

Infiltration BMPs: Factors Controlling Effectiveness

Water Quality Factsheet for Permit Applicants

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Introduction

Infiltration Best Management Practices (BMPs), which maintain or enhance on-site infiltration of stormwater runoff, should be considered for most projects, because of the effectiveness and low cost of using the natural features of a site to improve water quality, recharge groundwater, maintain stream base-flows, and protect stream channels. In addition to reducing stormwater runoff flows, infiltration BMPs generally also function as a type of Treatment Control BMP to filter pollutants out of runoff.¹

Examples of infiltration BMPs include preserving natural areas of the site that provide infiltration, directing roof-top runoff into landscaping, installing a rain garden, constructing trenches and basins to enhance infiltration of site runoff, and (where space is limited) providing a subsurface gallery to infiltrate runoff. The California Stormwater Quality Association (CASQA) provides guidance on how to implement infiltration BMPs.²

This factsheet presents some of the issues that applicants should consider while investigating whether infiltration is feasible and appropriate for their project. The ability of a site to infiltrate runoff is primarily dependent on the permeability of the substrate (e.g., soil or sand) and the depth to groundwater. However, other factors are also important in deciding whether to use infiltration BMPs, including the type of development, the available space, geotechnical issues, pre-existing site contamination, and the maintenance required for the BMPs that are considered.

¹ Treatment Control BMPs are structural systems designed to remove pollutants from runoff by processes such as gravity settling of particulate pollutants, filtration, biological uptake, media adsorption, or other physical, biological, or chemical process. Examples include vegetated swales, detention basins, and storm drain inlet filters.

² See the *Stormwater Best Management Practices (BMP) Handbook – New Development and Redevelopment*. 2003. California Stormwater Quality Association (CASQA): <https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook>

Low Impact Development Approach

A Low Impact Development (LID) approach to stormwater management should be given precedence in all development, where appropriate and feasible, to minimize changes in the runoff flow regime (i.e., volume, flow rate, timing, and duration) resulting from the development, and thereby also reduce the transport of pollutants from the site.³ LID integrates preventive Site Design strategies with small-scale, distributed BMPs to replicate the site's pre-development hydrologic balance through infiltration, evapotranspiration, harvesting, detention, or retention of stormwater close to the source.⁴ LID Site Design strategies and BMPs that involve infiltration include, for example:

- Preserve natural hydrologic features (e.g., drainage swales, groundwater recharge areas, floodplains, and topographical depressions) that can provide infiltration of small storm volumes
- Avoid building impervious surfaces on highly permeable areas that provide natural infiltration. Cluster buildings and other impervious areas onto the site's least permeable soils.
- Minimize unnecessary soil compaction, which can greatly reduce the infiltrative capacity of soils. Amend soil if needed to enhance its infiltration and pollutant removal capacity.
- Install an infiltration/evapotranspiration BMP such as a bioretention system, vegetated swale, or rain garden
- Where pavement is required, install a permeable pavement system BMP (e.g., interlocking concrete pavers, porous asphalt, permeable concrete, or reinforced grass or gravel), where appropriate and feasible. Design permeable pavements so that runoff infiltrates into a subsurface recharge bed and the underlying soil, if feasible.
- Minimize directly-connected impervious areas, which are areas covered by a building or impermeable pavement that drain directly into the storm drain system without first flowing across permeable areas (such as vegetative landscaping or permeable pavement) for infiltration.
- Direct roof-top runoff into permeable landscaped areas.
- Direct runoff from impervious pavement into distributed permeable areas such as turf, recreational areas, medians, parking islands, and planter boxes for infiltration.
- Install an infiltration BMP such as a vegetated swale or filter strip to intercept runoff sheet flow from impervious pavements.
- Install a rainwater harvesting BMP, such as a rain barrel or cistern, to capture and store roof-top runoff for later use in on-site irrigation

Although infiltration is a cornerstone of LID, infiltration may not be appropriate or feasible in certain types of development, or may not be necessary if low levels of pollutants and runoff are anticipated to be generated.

³ For more information on Low Impact Development, see the Coastal Commission's *Low Impact Development* webpage: <http://www.coastal.ca.gov/water-quality/low-impact-dev/>

⁴ Site Design strategies are project design and site layout techniques that integrate existing site characteristics that affect runoff (such as topography, drainage patterns, vegetation, soil conditions, natural hydrologic features, and infiltration conditions) in the design of strategies to minimize post-development changes in the runoff flow regime, control pollutant sources, and, where necessary, remove pollutants.

