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Non-Infrastructural Solutions for San Francisco's Combined Sewer Overflow Problem

Concept

San Francisco is California's only coastal city that operates a combined sewer system (CSS) (Heal the Bay, 2003). CSS refers to wastewater infrastructure that combines both raw sewage and run-off from city streets, including storm water run-off. Under normal circumstances, this mixture is transported to a water treatment facility and cleaned before being discharged into the San Francisco Bay and Pacific Ocean. However, during major storm events, massive amounts of rain can overwhelm the system and cause minimally treated wastewater to overflow into the waters surrounding San Francisco. At the present time, this occurs between one and ten times per year.

This is undesirable, as combined sewage overflows, or CSOs, can negatively impact humans and natural systems. Public health dangers are posed by bacterial contaminations. The discharge of copious amounts of nutrients can disrupt ecosystem functions. There are also quality of life impacts to those that use the Ocean and Bay recreationally, economically and as a source of food.

The traditional method of preventing future CSOs would prescribe upgrading San Francisco's infrastructure to handle major storm events. There may be alternatives to this costly proposition. I will investigate other, non-traditional ways, such as landscaping, pervious or permeable pavement, and the rainwater harvesting. For each possibility I will discuss economic, functional and political viability, as well as benefits and negative side effects. In the end, I hope to provide a strong understanding of what steps San Francisco can take to prevent future combined sewer overflows.

Introduction

The hardscape, a term that collectively consists of buildings, roads, sidewalks, parking lots and all other paved surfaces, forms an impermeable crust over a large portion of the urban environment. This crust prevents most precipitation from being absorbed into the ground. Instead, most rain is quickly channeled after it hits the Earth; it runs off of rooftops, over sidewalks, to roadway gutters where it is directed to nearby storm drains.

Until relatively recently, it was assumed that storm water runoff was relatively clean. In fact, it can convey all of the pollutants that are found in urban areas:

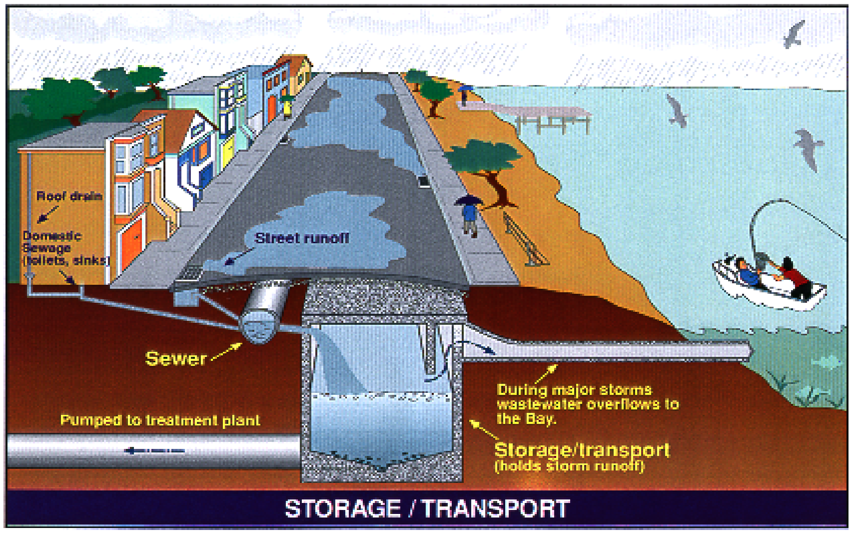
- Trace metals including copper produced by braking automobiles, lead from old paint, and cadmium used in batteries.
- Bacteria and viruses from a variety of sources including pet feces
- Nutrients such as fertilizers,
- Chemicals such as herbicides, pesticides, and oil.
- Air pollution fall-out

Many of the most environmentally damaging materials are picked up as water runs over streets, especially if it has been a while since it last rained.

Collectively, these are referred to as non-point source pollution, since it is difficult to target and regulate a single point where the pollution is produced. Non-point source pollution is now the leading cause of beach closures nationwide and is the main source of new pollution to our waterways. In fact, most water bodies near urbanized areas are presently considered unsafe for contact sports and fishing after rain events because of the presence of pollution from untreated runoff..

Consequently, combined sewer systems, such as the one in San Francisco, are beneficial in urban areas. Combined sewer systems are common in older U.S. cities. San Francisco is unique, as it is California's only coastal community with a combined sewer system (CSS). With the CSS infrastructure, sanitary wastewater, industrial wastewater, as well as storm water runoff that enters storm drains are mixed and directed to a treatment plant.

In contrast, a separate sewer system collects sanitary and industrial wastewater for secondary treatment, but does not process storm water and other so-called nuisance water (dry weather runoff produced by a variety of sources including washing cars and "irrigating" sidewalks) at a treatment facility. Instead, storm drains such as those in Oakland and Berkeley drain directly to the San Francisco Bay.



