1 Introduction

This Manual has been prepared for the Bay Area Stormwater Management Agencies Association (BASMAA), an association of regional stormwater quality agencies around the San Francisco Bay and Delta.

Finding that the way we design and build communities has a direct effect on water quality, BASMAA has prepared this Manual with a focus on residential, commercial and industrial development, including new development, infill development and redevelopment. It aims to help designers, developers, and municipal agencies create communities that achieve water quality goals.

The Manual attempts to communicate basic stormwater management concepts and to illustrate simple, practical techniques to preserve the natural hydrologic cycle. These techniques are combined in a series of case studies to show how they may be integrated into projects. These case studies reflect the wide range of geographical, hydrological and market conditions found in the San Francisco Bay area, and must be adapted to specific site conditions.

For planners, designers and engineers accustomed to approaching stormwater management as a challenge in controlling large concentrated flows, the approach presented here may require a shift in thinking. Rather than considering only the large, infrequent storms normally associated with drainage and flood control, this document focuses on the small, frequent storms that have the most impact on urban water bodies, and shows how controls for smaller storms can be integrated into a comprehensive drainage system. Also, rather than considering the generally more expensive and complicated end-of-pipe solutions, this document seeks to illustrate the simpler, more economical stormwater management opportunities presented by starting at the source.

The way we design and build communities has a direct effect on water quality.

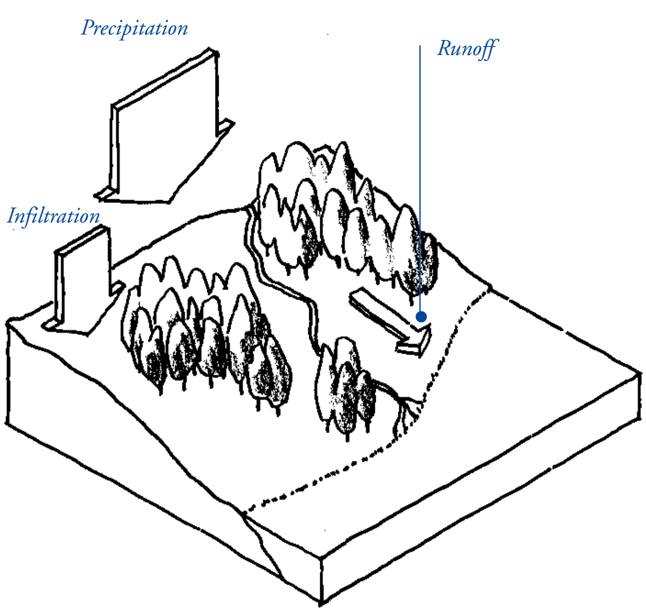
The Hydrologic Cycle

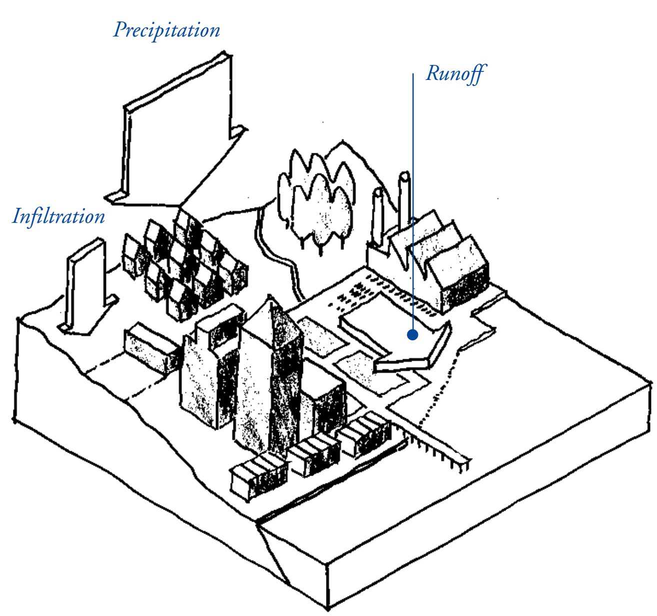
The continuous circulation of the earth's water from sky to land to sea to sky is called the Hydrologic Cycle.[1]

In its natural condition, soil is covered with a complex matrix of mulch, roots and pores which absorb rainwater. As rainwater infiltrates slowly into the soil, impurities are cleansed by natural biologic processes. Because most rain storms are not large enough to fully saturate the soil, only a small percentage of annual rainwater flows over the surface as runoff. What does become runoff usually travels in a slow meandering pace which allows suspended particles and sediments to settle. In the natural condition, the hydrologic cycle creates a stable supply of groundwater, and surface waters are naturally cleansed of impurities (although some sediment is carried with the flow) before arrival into the sea.