Type of Development

Industrial

Infiltration may not be appropriate for industrial land uses where concentrated pollutants from spills, or even from everyday industrial operations, may contaminate soil or groundwater. Industrial and vehicle service facilities (including retail gasoline outlets, commercial car washes, and vehicle repair facilities), for example, are not logical choices for infiltration BMPs, since they use large volumes of chemicals that could contaminate soil or groundwater if spilled. In addition, many of these facilities already have soil or groundwater contamination from past practices. Former industrial sites that are being redeveloped require careful site investigation before considering the use of infiltration BMPs.

For sites where ongoing use of potential pollutants creates an elevated risk, it may be possible to isolate the high-risk activities, or to “pre-treat” the runoff with Treatment Control BMPs to remove pollutants of concern prior to infiltration. This type of site would usually be subject to an industrial storm water permit that would require isolation of wastes and good housekeeping practices, and may actually prohibit infiltration BMPs.

Single-Family Residences

Under most conditions, California Coastal Commission (CCC) staff has not been recommending that Treatment Control BMPs (other than LID BMPs) be required for development of individual single-family residences (SFRs). In part, this is because the costs can exceed the benefits given the low levels of polluted runoff from a typical SFR. Residential use of pesticides and fertilizers, release of landscaping materials (e.g., bark) or yard waste (e.g., grass cuttings), contributions to dry weather runoff from over-watering or overspray, or pet waste, may all adversely impact important coastal resources. For most SFRs, protection of coastal water quality can be achieved using LID Site Design strategies and LID BMPs that maintain or enhance on-site infiltration of runoff, combined with Source Control BMPs⁵ that keep pollutants out of runoff.

On the other hand, even the relatively moderate levels of polluted runoff from a typical SFR (with >2,500 ft² impervious surface area) may require additional water quality protection if the development is within 100 feet from environmentally sensitive habitat areas (ESHA) or coastal waters (including the ocean, estuaries, wetlands, rivers, streams, and lakes), or discharges directly to coastal waters (i.e., does not discharge to a public storm drain system). In this case, the development should implement BMPs (giving precedence to LID BMPs) sized to retain on-site (by means of infiltration, evapotranspiration, or harvesting), at a minimum, the runoff produced by the 85th percentile 24-hour storm event for volume-based BMPs, or two times the 85th percentile 1-hour storm event for flow-based BMPs.⁶

⁵ Source Control BMPs are structural features or operational practices that control pollutant sources and keep pollutants segregated from runoff. Examples include covering outdoor storage areas, using efficient irrigation, proper application and clean-up of potentially harmful chemicals and fertilizers, and proper disposal of waste.

⁶ For more information, see *Sizing Stormwater Best Management Practices* on the Coastal Commission’s Water Quality webpage for permit applicants: <http://www.coastal.ca.gov/water-quality/permits/>

Pre-Existing Subsurface Site Contamination

A second consideration in using infiltration techniques is whether or not there is preexisting subsurface contamination at a site. Often, infiltrated runoff will eventually reach the water table and mix with groundwater. The time it takes varies with the substrate, the depth to the water table and how much runoff is infiltrated. As runoff migrates through soils that are contaminated, it can mobilize the pollutants in the soil and enable transport into groundwater. Some locations already have polluted groundwater that can be further mobilized by infiltration of stormwater. Infiltration of stormwater runoff in areas with existing contamination is problematic at best, and may be prohibited by regulatory agencies.

Contaminated soil or groundwater can result from past practices and activities that occurred at the site, such as aerially deposited lead along highways (from the days of leaded gasoline), residual materials from past industrial practices or even from concentrations of naturally occurring substances (e.g., selenium) that may concentrate in soils under certain conditions.

Infiltration BMPs also must be carefully sited to avoid adverse impacts to On-site Treatment Systems (OSTS or 'septic' systems) leach fields. OSTS work on the same principal as infiltration BMPs, using the soil and substrate to filter contaminants. BMPs that concentrate infiltration near OSTS leach fields can compromise both systems.

Available Space to Accommodate Infiltration

Infiltration BMPs need sufficient surface area and depth so that the volume of runoff that needs to be treated (i.e., 'design storm volume') will not overflow from the infiltration area, and so that changes to groundwater conditions will not cause adverse impacts to structures (e.g., excessive moisture in crawlspaces). The area needed for infiltration BMPs will depend on the soil infiltration rates, depth of unsaturated soil above the groundwater surface, and presence of materials that may slow infiltration (e.g., suspended solids in runoff, or leaves on the ground).