Combined Sewer System
Courtesy of the SFPUC

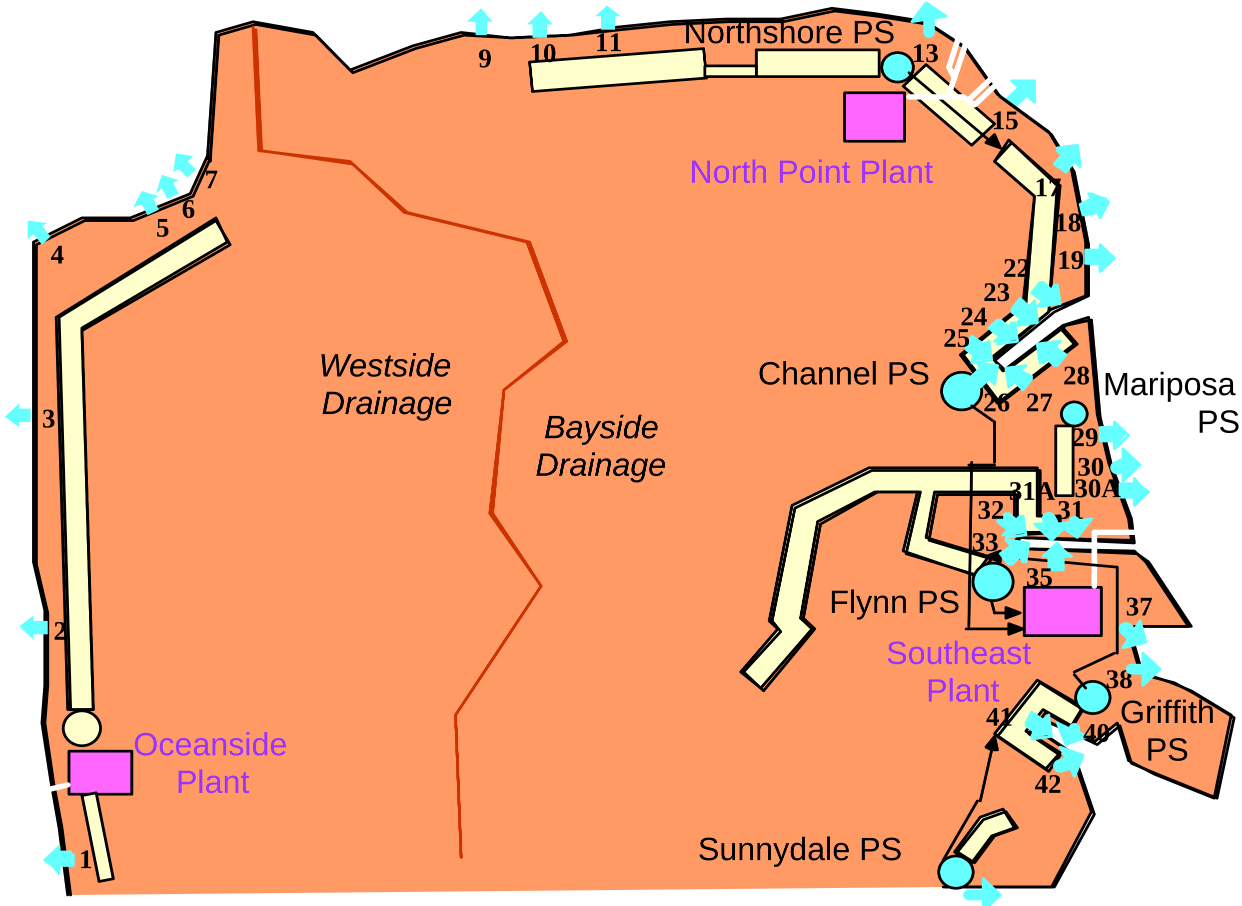
The San Francisco storm water treatment system generally provides secondary treatment during wet and dry weather. According to the SFPUC, this treatment removes up to 90% of pollutants (SFPUC Southeast Plant pamphlet, date unknown). However, during large storms, precipitation can occur at levels that overwhelm the system. These occurrences are known as Combined Sewer Overflows (CSO's). During a CSO, the mixture of storm water, raw sewage and industrial wastewater are provided only primary treatment before being discharged through one of the City's 36 overflow pipes. Primary treatment consists of the removal of floatables and solids.

San Francisco's combined sewer overflows are estimated to consist of about "6% sewage and 94% storm water" (SFPUC, 2004). This wastewater is further diluted when it is discharged into the San Francisco Bay and Pacific Ocean. The SFPUC conducts frequent water quality tests and posts signs at beaches if necessary. There is little conclusive information available regarding how these overflows affect human and environmental health, especially in the long term. One reason is that it is difficult, if not impossible, to separate the effects of CSOs from the effects of urban storm water runoff. In addition, natural ecological fluctuations can muddle studies. For example, one marine life study came to the conclusion that changes caused by releases of effluent could not be separated from extreme natural variations in [benthic] community characteristics (Jones & Stokes, 1980). Furthermore, the SFPUC does not have accurate measurements of how much wastewater is released during CSOs (Navarett, 2003).

Regardless of the lack of data, it is clear that combined sewer overflows are undesirable. The EPA contends that “because CSOs contain raw sewage and contribute pathogens, solids, debris, and toxic pollutants to receiving waters, CSOs can create serious public health and water quality concerns. CSOs have caused or contributed to beach closures, shellfish bed closures, contamination of drinking water supplies, and other environmental and public health problems” (EPA, 1994).

Perhaps more important, in a politically active city such as San Francisco is the fact that many people find the idea of raw sewage entering “their” water appalling. This issue has been the focus of campaigns by an array of organizations including: Save the Bay, Surfrider, Heal the Bay, and Alliance for a Clean Waterfront.

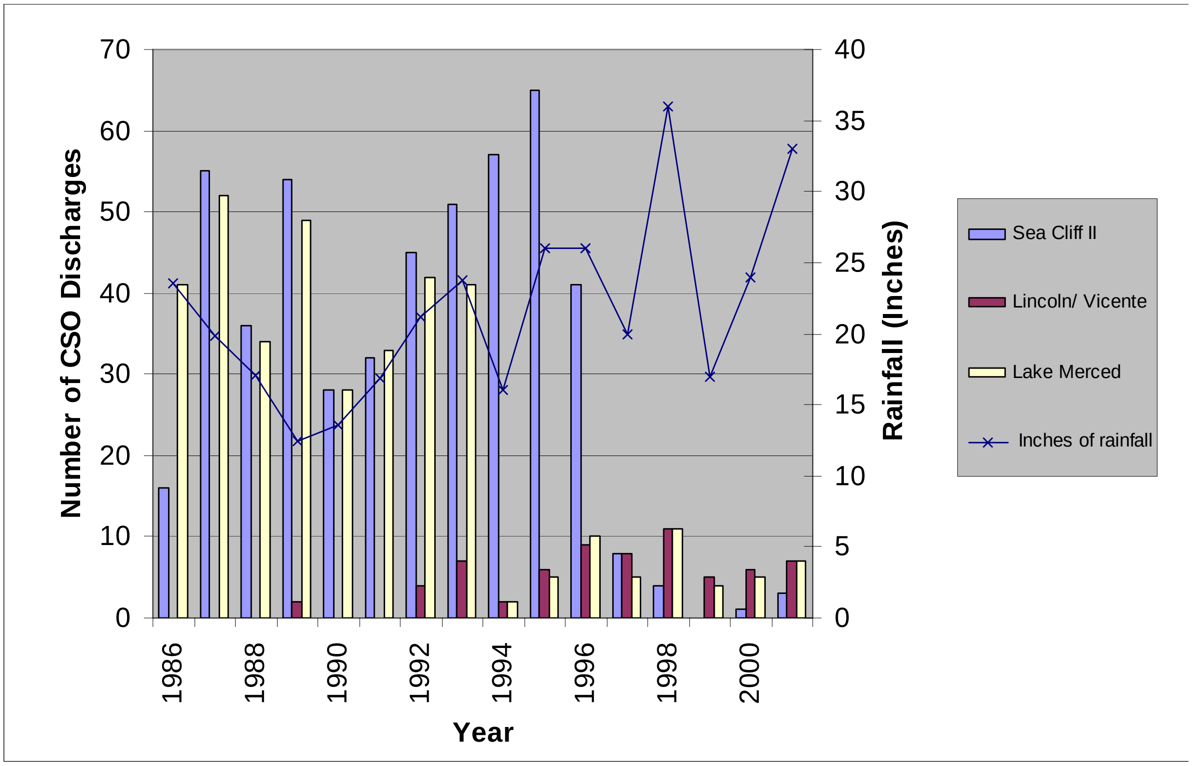
CSOs have been focus for agencies from at all levels since the Clean Water Act was tightened in 1982. Municipalities nationwide are spending huge amounts of money to upgrade combined sewer systems to reduce the occurrence of CSOs. San Francisco has implemented a 20 year, $1.5 billion dollar Master Plan that has dramatically reduced the number of overflows (Navarret, personal communication). Prior to implementation, the City “estimated that CSO discharges from 43 combined sewer outfalls occurred approximately 58 times per year, with a total annual overflow volume of 7.5 billion gallons, discharging into Islais Creek, San Francisco Bay, and the Pacific Ocean” (EPA, 1994). Bill Keaney of the San Francisco Public Utilities Commission says that these upgrades to treatment plants and building of additional facilities, such as the storage tanks that almost completely ring the city (shown below), and the Oceanside Wastewater Treatment plant, have “reduced CSOs by 90 percent” (Bill Keaney, personal communication). Current overflow rates average one to two billion gallons per year (Tom Franza, personal communication).