The impervious surfaces associated with urbanization prevent water from infiltrating into the soil. Even the smallest rainstorms generate runoff, which collects pollutants and sediments, and is concentrated in narrow channels or pipes. This rapid, concentrated water flow can affect the hydrologic cycle in four ways: increased volume of flow which could mean increased flood potential, minimized impacts on channel destabilization, increased concentration of pollutants, and reduced groundwater levels. [2]

Builders can avoid these negative impacts by designing developments with stormwater systems that preserve and restore the natural hydrologic cycle.





The hydrologic cycle

In **pre-development** landforms, a large percentage of precipitation infiltrates into the soil. A small percentage remains on the surface as runoff.

In **Post-development,** opportunities for infiltration are typically reduced, and a larger proportion of total precipitation becomes surface runoff.

Regulatory Context

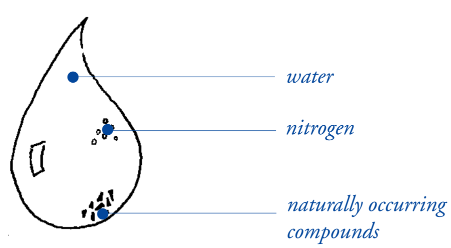
As rain falls, it picks up pollutants from the air. Then as it becomes runoff it collects more impurities while passing over rooftops, streets, parking lots, landscaping, and gutters. This runoff typically enters a storm drain system that rapidly conveys it, untreated, to a lake, creek, river, bay or ocean. With the progress made in the past twenty-five years in controlling pollution from factories and other industrial point sources, this concentration of pollutants from various dispersed sources – nonpoint source pollution – is today responsible for over half of the water quality problems in waters of the United States.[3]

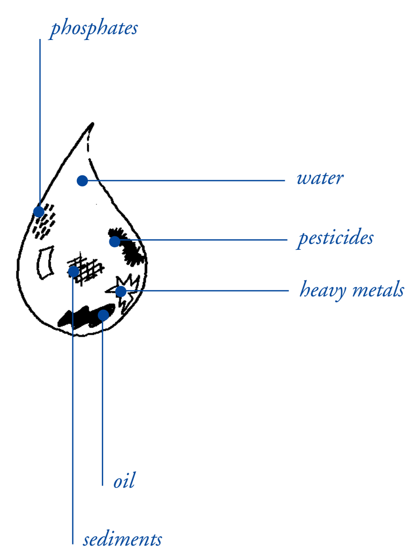
The Clean Water Act of 1972, as amended in 1987, prohibits the discharge of pollutants into waters of the United States unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. Most large population centers are already subject to NPDES permits, and smaller population centers may be required to comply in the next few years. Certain industries and construction projects specified by the U.S. Environmental Protection Agency must also obtain an NPDES permit in order to discharge stormwater runoff. Thus most Bay Area cities, and most large development projects, must comply with NPDES permit requirements.

The federal NPDES permit program requires that subject municipalities "develop, implement and enforce controls to reduce the discharge of pollutants from municipal separate storm sewers which receive discharges from areas of new development and significant redevelopment… [including] after construction is completed."[4]

Within this regulatory context, developers and municipal permitting agencies are required to implement controls that reduce water pollution carried in runoff. These techniques may include storage (detention), filtration, and infiltration practices.

The Nationwide Urban Runoff Program and recent studies "indicate that planning and designing for the minimization of pollutants in stormwater discharge is the most cost effective approach to stormwater quality management." Reducing pollution in stormwater by preventing or reducing the discharge of pollutants at the source is a technically sound and cost effective strategy to bring development into compliance with Federal law.





What's in a drop of runoff?

Pre-development runoff generally contains water and a low concentration of naturally occuring compounds.