Infiltration BMPs can be as small as 2-3% of the property's surface area, but they can also be larger, depending on the amount of impervious surfaces, infiltration rates, and design storm volume. In Contra Costa County, it is recommended that new development (presumably on appropriate soils) set aside 4% of the property for infiltration BMPs, and that the setback between the BMP and structures be 10 feet (or as recommended by a structural or geotechnical engineer).⁷ In either case, infiltration BMPs are likely to take up more space than simple inlet filter BMPs, and planning for their surface area and appropriate location during site design is important.

Permit conditions for project approval can establish thresholds for the amount of impervious surfaces that can be created or replaced during development of a site, can minimize building footprints, can maximize the use of permeable pavements, and can set other restrictions to control runoff. Permit conditions may also require that all runoff be retained on-site to the maximum extent practicable, or that the post-development hydrograph closely matches the pre-development hydrograph for a 2-year return interval storm event. The concept here is that the 2-year storm has the most influence on channel-forming processes. If the hydrograph for these storms is unaltered by development, most impacts to stream channels can be avoided. In

⁷ See *Stormwater C.3 Guidebook – Stormwater Quality Requirements for Development Applications, Municipal Regional Permit Edition*. 2010. Contra Costa Clean Water Program: http://www.cccleanwater.org/Publications/Guidebook/Stormwater_C3_Guidebook_5th_Edition.pdf

addition, the 2-year storm is approximately the 85th percentile storm, which has been found to be an appropriate design storm for many BMPs.

Because infiltration BMPs may change soil conditions by concentrating site infiltration into a small area, the substrate in that area will be saturated for longer periods and could impact nearby structures. In addition, the design and proper maintenance of the BMP will restrict types of activities on or adjacent to the BMP. Infiltration BMPs may need setbacks from structure foundations for geotechnical reasons, from steep slopes or coastal bluffs to avoid slope failure, or from sensitive habitats to protect from seepage of degraded runoff. Minimum required setbacks from foundations, basements, and utilities have not yet been published for the State of California, but are sometimes stated in local ordinances and stormwater manuals.

CASQA has published the following guidance on setbacks for infiltration BMPs, although this may be more appropriate for large developments and may be too conservative for small infiltration BMPs (e.g., at a SFR):⁸

Locate away from buildings, slopes and highway pavement (greater than 6m) and wells and bridge structures (greater than 30 m). Sites constructed of fill, having a base flow or with a slope greater than 15% should not be considered.

Another spatial constraint on infiltration BMPs is the proximity of the location to coastal waters or wetlands. Infiltration may be a benefit near surface waters or wetlands if it helps to maintain the existing hydrology, but such situations will require close attention to potential sources of contamination to the runoff. Proximity of surface waters to the BMP could mean an additional source of fresh water, but would also increase the risk that any pollutants passing through the BMP could be discharged to the surface with inadequate treatment. This is especially true for compounds that can pass through soils in a dissolved form without adsorbing to the substrate. For example, many nitrogen compounds can stay in a dissolved form and may cause eutrophication if discharged to the surface.

Projects within 200 feet of coastal waters should be considered for an additional site-specific evaluation. That evaluation may call for procedures that isolate the chemicals from the infiltration BMP, or else show that the soil has the capacity to adsorb the potential pollutants.

Geotechnical issues

Infiltration BMPs may not be appropriate on steep slopes, near coastal bluffs, or where soil saturation lowers the slope factor of safety or reduces the strength of a structural foundation.

Slope of Property

CASQA recommends that infiltration should not be considered on properties with a slope over 15%. Infiltration on steep slopes could lead to problems with captured runoff moving at higher velocities, as well as slope failure concerns. In addition, construction of a flat basin on a steep slope would require cut and fill work exacerbating slope stability issues, and possibly leading to infiltrated water exfiltrating (i.e., coming to the surface) prematurely.

⁸ *Stormwater Best Management Practices (BMP) Handbook – New Development and Redevelopment*. 2003. California Stormwater Quality Association (CASQA): <https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook>

Coastal Bluffs or Cliffs

Infiltration BMPs could cause new problems if they are above and close to coastal bluffs or cliffs. The focused area of infiltration could result in groundwater discharging through the bluff or cliff face, leading to reduced cohesive strength and subsequent increased erosion. This type of impact on coastal bluffs is already a problem caused by overwatering on some portions of the coast, and infiltration BMPs should not be used if it is likely that they will make the problem worse.