San Francisco Wastewater Master Plan
Figure Courtesy of San Francisco PUC

Wastewater is collected in 900 miles of sewer lines running through the City, then pumped to one of the treatment plants. The figures regarding the capacity of the plants are astounding. For instance, the Oceanside Treatment Plant can treat and pump out 17 mgd (million gallons per day of wastewater) during dry weather, increasing to 43 mgd secondary treatment, and if necessary, an additional 22 mgd primary treatment during wet weather. The Southeast plant treats 70 mgd secondary during dry weather, which can be increased to 150 mgd during wet weather, plus an addition 100 mgd can receive primary treatment if needed. The North Point Plant can be activated during wet weather to provide primary treatment to 150 mgd (Navarett, personal communication).

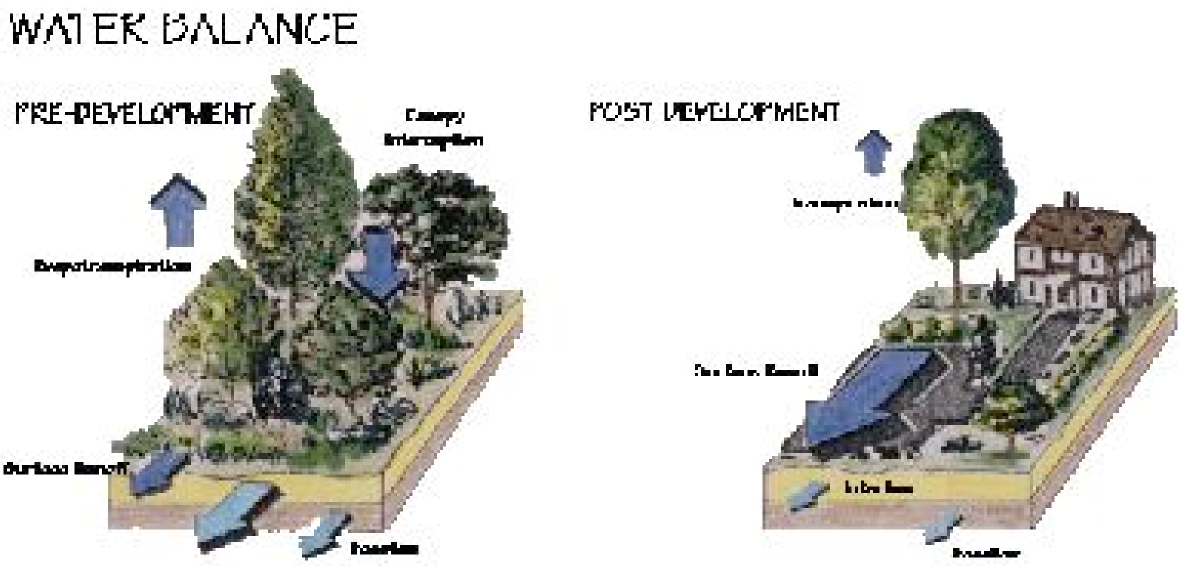
Overflows now occur between one and ten times per year. San Francisco has made a marked improvement in the amount of wastewater it can handle without overflowing. However, it seems that as the number gets closer to zero, the costs become prohibitively expensive. Arleen Navarret of the SFPUC related another staff member's informal analysis that it would be less expensive to send every surfer who wants to enter the water after a CSO event to Hawaii than to decrease the number of average yearly overflow events from eight to seven.



Reduction in Combined Sewer Overflows on San Francisco's West Side
Figure Courtesy of the San Francisco PUC

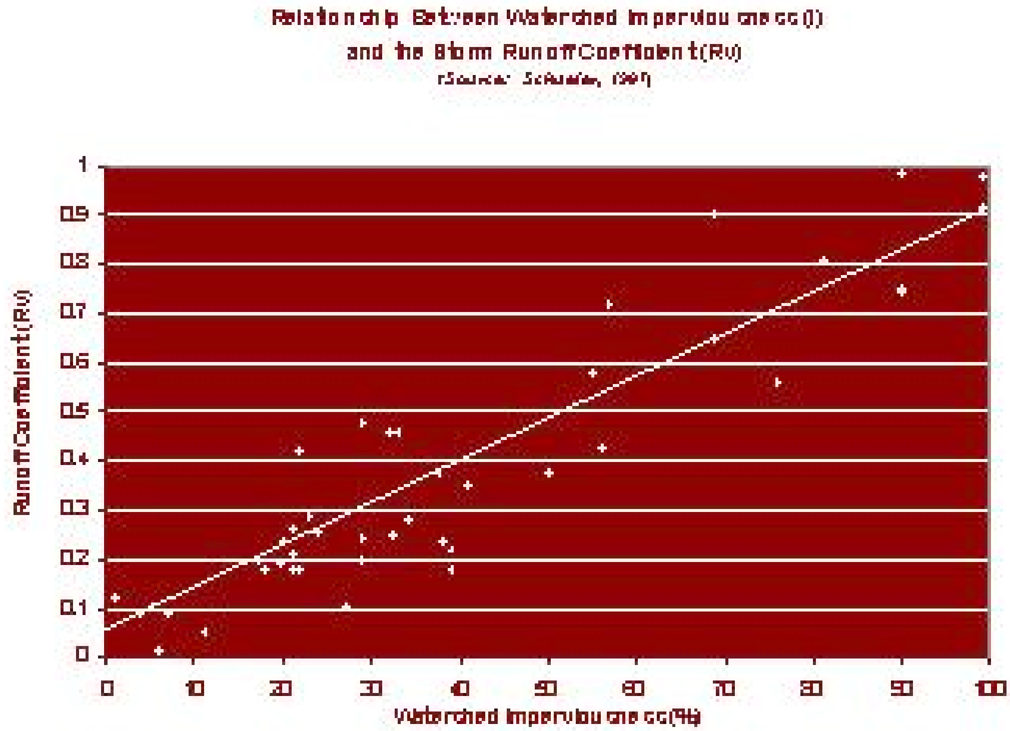
Additionally, the largest negative aspect of the combined sewer system is a product of its best attribute. It is supposed to provide secondary treatment to all water that enters the system. Though this works most of the time, "you could never make enough storage to capture every conceivable rain event because you'd never have enough room and you never can predict what the largest conceivable rain event would be. You have to have vents throughout the City that allow the system to purge when the capacity is exceeded" (Navarett, personal communication).