Post-development runoff contains water and a variety of pollutants collected and concentrated from impervious surfaces.

Infiltration and the risk of groundwater contamination

The purpose of this manual is to encourage landscape designs and features that mitigate increases in site runoff by promoting infiltration through the soil. Allowing rain and runoff to infiltrate into the soil reduces the quantity of pollutants reaching local streams and San Francisco Bay. When implemented throughout a stream's watershed, infiltration protects the stream from increased peak flows, which can cause down-cutting, bank erosion, sedimentation, and losses to property and habitat. The Regional Water Quality Control Board encourages the use of infiltration as a strategy to manage urban runoff and to help protect the beneficial uses of streams and San Francisco Bay. Regional Board staff expects that, as part of their NPDES-permitted stormwater management programs, municipalities will encourage developers to implement the designs and methods described in this manual.

However, any drainage feature, including many of those described in this book, that infiltrates runoff poses some risk of potential groundwater contamination. The Regional Water Quality Control Board prohibits the unauthorized construction or use of any "artificial excavation for the purpose of extracting water or injecting water into the underground."[5] The "Explanation of Policy" attached to Regional Board Resolution 81 states: "wells used to dispose of sewage and surface drainage bypass the normal processes of nature that occur at or near the surface of the soil. The use of such wells may allow for injection of waste into subsurface strata rapidly and unchanged in chemical quality." Illegal disposal of chemical wastes into dry wells and chemical spills have contaminated groundwater in some locations in the Santa Clara County. In some cases, the contamination is severe.

The risks associated with groundwater infiltration can be managed by:

- Designing landscape drainage features so that they promote infiltration of runoff, but do not inject runoff so that it bypasses the natural processes of filtering and transformation that occur in the soil.
- Taking reasonable steps to prevent the illegal discharge of wastes to drainage systems.

The designs in this book promote infiltration only to the top 10 feet of soil. In general, designs that disperse runoff over landscaped areas, or through permeable surfaces, are the most effective, easiest to maintain and have lowest initial costs. These designs also minimize the risks of illegal disposal because the surface is visible and the infiltration rate (per unit area) is relatively low.

For some sites, it may be feasible to use detention basins or dry wells to infiltrate additional runoff in a more compact area. When these techniques are used, the designer should consider the potential for illegal disposal or chemical spills. Detention basins and dry wells should not drain, or be located near, work areas where wash-waters or liquid wastes are generated or where hazardous chemicals are used or stored. If dry wells are used, there should be a sufficient thickness of unsaturated zone below the dry well to allow natural processes to function effectively. Detention basins and dry wells should be clearly marked with a "no dumping" message and should be inspected regularly by the municipal stormwater management program. In some jurisdictions, the local groundwater management agency may require that detention basins, dry wells and similar structures be permitted at the time of construction. Always check with the local groundwater management agency and municipality for construction standards and permitting requirements.

Impervious land coverage as an environmental indicator

A new environmental indicator is emerging to measure the health of urban watersheds — impervious land coverage.[6]

Impervious land coverage is a fundamental characteristic of urban and suburban areas. The rooftops, roadways, parking areas, and other impervious surfaces of development cover soils that, before development, allowed rainwater to infiltrate. By depriving the soil of its ability to infiltrate rainwater, a host of environmental consequences follow.

One of the environmental consequences of impervious land coverage is stream degradation. Impervious surfaces associated with urbanization cause stream degradation in four ways:

1. Rainwater is prevented from infiltrating into the soil, where it can recharge groundwater, reducing base stream flows.

2. Because it cannot infiltrate into the soil, more rainwater runs off, and runs off more quickly, causing increased flow volumes, accelerating erosion in natural channels, and associated reduction of habitat and other stream values. Flooding and channel destabilization may require construction to channelize the stream, with further loss of natural stream uses.

3. As runoff moves over large impervious areas, it collects and concentrates nonpoint source pollutants – pollution from cars, roadways, parking lots, rooftops, etc. – increasing pollution in streams and other water bodies.

4. Impervious surfaces retain and reflect heat, causing increases in ambient air and water temperatures. Increased water temperature negatively impacts aquatic life and reduces the oxygen content of nearby waterbodies.