Slope Stability

The driving forces combining to make a particular slope geometry fail are its weight, including the weight of water within the slope, and the force of gravity. The forces resisting failure are cohesion and the internal friction of the particles that make up the slope material. Retaining structures, reducing the slope steepness, loading the ‘toe’ of the slope, and adding soil binders are all techniques used to increase slope stability.

Infiltration of runoff can increase the weight (and thus the driving forces) of the slope, increasing the chances of a slope failure. The introduction of water in a slope may also decrease the resisting forces, by raising the groundwater elevation within a slope, adding pore pressure within the soil mass, and making it easier for soil materials to slip by each other. Typically, when development is planned an engineer will perform a slope stability analysis to determine whether or not a slope has an adequate factor of safety. Infiltration should be considered in these analyses.

Structural Foundations

Buildings and other structures distribute the weight of the structure on a foundation to reduce the pressure on the substrate or soil around it. The foundation may support either vertical or horizontal loads. The impact of infiltration needs to be considered where foundations or structures could be affected. In the same way that water can affect soil cohesion and internal friction, infiltration can shrink or swell a soil or change the soil properties so that the load-bearing capacity of the soil changes in a way that compromises the ability of the foundation to support the structure.

The most common impacts of saturating the soil near a foundation include settlement or rotation of the foundation, but foundations can also be affected by hydrostatic uplift pressures in the event of a water table rise. Other impacts of infiltration on foundations include deterioration of the foundation, or dampness leading to mold problems inside the building supported by the foundation.

Soil and Substrate Characteristics

Clay soils absorb runoff slowly, but are effective in removing pollutants. Sandy soils absorb water quickly, but are not as efficient at removing pollutants. Infiltrated runoff that mixes with unconfined groundwater moves slowly through the substrate, which further removes pollutants, but eventually it flows to a surface water or may be extracted for use. The substrate’s hydraulic conductivity, pollutant removal effectiveness, and groundwater characteristics are all factors in designing infiltration BMPs.

Hydraulic Conductivity

Hydraulic conductivity is a property of porous materials that expresses the ease of fluid movement through the substrate. Permeability is a measure of the actual rate of flow as it is affected by the hydraulic conductivity and the properties of the fluid (e.g., viscosity and density). A substrate or soil with high hydraulic conductivity is good for infiltration, because runoff quickly soaks in. Sandy substrates have moderately high hydraulic conductivities because the sand is porous and the voids (or pore spaces) are well connected. In contrast, clay has low hydraulic conductivity because the voids are poorly interconnected, and the clay particles absorb water.

Although a similar volume of water can reside in either clay or sand, the hydraulic conductivity of sand allows the water to pass through it quickly, whereas clay both absorbs and releases water very slowly. Solid rock has even less hydraulic conductivity than does clay, but some seemingly solid rocks have connected fractures or structural voids that allow for fluid flow (e.g., even granite can be a significant source of groundwater if a water well encounters fractured rock).

The variability in infiltration rates depends greatly on the site geology (i.e., stratigraphy, structure, and other properties of the soil, sand, clay, and rock). Sites with uniform subsurface conditions will have relatively uniform infiltration rates, whereas sites underlain by variable subsurface conditions (e.g., landslide debris, buried stream channels, fine-grained alluvial deposits, and where there have been previous earthwork activities such as cuts and fills) will have much higher infiltration rate variability. A small difference in grain size can change hydraulic conductivity by orders of magnitude, and substrates with mixed grain sizes have a lower hydraulic conductivity than those with uniform grain size distribution. Thin layers of low-permeability material may ultimately control the rate and the direction of infiltration.

Pollutant Removal Effectiveness

The high hydraulic conductivities in some bedrock and in sandy materials allow infiltration of large volumes of runoff, but on the other hand, may have little efficacy at removing pollutants in the runoff. CASQA recommends that where a substrate supports an infiltration rate over 2.4 inches/hour, the runoff should be pre-treated to protect groundwater.

The removal of pollutants by infiltration is due to the natural properties of the substrate. These properties include physical filtering, sorption, chemical precipitation into the substrate, and (for certain organics) biotransformation to less harmful constituents. The abundance and types of pollutants that are present in runoff will impact the effectiveness of the substrate to remove these pollutants. Clays, or silts with a substantial proportion of clay, tend to have the highest pollutant removal capacity, but the lowest infiltration rates. In order for clay-rich substrates to be effective in pollutant removal, larger areas must be available for infiltration, which may cause conflicts with other site resources.

