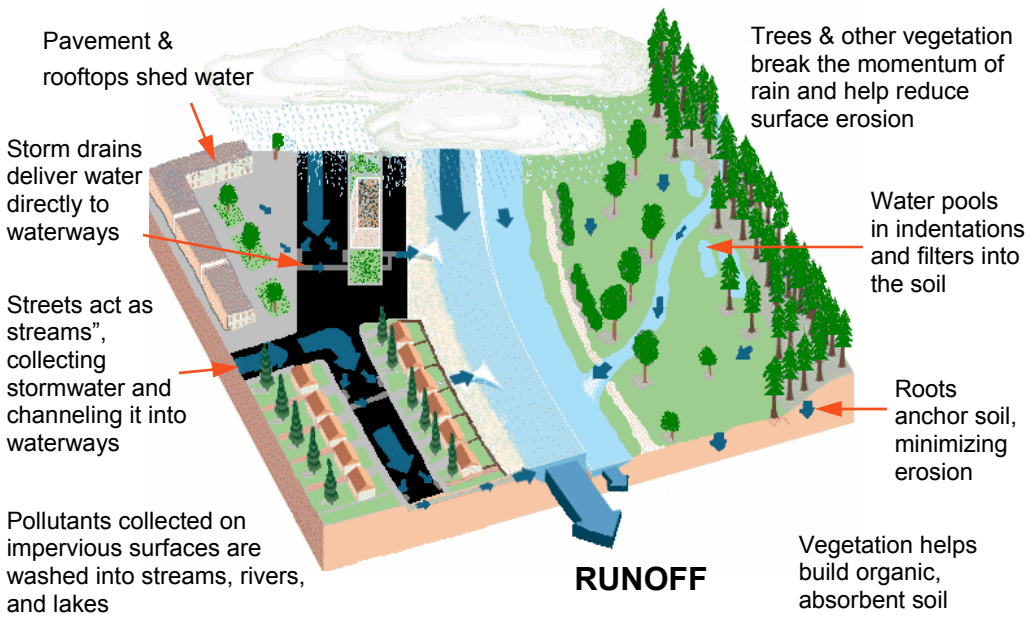


Figure 1 (left) illustrates how impervious cover and urban drainage systems increase runoff to creeks and rivers. The larger volume, velocity and duration of flow acts like sandpaper on stream banks, intensifying the erosion and sediment transport from the landscape and stream banks. This often causes channel erosion, clogged stream channels, and habitat damage.

Channelized rivers and streams exhibit similar problems accommodating large peak runoff volumes and supporting aquatic ecosystems ^{4,5}.

Graphic Sacramento Bee²

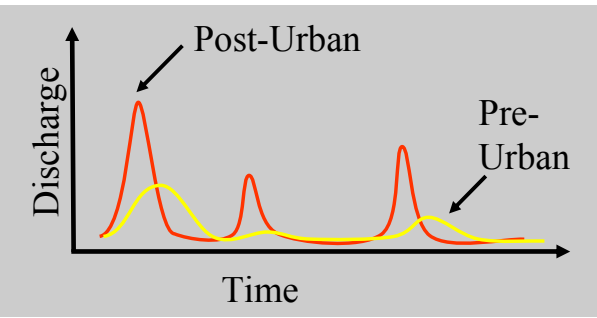


Figure 2 The hydrograph (left) illustrates stormwater peak charges in a urban watershed (red line) and a less developed watershed (yellow line). In watersheds with large amounts of impervious cover, there is a larger volume and faster rate of discharge than in less developed watersheds, often resulting in more flooding and habitat damage.