Impervious surfaces can be defined as any material that prevents or reduces the infiltration of water into the soil. While roads and rooftops are the most prevalent and easily identified types of impervious surface, other types include sidewalks, patios, bedrock outcrops, and compacted soil. As development alters the natural landscape, the percentage of the land covered by impervious surfaces increases.

Roofs and roads have been around many years, but the ubiquitous and impervious pavement we take for granted today is a relatively recent phenomenon. A nationwide road census showed that in 1904, 93 percent of the roads in America were unpaved. With the ascendancy of the automobile in the mid-twentieth century, the interstate highway system, and the growth of suburbia, the percentage of impervious surfaces increased dramatically. A prime contributor to the increase of impervious land coverage is the residential street network – since World War II, typical residential street widths have increased by 50%.

An increasing body of scientific research, conducted in many geographic areas and using many techniques, supports the theory that impervious land coverage is a reliable indicator of stream degradation. Furthermore, impervious land coverage is a practical measure of the impact of development on watersheds because:

- it is quantifiable, meaning that it can be easily recognized and calculated.
- it is integrative, meaning that it can estimate or predict cumulative water resource impacts independent of specific factors, helping to simplify the intimidating complexity surrounding nonpoint source pollution.
- it is conceptual, meaning that it can be easily understood by water resource scientists, municipal planners, landscape architects, developers, policy makers and citizens.

Water resource protection at the local and regional level is becoming more complex. A wide variety of regulatory agencies, diverse sources of nonpoint source pollution, and a multitude of stakeholders makes it difficult to achieve a consistent, easily understandable strategy for watershed protection. Impervious land coverage is emerging as a scientifically sound, easily communicated, and practical way to measure the impacts of new development on water quality.

This document illustrates a variety of site planning principles and design techniques for development. They all aim to reduce impervious land coverage, slow runoff, and to maximize opportunities for infiltration of rainwater into the soil.

Impervious land coverage thresholds

A certain amount of impervious land coverage is unavoidable in any development. Rooftops, by definition, must prevent infiltration of rainwater. Circulation systems– roads, parking, driveways– are the other, and usually most extensive, component of impervious land coverage. For planners, designers and regulators, the essential question is at what threshold of impervious land coverage does significant stream degradation begin?

Many recent studies have evaluated stream and wetland health using many criteria such as pollutant loads, habitat quality, and aquatic species abundance and diversity. These studies consistently show that significant water quality impacts begin at impervious land coverage levels of as little as 10%. At impervious land coverage over 30%, impacts on streams and wetlands become more severe, and degradation is almost unavoidable without special measures.

These impacts on stream health include:

- Creation of significant "new runoff," because soil that would normally absorb rainfall is covered with impervious surfaces.
- Streams receive greater flows more frequently. For example, flow equal to a pre-development 2–year storm may occur every 2–3 months after development.
- The stream channel may need to enlarge itself to contain increased flows, causing stream bank erosion and loss of habitat.
- Stream bank erosion produces sediment which settles where and when velocities slow, covering aquatic vegetation and fish spawning beds, furthering the loss of habitat.

These studies suggest that three broad categories can be established using simple numeric thresholds illustrating the general relationship between impervious land coverage and stream health (exact thresholds/percentages may vary depending on region):

Impervious land coverage	*Stream health*
< 10%	"sensitive"
> 10 and < 30%	"degrading"
> 30%	"non-supporting"

Sensitive streams generally have stable channels, good water quality and good stream biodiversity. Degrading streams generally have unstable channels, fair water quality and biodiversity. Non-supporting streams may have highly unstable channels, fair to poor water quality and poor stream biodiversity.[7]

These impervious land coverage percentages must be measured across an entire site or development area. Sometimes lower overall impervious coverage can be achieved by clustering development at higher densities on one portion of a site, while maintaining open space elsewhere.

Given land values and population densities in the Bay Area, less than 30% overall impervious coverage may be difficult to attain in many basins of a water resource. Even in higher density developments, the impact of impervious land coverage can be mitigated by a variety of site planning and design techniques, which are illustrated in the following pages.

These techniques have three basic goals:

- to minimize overall impervious land coverage and maximize infiltration,
- to minimize as much as practical remaining impervious areas that are not-directly-connected to the storm drain system, and
- to slow runoff within a drainage system.