It looks like we are at an impasse in terms of further infrastructure development. There is, however, a growing movement to mimic natural systems in dealing with storm water management. In a highly urbanized environment such as San Francisco, most natural drainage patterns have been modified and paved over.



This diagram shows how development and its corresponding increase in impervious cover disrupts the natural water balance. In the post-development setting, the amount of water running off the site is dramatically increased.

This is unfortunate since many soil types, especially the sandy soil found in much of the City, allows for a high rate of infiltration. Concrete, on the other hand, has a very high rate of runoff. The higher the amount of hardscape, the more precipitation runs off the land and into the sewer system. Impermeable surfaces put pressure on the sewer system to treat extremely large volumes of water quickly. Each time it rains in an urban area there is a spike in the amount of water, the urban equivalent to a flash flood, entering the combined sewer system. For instance, “[A] one acre parking lot can product 16 times more storm water runoff than a one acre meadow each year” (Maryland Department of the Environment website).



This graph shows that as the percentage of watershed imperviousness increases, the volumetric runoff coefficient increases as well.

Since San Francisco is not likely to find much more in the way of open meadows and forests, we have to find solutions that can be retrofitted into the urban environment. In this study I will investigate three solutions or Best Management Practices (BMPs) that other Cities have implemented. All of them are based on the principal of allowing infiltration of water into the soil. Currently, about 70% of precipitation in the City is directed into the sewer system (Tom Franza, Personal Communication).

Infiltration has many benefits. There is the direct benefit of diverting water from the sewer system could lead to a decrease in CSO occurrence. There is a clear financial incentive to reduce costs of infrastructure capital as well as maintenance fees. There are also indirect benefits, such as mitigating the urban heat island effect, replenishing the aquifers that feed San Francisco's three remaining natural lakes and supporting plant life.

Major Questions Posed

1. Are trees a viable solution?
2. Is permeable pavement a viable solution?
3. Is rainwater harvesting a viable solution?

Findings/Answers to Questions

1. Are trees a viable solution?

There are many studies that show that trees provide a variety of benefits in managing storm water. They catch and slow rainfall, absorb and transpire large amounts of precipitation, act as pollution filters, are affordable, and communities find them attractive. Gary Moll of American Forests states, “Urban forests offer substantial dollar benefits that are not replaced easily by costly, manmade alternatives. This presents an opportunity to utilize trees in designing more cost-effective city infrastructures” (Moll, 2002).

We have all sought shelter under a tree during a light rain. Tree canopies can catch and store rainfall before it hits the ground. A Forest Service study in Chicago showed that the presence of street tree canopies could decrease runoff by 4 to 8 percent. Each mature tree was estimated to prevent 327 gallons of runoff per year (MacPherson et al, 1994). Its ability to do this depends on many factors including the canopy width, whether it is evergreen or deciduous, how hard it is raining, and how windy it is. Some of this rain will evaporate, though since most of our storms occur in the cooler months, this rate is relatively low.

The rest of the rain will eventually fall through the canopy, but at a slower rate than rain that falls directly to the ground. This slow metering of out of water allows for less erosion, slower runoff rates, and better absorption by the soil. The surfaces underneath the canopy can be graded to direct the largest amount of water to the base of the tree.

Trees can absorb and release huge amounts of water. A single large tree has an average transpiration rate of about 100 gallons of water per day (Galveston-Houston Association for Smog Prevention, 1999). This function becomes more effective with time as the tree grows and reaches maturity. In addition, the soil surrounding the tree will hold and store additional moisture as well as allow for percolation to the aquifer.

Trees also act as pollution filters for water, soil and air. The urban forest improves air quality by removing nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and particulate matter (Moll, 2002). In fact, a tree can remove up to 13 percent of particulate matter from air surrounding their leaves (Leon, 1980). Through the process of phytoremediation, tree roots cleanse storm water runoff and soil of nutrients (much more effectively than secondary wastewater treatment), oil, and metals.

In addition to the environmental benefits that trees provide, urban forests are economically and socially beneficial. Neighborhoods with a large canopy cover are considered more attractive and “livable” than those without. Landscaping increases real estate values. Studies show that “greening” streets slows traffic and improves safety.

There are costs and responsibilities in planting a tree. A tree requires periodic maintenance including trimming and cleaning of leaf or fruit litter. In our Mediterranean climate trees will often require water until they become established, even if they are drought-tolerant. It is important to choose the right tree for the site.

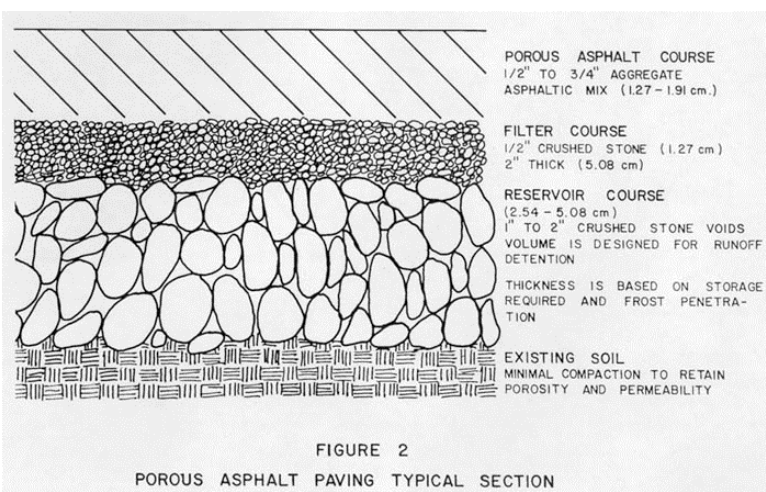
The non-profit organization, Friends of the Urban Forest, helps San Franciscans to plant street trees. They recommend a suitable street tree to a homeowner, cut concrete, help with the planting and provide a certain amount of maintenance for the tree for a fee of $150 (with an additional City subsidy of $175) (Doug Wildman, personal communication, 10/31/03).