Adapted from Santa Clara Hydromodification Management Plan ³

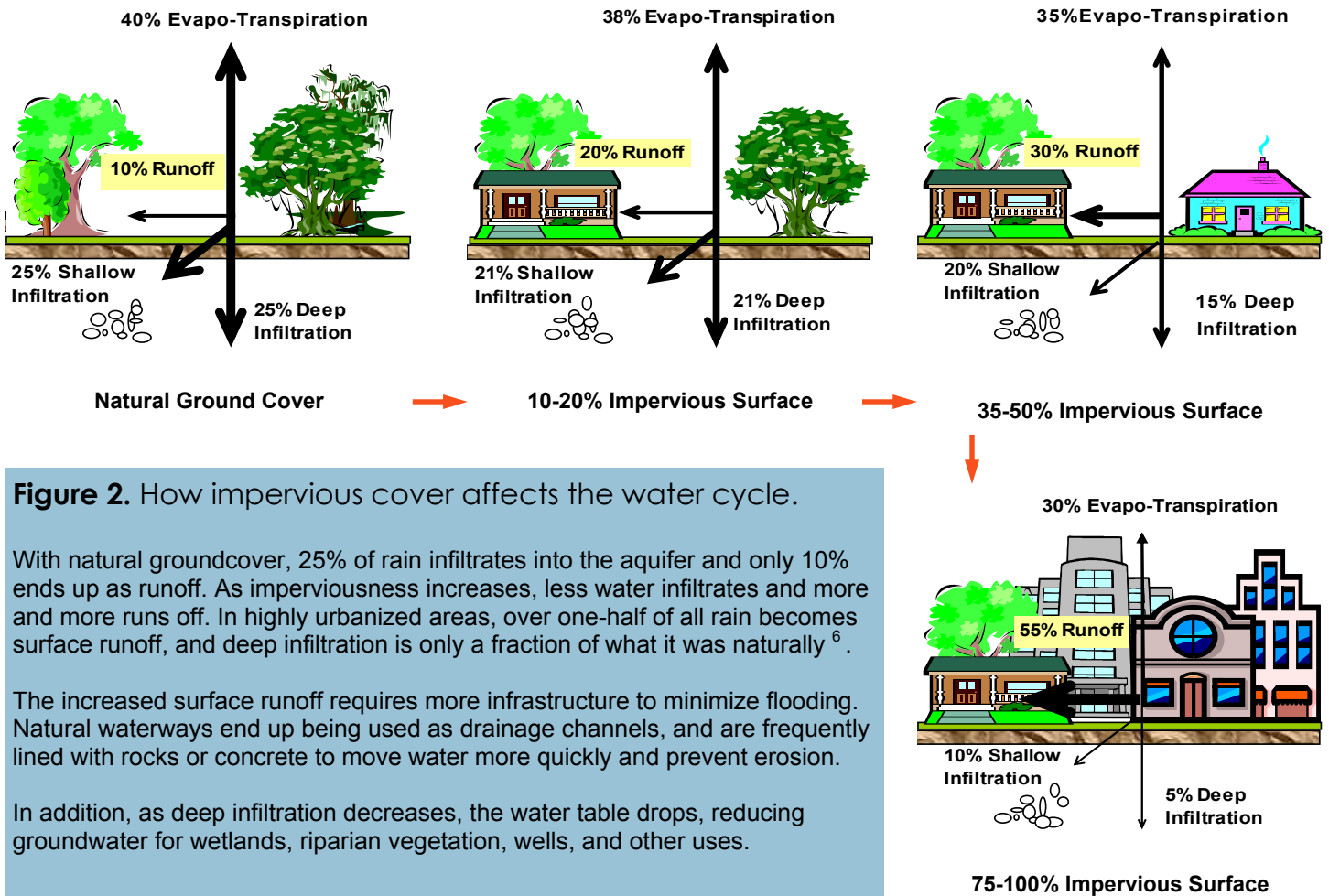


Figure 3. Relationship between imperviousness and stream quality.