The removal of organic pollutants such as polynuclear aromatic hydrocarbons (PAHs), pesticides, petroleum hydrocarbons, oil, and grease is primarily dependent on the organic carbon content of the aquifer solids. Typically, higher total organic carbon of the aquifer solids tends to have higher capacities for removal of dissolved organics present in runoff.

The organic content of the soil below an infiltration trench/basin is likely to change over time, due to the coating of particles with high molecular weight organics derived from the infiltrating runoff, as well as biological growth that occur within the infiltration trenches/basins through the release of aquatic plant excretory products to the infiltrating runoff. Theoretically, this removal of dissolved organics would have a finite limit for any types of organics where typically lower

molecular weight organics would tend to be displaced from sorption sites by higher molecular weight organics. The longevity of infiltration BMPs is still being studied; however, long-term effectiveness is a reality and has been documented in a number of case studies.

Vector Control

The BMPs should be sized based both on the runoff from the design storm and the measured percolation rate. In order to control disease vectors (e.g., mosquitoes), the infiltration BMPs should be designed to drain completely within 72 hours of the last storm, with a factor of safety to account for slowing of infiltration rates over time and between maintenance cycles.

Groundwater Characteristics

The portion of the soil where some pore spaces are filled with water and others are filled with air is called the unsaturated zone or vadose zone. Water in that zone may remain adsorbed to the soil, be released to the air through evaporation, be taken up by plants for eventual transpiration, or (if enough water goes into the ground) can move down by gravity. When enough rainfall soaks into the ground, it can overcome the surface tension of the soil and migrate to where the soil or underlying bedrock is saturated with water, in a zone called the phreatic zone (or simply “groundwater”).

The top of the groundwater is called the water table, and it can move up and down through the soil or bedrock, depending on the amount of water that infiltrates or migrates to the site of measurement. Where the groundwater table comes to the surface of the ground for a significant period of time, wetland conditions or other forms of surface water can exist.

If infiltration BMPs are to be used to treat surface runoff or reduce runoff volume, there needs to be an adequate thickness of unsaturated substrate between the bottom of the BMP and the groundwater table; this is called the zone of separation. The thickness of the zone of separation needed to adequately treat the infiltrated runoff depends on the types of contamination and the type of soils beneath the BMP. The CASQA fact sheets on Infiltration Trenches and Infiltration Basins recommends that vertical separation be at least 3 meters, and horizontal separation of the BMPs from foundations, slopes, and highway pavement be at least 6 meters.⁹

Under infiltration BMPs, the water table will rise due to the concentrated area of infiltration, forming a “groundwater mound” and decreasing the zone of separation. Those pollutants not removed in the unsaturated zone eventually find their way into the groundwater.

Typically, the water table is inclined at a gentle angle formed by the location of infiltration and the movement of the groundwater due to gravity. Groundwater moves slowly down-gradient through the pore spaces in the substrate. As the groundwater moves through the substrate, further removal of pollutants occurs.

Often, the groundwater in the unconfined aquifer flows into a surface water body, such as a stream, lagoon, estuary, wetland, or the ocean. The evaluation of potential impacts of the eventual discharge of the infiltrated runoff within the groundwater must consider both the mixing of the polluted groundwater discharge with the surface waters, as well as the potential for the polluted waters to enter the waterbody sediments in such a way as to be adverse to benthic and epibenthic forms of aquatic life.

⁹ Ibid.

Unlike the turbulent mixing that can occur when two surface water sources combine, groundwater moves slowly, usually as laminar flow. Under these conditions, waterbodies with different chemical or physical properties will only mix slowly, primarily by dispersion. Because groundwater tends to move slowly through porous media, the effects of sorption and biotransformation can be effective in removing pollutants from groundwater.

Proper Maintenance of Infiltration BMPs

Infiltration BMPs require ongoing and sometimes intensive maintenance in order to retain their effectiveness over the long-term. In fact, CASQA states:¹⁰

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin with a different technology after a relatively short period of time.

Clogging of the substrate pore spaces and infiltration surface is probably the most obvious problem that can develop with an infiltration BMP. Many infiltration BMPs take the form of a depression in the landscape where water temporarily collects prior to soaking into the ground. The rate at which this runoff infiltrates (or percolates) depends on two primary factors. The first factor is hydraulic head (which is the pressure of water at the top of the BMP substrate); this is proportional to the depth of water over the substrate. Infiltration basins are designed to have a maximum water depth that will capture the design storm runoff volume, and then to bypass any additional runoff.