In the end, most individuals and municipalities believe urban forests provide many services at a relatively small cost. Trees are already considered a “Best Management

Practice" in many urban areas. A study of Metropolitan Washington D.C. concluded that the urban forest (with an estimated tree canopy of 46%) stores 949 million cubic feet of storm water. The cost of building infrastructure to retain the same amount would cost $4.7 billion based on construction costs of $5/cubic foot (American Forests, 2002). . From the standpoint of storm water management, it is easy to see the benefits.

2. Is permeable pavement a viable solution?

Permeable pavement applies to a variety of hard ground coverings that provide a clean, level surface that allow precipitation to infiltrate into the soil while resisting puddling. People have covered much of the urban environment in concrete because it is easy to walk and drive on and doesn't get muddy when it rains. Because traditional concrete is so common in the urban environment, it seems that it is acceptable to retrofit suitable sites with permeable pavement. Pervious concrete has a very similar look and feel to traditional concrete. Since there is nothing new to adapt to, it is considered generally acceptable to communities (Stormwater Center, 2003).



Cross-section of porous pavement
Figure courtesy of USEPA

Infiltration capability of porous pavement
Photo by Greg McKinnon from Puget Sound Online

Traditional concrete has about a 95% runoff coefficient. This means that for the most part, the soil's water absorption capabilities are unutilized. Permeable pavement is a concrete mixture that uses a mixture that contains fewer small grains, thereby leaving gaps large enough to allow water to pass through. This porosity allows an infiltration rate of between 3 and 5 gallons per square foot per minute which translates to up to 270 inches of rain per hour. This means that the absorption rate of the underlying soil has more of an impact on the level of permeability that the pavement itself (Pilat, 2002).

The underlying soil is one of the important factors that should be considered in making a decision regarding the use of permeable pavement. San Francisco's western neighborhoods were built upon fields of very sandy soil that allow water to quickly percolate through. The rate can be up to 20 inches an hour (SCS, 1991). In areas of the city that sit on heavy clay soils, a detention basin is necessary to store water until it can drain away. There are various maps that show soil types throughout the City, but a inspector can assess a site relatively easily just by seeing how quickly it drains after a good rain.

Permeable pavement is not appropriate for all uses or in all locations. The site's grade should be minimal. Use on steep hillsides could over-saturate soil and cause slippage. Though studies have shown that the pavement does filter out some contaminants, the rates of pollution filtration is variable (Stormwater Center, 2003). Therefore, it should not be used in areas where there is a high risk of groundwater contamination such as heavy industrial areas.

There are however, a wide variety of surfaces that can be successfully retrofitted with this material. Residential areas such as driveways, sidewalks and patios are commonly modified. Large commercial projects are increasingly using permeable pavement as a parking lot surface. It has been used on the corporate campuses of Ford, SmithKline Beecham, and Siemens (Adams, 2003). In a study of parking lots installed up to 20 years ago, permeable pavement lots are proving more durable and better at managing storm water than conventional parking lots (Adams, 2003). In Europe, it is even being used in roadways because of its ability to wick water away from the surface.

Permeable pavement does have a high rate of failure, though - almost 75%. Generally, this is because most contractors do not know how to install it. It is highly recommended that an experienced installer oversee the job. In addition, routine maintenance is required to keep the pavement from clogging. This is usually satisfied with a yearly pressure wash or vacuum sweeping (USEPA, 1999).

The cost of porous and impervious pavements is similar (Adams, 2003). Likewise, the installation cost of a porous pavement (concrete) parking lot where an infiltration bed is needed underneath is similar to that of traditional concrete where stormwater must be piped offsite (Field, 1989). When an infiltration bed is not necessary, "porous pavement is always an economically sound choice. On those jobs where unit costs have been compared, the porous pavement has always been the less expensive option" (Adams, 2003).

3. Is rainwater harvesting a viable solution?

Rainwater harvesting refers to the collection of precipitation during wet weather for use during dry weather. This practice has historically been used in arid and semi-arid areas around the world. It provides a wide variety of benefits such as water bill savings, reduced dependency on Hetch Hetchy water for irrigation, and a decreased risk of basement flooding during storm events. Generally, these systems are easily implemented, as they are inexpensive and simple to install.

Photo courtesy of Milwaukee Metropolitan Sewerage District website

Some projects are as simple as directing outflow from the disconnected rooftop leader towards vegetated areas. Others methods can include above or below ground water storage barrels. The price depends on system. The parts and barrels for an above ground system cost approximately $110 to $210 (Canada Mortgage and Housing Corporation website, 2003). Below ground systems require pumps and can cost upwards of $2,000.

Currently in San Francisco, most rooftops drain directly into the combined sewer system. This is because downspouts are supposed to be connected to the system under the following Ordinances:

> SECTION 1506 - ROOF DRAINAGE
> 1506.1 All storm or casual water from roof areas which total more than 200 square feet (18.58 m2) shall drain or be conveyed directly to a public sewer or storm drain. Such drainage shall not be directed to flow onto adjacent property or over public sidewalks. Building projections not exceeding 12 inches (305 mm) in width are exempt from drainage requirements without area limitations.
>
> SECTION 3315 - DRAINAGE AND TERRACING
> 3315.6 Surface Drainage. All areas which are surfaced with asphalt, concrete or other paving of similar imperviousness, and which exceed a total area of 200 square feet (18.58 m2), shall have storm and casual water drained directly to a public sewer or storm drain. Drainage shall not be directed to flow onto adjacent property or to drain onto public sidewalks. See Section 1506.1 for roof drainage.

Since these laws are quite antiquated and seem to have been enacted to protect public sidewalks and yards of neighbors, I will ignore them for the moment.