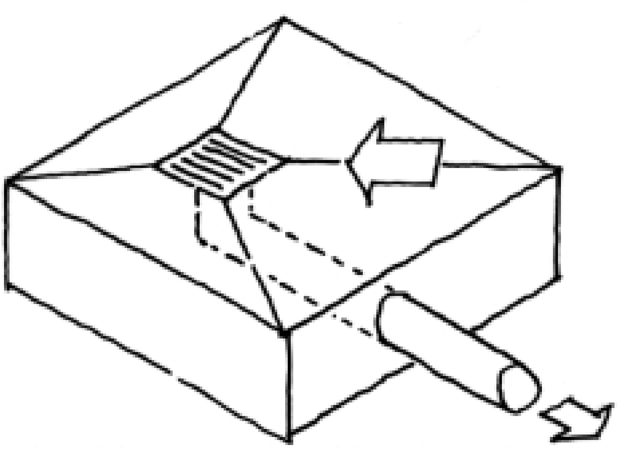
Two approaches to stormwater management

The conveyance approach to stormwater management seeks to "get rid of the water." A conveyance stormwater system collects and concentrates runoff through a network of impervious gutters, drainage structures and underground pipes. As the conveyance system flows downstream, additional tributary conveyance systems feed into it, requiring it to be continually enlarged as it approaches its outfall. Because the system collects water from impermeable surfaces and carries it through impervious pipes, suspended pollutants are concentrated in the rapidly flowing runoff. When the system reaches its outfall, large volumes of polluted water can be emptied, untreated, into a natural water body.

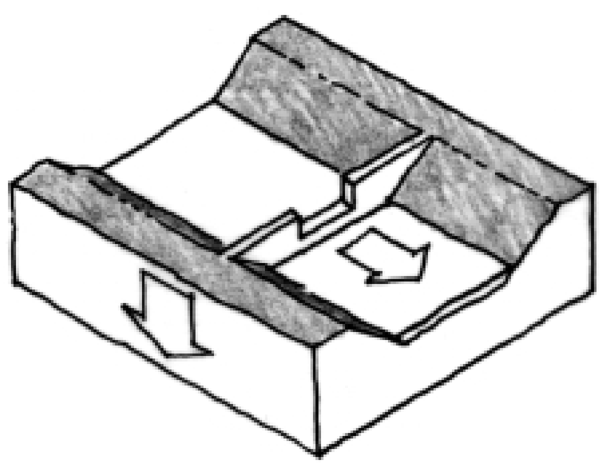
Several factors contribute to stormwater degradation in a conventional development. Large paved roadway surfaces create and collect runoff. Building sites may be graded severely, removing natural vegetation that absorbs runoff. The curbs, gutters and catch basins collect runoff and carry it rapidly, providing little opportunity for infiltration. In this way, large quantities of runoff are created and carried in a short time to the outfall of a conveyance stormwater system, carrying sediments and other pollutants as a fast flowing untreated discharge into the bay.

The infiltration approach to stormwater management seeks to "preserve and restore the hydrologic cycle." An infiltration stormwater system seeks to infiltrate runoff into the soil by allowing it to flow slowly over permeable surfaces. These permeable surfaces can double as recreational and landscape areas during dry weather. Because the infiltration network allows much of the runoff to return to the soil, overall runoff volume is reduced, and more water is available to replenish groundwater and maintain stream base flows. The slow flow of runoff allows pollutants to settle into the soil where they are naturally mitigated. The reduced volume of runoff that remains takes a long time to reach the outfall, and when it empties into a natural water body, its pollutant load is greatly reduced.

A development designed for stormwater quality generates less runoff because overall impervious land coverage is reduced through clustering and other means. Building sites are fit into the contours, and preserve vegetation as far as feasible. The drainage system attempts to slow runoff, and provides opportunities for it to filter into the soil. In dry weather these infiltration areas can be used for recreation or wildlife habitat. Smaller runoff volumes are created overall, and these volumes take a longer time to the outfall. When runoff from an infiltration-based system arrives, it's cleaner, and moving more slowly as it empties into the bay.



Conveyance Approach



Infiltration Approach