The second factor is the permeability of the substrate (which is basically equivalent to hydraulic conductivity where water is the fluid of interest). Permeability of the BMP substrate (which can be an existing soil or a specific medium developed for the BMP) can decrease over time, due to covering the substrate with new particles from runoff or by growth of organisms (e.g., bacteria or algae) that can clog pores. In addition, larger materials that cover the substrate (e.g., leaves or plastic bags) also reduce permeability and slow infiltration. When infiltration BMPs take more than 72 hours to drain, they need immediate maintenance, possibly including removal and replacement of the media in order to restore drainage rates and prevent the hatching of disease vectors such as mosquitoes.

In addition to changes in infiltration rates, other soil properties that promote pollutant removal can decrease over time. Organic materials that capture organic pollutants can decay over time and be removed from the substrate particles. Cation exchange sites that capture charged ionic particles can eventually become saturated, thereby reducing pollutant removal effectiveness. Studies have shown, however, that most pollutants are trapped in a limited soil volume under the BMP. CASQA's fact sheets suggest that removing any artificial media from the BMP and excavating as little as two inches around the BMP boundaries can restore the BMP's pollutant removal effectiveness.¹¹

Alternatives to Infiltration BMPs

If on-site infiltration of runoff may potentially result in adverse impacts, including, but not limited to, geologic instability, flooding, or pollution of coastal waters, the development should substitute alternative BMPs that do not involve on-site infiltration, in order to minimize changes in the runoff flow regime to the extent appropriate and feasible. Alternative BMPs should also be

¹⁰ Ibid.

¹¹ Ibid.

used where infiltration BMPs are not adequate to treat a specific pollutant of concern attributed to the development, or where infiltration practices would conflict with regulations protecting groundwater. Examples of alternative BMPs include a vegetated roof (“green roof”), flow-through planter, rainwater capture system, or directing runoff to an off-site infiltration facility. If appropriate and feasible BMPs have been implemented to reduce runoff volume, velocity, and flow rate, directing runoff to the storm drain system would also be a viable alternative to infiltration where necessary.

Conclusion

Infiltration is an important low-cost method that can be used to both reduce runoff from a site and filter out pollutants entrained in the runoff. Infiltration BMPs should be considered for most projects, since they keep runoff and pollutants from smaller storms on-site, help recharge groundwater, and maintain stream base-flows closer to natural conditions. Even where Treatment Control BMPs are not required, promoting infiltration on-site is a good way to protect coastal resources and minimize adverse impacts of new impervious surfaces.

As detailed above, infiltration BMPs should not be used where the site conditions indicate that infiltration rates may be too slow or too fast; where excessive groundwater may threaten foundation or bluff stability; or where concentrated pollutants in runoff are not likely to be adsorbed by the BMP media or site soil. Some of the general site conditions that would make the use of infiltration BMPs either feasible or infeasible should be recognized (e.g., where the only potential BMP locations are too close to a bluff, contaminated soils, or a septic system leach field, or where ground water is less than 3 meters below the ground surface).

Coastal Commission staff may ask for more information from the applicant regarding the proposed uses of infiltration BMPs, potentially including a site-specific analysis by an appropriate California licensed professional. Infiltration BMP factsheets by CASQA provide guidance on design specifications and methods to assess whether infiltration BMPs are appropriate for a specific site.¹²

References & Additional Resources

- ❖ *Stormwater Best Management Practices (BMP) Handbook – New Development and Redevelopment*. 2003. California Stormwater Quality Association (CASQA): <https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook>
 - Infiltration Trench Factsheet, TC-10
 - Infiltration Basin Factsheet, TC-11
- ❖ *Low Impact Development (LID) Urban Design Tools Website*. Low Impact Development Center, Inc.: <http://www.lid-stormwater.net/>
- ❖ *Stormwater C.3 Guidebook – Stormwater Quality Requirements for Development Applications, Municipal Regional Permit Edition*. 2010. Contra Costa Clean Water Program: http://www.cccleanwater.org/Publications/Guidebook/Stormwater_C3_Guidebook_5th_Edition.pdf
- ❖ *Water Quality Guidance for Permit Applicants*. California Coastal Commission’s Water Quality Program webpage: <http://www.coastal.ca.gov/water-quality/permits/>

¹² Ibid.