The disconnection of downspouts is quickly becoming an implemented BMP in developed cities around the world. Vancouver BC, Portland OR, Milwaukee WI, Toronto ON, and St Paul MN all have programs to provide educational, financial, or volunteer assistance to help residents get started (Pilat, 2002). It is one of the least expensive ways to reduce non-point source pollution and CSOs for both individuals and municipalities.

According to the Portland's Bureau of Environmental Services, "More than 38,000 homeowners have disconnected downspouts removing more than 768 million gallons of storm water per year from the combined sewer system" (City of Portland Environmental

Services website). The following table can serve as a guide for the amount of storm water that can be harvested:

Annual Supply Form Roof Catchment

Inches/Rainfall	Gallons/Square Foot
0	0
1	.6
2	1.3
3	1.9
4	2.5
5	3.1
6	3.7
7	4.4
8	5.0
9	5.6
10	6.2
11	6.8
12	7.5
13	8.1
14	8.7
15	19.3

Rooftop runoff is generally considered relatively unpolluted. "Though you may get some of the air depositions getting washed down, certainly anything that doesn't hit the street is a lot cleaner than what does hit the street" (Arleen Navarett, personal communication). The PUC has requested grant money to do a pilot project, but have never been approved.

I. Discussion

The SFPUC's upgrades to the municipal combined sewer system have greatly reduced the occurrence of combined sewer overflows into the San Francisco Bay and the Pacific Ocean. However, the present rate of 1 to 2 billion gallons per year of combined storm water and sewage entering these water bodies is not easily accepted by City residents. The water treatment facilities are the pinch-point. With the prohibitive cost of increasing storm water treatment capacity, this looks to be true into the foreseeable future.

For as long as cities have had sewer systems, storm water management has been a responsibility of engineers. Though their public works are integral to city life, a number of cities are beginning to see the economic, social, and ecological benefits of mimicking natural systems through a variety of best management practices. I believe that these practices are necessary in order to decrease or prevent the number of CSOs in San Francisco.

The key for each BMP I've investigated is detaining or allowing infiltration of storm water. In a perfect system, large portions of rain events could be managed on-site and the sewer system would act as a catch basin for overflow rather than the first line of defense by default.

Though I've concentrated on the impacts these BMP's could have in San Francisco, I think it is important to mention that these methods are appropriate in many municipalities. In fact, they are becoming extremely important for cities with separate sewer systems where storm drains collect and discharge untreated rainwater. Under Clean Water Act regulations, towns must meet permit guidelines for Total Maximum Daily Loads (TMDLs) of pollutants that can be released into receiving waterways while maintaining water quality standards (EPA, 2003).

In addition, street tree plantings, installation of permeable pavement, and disconnection of downspouts are relatively simple and inexpensive methods that can be implemented by individuals, businesses, or City agencies. Each "technology" is easy to retrofit into San Francisco's ultra-urbanized high and medium density neighborhoods. It is only a matter of finding the best method(s) for the particular site.

Street Trees

Tree plantings are appropriate for most lots in the city. Currently, San Francisco is lagging behind most urban areas in terms of street trees. The City has approximately 90,000 street trees, which is between 80 and 100 per mile compared to the national average of 200 per mile (Sustainability Plan for San Francisco, 1996). Just to bring the City up to par with the nation, an estimated 36,000 to 45,000 trees should be planted!

Before planting, gardeners should think about height and shape of the tree in terms of interfering with power lines, sidewalk right of ways, or structures. They should also choose trees in accordance with the many micro-climates and soil types that occur in San Francisco. In addition, trees that do not shed their leaves in the winter are preferable, since most of our rain occurs during the wintertime months.

Currently, most trees planted on San Francisco's public right-of-ways are tended by the City's Department of Public Works (DPW) or by owners of adjoining properties. Even before the latest City budget cuts, DPW's urban forestry division was struggling to maintain current trees and, in my opinion, probably not terribly motivated to add to their inventory. For instance, a tree in front of my home was deemed dangerous in 1999. The tree was cut down to a 4-foot tall stump that remained in the ground for the next two years despite multiple calls to DPW to replace it. Their responses always conveyed that their staffing levels were at least part of the reason for their slow action.

The most innovative greening program that San Francisco currently has is the non-governmental organization, Friends of the Urban Forest (FUF). FUF offers consultation and even has an online tree selection service that offers a list of appropriate trees when you enter preferred size, growth rate, and site/condition tolerance criteria. It also assists homeowners in all of the steps in planting a new street tree. This includes site selection (limited to a public sidewalk), acquisition of necessary permits, planting education and assistance, and three maintenance visits. In its 23 years, FUF has added approximately 34,500 trees to the City's landscape (Friends of the Urban Forest website, 2003).

Though FUF's mission is an important part of improving the City's urban forest, I don't think that it can fully replace a well-funded City program or individual property-owner incentives. FUF requires that 35 participants sign up to plant trees on a neighborhood workday. Those who want trees are required to help on the planting day. This may mean that neighborhoods with moderate tree coverage, older populations, or a high percentage of renters may not be able to find enough people willing or able to participate. In addition, the City's contribution to this program has been falling over the years. Consequently, the fee for a FUF street tree has been rising. In 1999, the fee was $75 and now it is twice that.

FUF's program, which stresses personal ownership and participation, allows more control than City agencies over how and when maintenance is performed and which species planted. However, when a homeowner plants a tree, he or she also takes on the full cost, responsibility, and legal liability for maintenance of the tree, basin, and surrounding sidewalks where root damage may occur. For many, especially the elderly and those with low-incomes, this provides a dis-incentive. Perhaps the City could supplement the current DPW and FUF methods of street tree acquisition by incentivizing tree ownership. This could include offering assistance with the permit process, discounts on digging holes, maintenance assistance or tax write-offs dependent on the lot area covered in vegetation (perhaps even for green rooftops).

In addition to planting individual trees in 2 by 3 foot basins or back yards, as is common in San Francisco, the City should look at how other cash-strapped cities have found innovative ways to maximize their "green" potential. For instance, Chicago has implemented a "Green City" program that supports a variety greening activities. Through a partnership with the Chicago School District, 200 acres of cement were replaced with trees and vegetation in schoolyards. The "Green City" program has also spearheaded a Boulevard beautification plan in order to landscape Chicago's historic main streets. The City also assists the NGO "Chicago Gateway Green" in its "Expressway Partnership" program. Through partnerships with host companies, the program receives funding to "transform expressways into Parkways'' through the commission of professional landscape plans and long-term maintenance. In five years, the Partnership planted “800 trees, 18,000 shrubs and mixed perennials, and 30,000 bulbs….and picked up over 275,000 pounds of litter on approximately 100 acres of lands” (Chicago Gateway Green website).