In most cases, when impervious cover (IC) is less than 10% of a watershed, streams remain healthy. Above 10% impervious cover, common signs of stream degradation are evident. They include ^{1,4}:

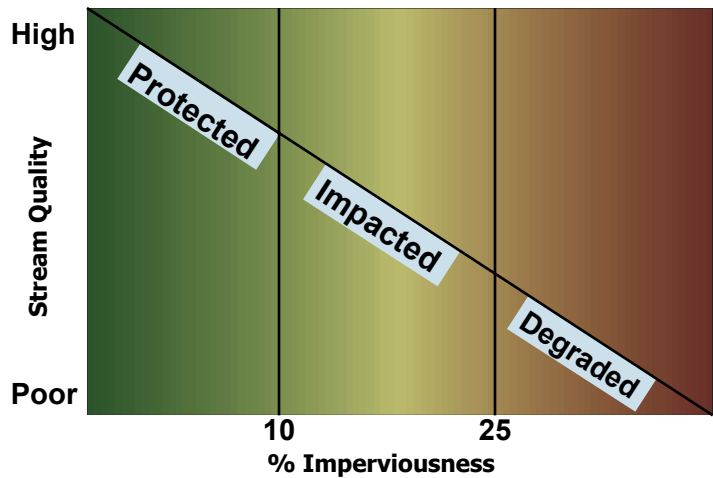
- Excessive stream channel erosion (bed and bank)
- Reduced groundwater recharge
- Increased size and frequency of 1-2 year floods
- Decreased movement of groundwater to surface water
- Loss of streambank tree cover
- Increased contaminants in water
- Increased fine sediment in stream bed
- Overall degradation of the aquatic habitat



Pictures from different reaches of Secret Ravine Creek, Placer County, California

Figure 4. Conceptual relationship between IC and stream habitat quality.

Between 10 – 25% imperviousness, major alterations in stream morphology occur that significantly reduce habitat quality. At greater than 25% impervious cover, streams suffer from loss of habitat, floodplain connectivity, and bank stability, as well as decreased water quality ¹.



California Examples

Studies on urban streams across California have consistently found similar patterns of degradation. For example, in Los Penasquitos Creek in San Diego County, watershed development grew from 9% to 37% urbanization between 1966-2000. From 1973-2000, the total annual urban runoff in the upper watershed increased by 4% per year, resulting in more than a 100% increase in runoff for the measured time period. The flood magnitude for the 1-2 year storm also increased by more than 5 fold from 1965-2000 ⁷.

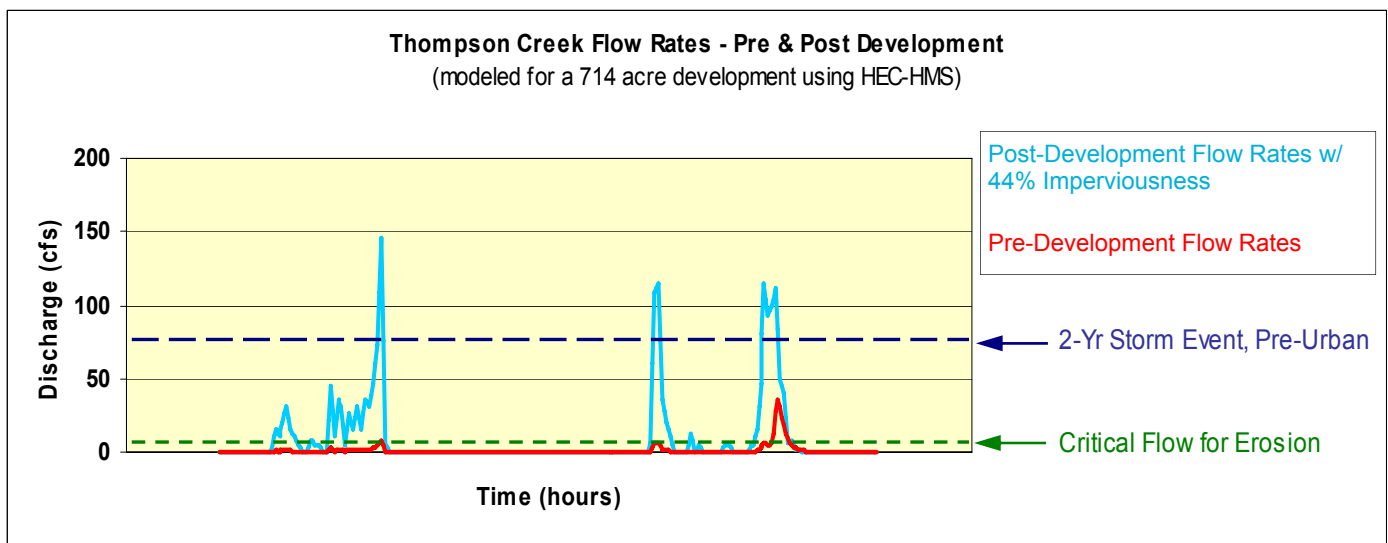


Figure 5. Comparison of Pre- and Post-Development Flow Conditions, Thompson Creek, Santa Clara Valley, CA.