Photos of expressway landscaping.
Courtesy of Chicago Gateway Green.

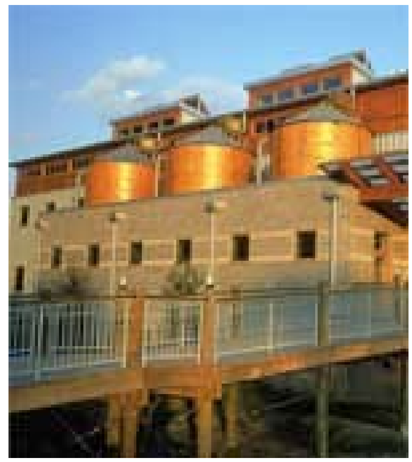
Garland, Texas’s City managers came up with a very different kind of plan. The utility district, which manages flood control, water treatment, groundwater, and habitat restoration projects mapped all impermeable surfaces in the city. Based on this model, engineers were able to figure out how much runoff was created by each lot and then assess storm water treatment fees based on those measurements. Now, the city can share these figures with residents as well as provide estimated savings by increasing vegetation, thereby creating an incentive (Beattie et al, 2000).

There are a variety of examples that San Francisco can use as green models for tree planting. Using a combination of incentives, assistance, public-private partnerships, and Agency programs, I believe San Francisco can plant more trees in all of the City’s neighborhoods.

Rainwater harvesting

A rainwater harvesting program is also a feasible alternative for most San Francisco lots. Using either a rainwater catchment system or simple downspout disconnection, homes and businesses can put storm water to use rather than simply allowing it to enter the combined sewer system. The main limitations for an above ground water storage barrel is space availability. These are inexpensive and can even be quite attractive. Where space is an issue, underground systems can be used, though the expense may be a limitation for some.

One of four 12,000 gallon cisterns at
Chicago Green Tech Headquarters
Photo courtesy of Chicago Green Tech



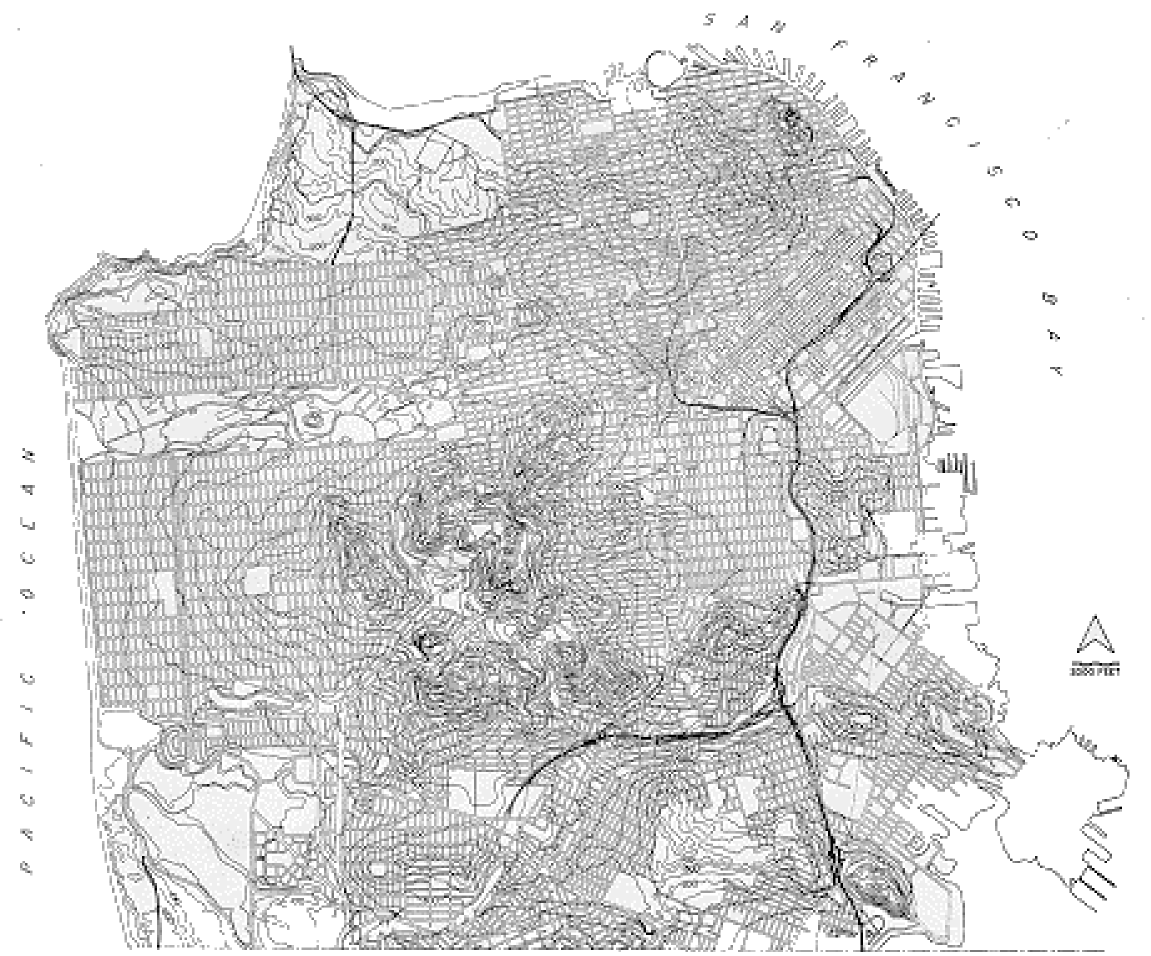
Three cisterns atop the Phillip
Merrill Environmental Center
Courtesy of the US Dept. of Energy

The simplest and least expensive BMP is simple downspout disconnection where storm water is allowed to immediately drain to a vegetated area. This particular method may not be suitable for all areas of the city. For instance, the water must be allowed to run directly to a vegetated area. This effectively eliminates lots that don’t have a front or rear yard. In addition, this BMP is not appropriate in areas with steep slopes or poorly draining soil.

Below is a very generalized map of soil types in San Francisco. The darker green soils signify areas of rocky soil where downspout disconnection may not be suitable.

Soil Types in San Francisco
Courtesy of U.S. Geological Survey

Below is a topographic map which provides a general overview of the City. Downspout disconnection should not be employed without catchment in the hilly areas.



TOPOGRAPHIC MAP OF SAN FRANCISCO

Map courtesy of U.C. Berkeley's Earth Science & Map Library

As I mentioned in my findings, water harvesting and downspout disconnection is currently illegal. The ordinances appear to have been enacted to protect public sidewalks and homes of neighbors from receiving a structure's runoff. There are a variety of environmental groups that are interested in repealing the ordinances. It seems that if the San Francisco Planning Department can be reminded that these ordinances exist and convinced that there are ways to manage storm water that are different, yet still effective and safe to humans and structures, those interested in changing the laws may be able to succeed.

Though there are no City agencies currently involved in implementing this BMP, there are many model programs that San Francisco can look to for guidance. One interesting example is Portland, which also has a combined sewer system. As I mentioned before, their downspout disconnection outreach and assistance program has allowed 38,000 homeowners (of Portland's 237,307 occupied housing units) to take their rooftops "offline" since 1994, diverting 768 million gallons of runoff from treatment each year. Since 2000, CSOs into the Columbia Slough have been eliminated. The Bureau of Environmental Services estimates that CSOs into the Columbia River will be reduced by 94% by 2011" (City of Portland Environmental Services website).

So how does Portland do it? The program offers $53 incentives to homeowners who do the retrofit themselves, $13 to community groups for each house, or will send volunteers out to do the work for free. The city offers advice and instruction and inspects the work before offering payment (City of Portland Environmental Services website). Allowing community groups to raise funds while contributing civic duties is an interesting concept that has proven successful in Portland

Toronto also has a downspout disconnection program. It is estimated that 20% of Toronto's urban surface is comprised of rooftops. If 25% were disconnected, the city's 15 annual CSOs could be reduced by half. Furthermore, it is estimated that no more CSOs would occur if 2/3 downspouts disconnected (Canada Mortgage and Housing Corporation website, 2003).

Though participation might be different in San Francisco, these numbers are quite promising. There are approximately 329,700 households in the City. About 111,900 households live in single-family residences while the remaining 217,000 live in multi-unit structures (U.S. Census Bureau, 2002). If San Francisco could achieve a participation rate similar to Portland's 16% for just our single-family residences, it could divert approximately 350 million gallons per year. That would go a long way towards dealing with the estimated 1 to 2 billion gallons of overflow that we experience each winter.

Permeable Pavement

Pavement covers a large portion of San Francisco, but that doesn't mean that these areas have to be impervious. There are countless opportunities to reduce runoff while maintaining the benefits the benefits of paved surfaces. These include sidewalks, bicycle trails, park paths, driveways, parking lots, and patios.

Atlanta's Department of Corrections has built a permeable parking lot for its employees that it touts as "environmentally friendly."
Photos courtesy of Cool Communities.org

This best management practice has been around for about 30 years, but it is just starting to receive widespread attention. Because of fears of high failure rate, it has not been used very often. However, as I discussed in my findings, most failures are due to incorrect installation and lack of maintenance. However this material may not be suitable for individuals or a City that will not take proper precautions during and after installation or in areas where there is extremely heavy use. For this reason, I would suggest that San Francisco undertake pilot projects in order to get used to using this technology before undertaking larger projects.

Luckily there is guidance available from a variety of resources. Seattle, Olympia, and Marysville, Washington have all installed pervious concrete sidewalks. Atlanta, Walden Pond, Massachussets, Des Moines, and a variety of private companies are using permeable parking lots.

The site constraints of this BMP are similar to those of disconnection of downspouts. The site must be level and soil should have good drainage. The areas of the San Francisco where this can be used are the same as those shown on the maps in the downspout disconnection section.

In order to get these projects implemented here, the Planning Department could provide homeowners with incentives to replace traditional concrete during home remodel projects through relaxing of planning permit fees. Another option is to discount water treatment fees based on amount of property's permeable surfaces.

Funding for public outreach and implementation

Implementing programs to benefit urban storm water management has costs. In a budget crisis such as the one we are now in, funds are difficult to come by. However, there are ways. The EPA has long funded storm water management projects. Many federal, state, and non-profit agencies offer grants are available for "green" non-infrastuctural pollution management. Administrative fees on futher impermeable development should be a part of the plan. In addition, utility fees based on impervious areas on lots are being used in many cities.

As the Environmental Finance Center states, "A well-structured fee system can be an equitable means of matching program costs to program beneficiaries. In many cases, instituting a fee essentially eliminates a subsidy for a government service, freeing up general revenues that could be used to fund other environmental programs. Thus, by definition, many fees have a very close cost/benefit relationship and, if graduated rate structures are used, are highly equitable. Because they are imposed at the time of service or through regular billing, they may be relatively easy to collect" (The Environmental Finance Center, University of Maryland, 2003). For instance, Santa Monica's storm water utility fee has collected about $1.2 Million a year since 1995. This fund is used to promote education and implementation to manage urban runoff (California Department of Water Resources, 2003).

Interagency Cooperation

The level of cooperation and communication between the SFPUC and other agencies, including the SF Department of the Environment has admittedly been lacking. This is a common, but unfortunate problem amongst problem solvers in most agencies and organizations. Each has its responsibility and approach to solving problems. Most are very busy and lack staff dedicated to fostering a relationship. However, a coordinated management plan could, in the long-run save money, time, and staff.

In addition, the solutions to storm water management problem require a multi-disciplinary approach. If these projects are going to be successful on a large scale, it is important to have all of the stakeholders at the table when decisions are made. This includes City Agencies, engineers, residents, non-profits, and business owners.

Conclusion

As we gain knowledge about how natural processes work and what they are capable of, we can better understand how they can help us manage modern urban issues such as storm water management. The best management practices I've researched all have great potential to mitigate runoff and combined sewer overflow problems in San Francisco.

The EPA says, "In general, on a mass basis, toxics, bacteria, oxygen demanding suspended, and visual matter in CSO and urban storm water are significant. Ignoring the problem because it seems too costly to solve, will not make the problem go away. The integrated approach to wet-weather pollution control is the only way which is going to be feasible, economical, and therefore acceptable" (Field, 1989)

Abstract

San Francisco's combined sewer system is supposed to treat both raw sewage and storm water. Despite massive upgrades to the system's treatment capacity, combined sewer overflows still occur during large rain events. Since it is now considered financially and logistically impossible to increase the storage and treatment capacity, it is important to look at other methods of controlling CSOs.

This paper explores the feasibility of three best management practices that allow for storage and infiltration: trees, rainwater harvesting, and permeable pavement. For each, benefits, constraints, site specifications, costs, model programs and funding are examined. Though each practice has limitations, there is promise enough that further, more focused, studies should occur. It is possible that these low-tech solutions could prevent many of San Francisco's combined sewer overflows.

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