The impact of 44% impervious cover on a variety of hydrological parameters on Thompson Creek were predicted during a random seven-day period. 50 years worth of data was used in the modeling process. The most obvious difference between the pre and post development conditions is the significantly greater volume of runoff generated after development, as seen in the above graph. Whereas pre-development flows were typically at flow rates that would not cause bank erosion (green line), post-development flows mainly exceeded the flow needed to destabilize stream banks. Further, post-development flows, in contrast to pre-development flows, would regularly exceed the historic 2-year storm event.

The impacts of these altered conditions are degradation of the aquatic habitat and increased frequency of flood events. In the Thompson Creek sub-watershed, hydrologists also found that the increased imperviousness associated with development approximately doubled stormwater runoff for peak discharges for 2, 5, and 10-year storm event. Results in this watershed and elsewhere have shown that the 0 – 10 year storms are the events that overwhelmingly alter the shape and size of streams. Thus, doubling of the rate of runoff will have significant impacts on aquatic resources as well as the risk of flooding ³.





In a Nutshell

Increased impervious cover associated with urbanization alters the natural cycling of water. Changes in the shape and size of urban streams, followed by decreased water quality, are the most visible effects of increased imperviousness. Greater frequency and severity of flooding, channel erosion, and destruction of aquatic habitat commonly follow watershed urbanization. Alterations in the aquatic environment associated with these hydrological changes greatly compromise the normal functioning of our waterways.

Resources on the Web

Center for Watershed Protection

www.cwp.org

State Water Resources Control Board(NPS Encyclopedia)

www.waterboards.ca.gov/nps/encyclopedia.html

National NEMO Network

<http://nemonet.uconn.edu/>

Low Impact Development Center

www.lowimpactdevelopment.org/

EPA information on hydrological cycle

www.epa.gov/seahome/groundwater/src/cycle.htm

The Stormwater Manager's Resource Center

www.stormwatercenter.net

California WALUP Partners

California Coastal Commission

Office of Environmental Health
Hazard Assessment, Cal/EPA

USC Sea Grant

State Water Resources Control Board

California Association of
Resource Conservation Districts

Local Government Commission

UC Davis Extension

UC Santa Barbara

NOAA Coastal Services Center

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- 2 Knudson, Tom, and Nancy Vogel. Graphic by Scott Flodin. "The Gathering Storm Part II, Bad land-use policies invite a catastrophe." The Sacramento Bee 24 Nov 1997. 21 Jul 2005, www.sacbee.com/static/archive/news/projects/gathering_storm/floodplains.html
- 3 Santa Clara Valley Urban Runoff Pollution Prevention Program Hydromodification Management Plan, 2005. Posted at: http://ci7e.secoresites.net/hmp_final_draft/
- 4 Booth, Derek B. "Urbanization and the Natural Drainage System-Impacts, Solutions, and Prognosis." The Northwest Environmental Journal 7.1 (1991): 93-118.
- 5 Hollis, G. E., 1975, The effects of urbanization on floods of different recurrence intervals. Water Resources Research, 11, 431-5
- 6 Chester L. Arnold and C. James Gibbons. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." Journal of the American Planning Association. Spring, 1996. p. 255
- 7 White, Michael D., and Keith A. Greer. "The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Penasquitos Creek, California" 2005.
- 8 Stein, Eric D. "(NB21F-05) "Effect of Increases in Peak Flows and Imperviousness on Stream Morphology of Ephemeral Streams in Southern California." North American Benthological Society (2005).