STORMWATER PROGRAM

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Lessons Learned: The Caltrans Storm Water Best Management Practice Retrofit Pilot Study

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ABSTRACT

In 1997, Caltrans began an extensive program to evaluate structural best management practices (BMPs) for the treatment of storm water. Thirty-nine structural BMPs were designed for installation at Caltrans facilities in the Los Angeles and San Diego areas including roadways, maintenance yards, and park and ride lots. BMPs being evaluated include: extended detention basins, drain inlet inserts, infiltration basins and trenches, oil/water separators, media filters, multi-chambered treatment trains, biofiltration swales and strips, wet basins, and Continuous Deflective SeparatorsTM (CDS). Constituent removal efficiencies, capitol costs, and annual operation and maintenance costs are key factors in determining the cost effectiveness of the BMPs. BMP influent and effluent water quality are being monitored to determine each BMP's constituent removal efficiency. Issues concerning siting, design, construction, operation, maintenance, monitoring, and vector control are also significant factors in determining the effectiveness and applicability of retrofitting BMPs into Caltrans facilities. This paper will describe the lessons learned during siting, designing, constructing, and the first year of operating and monitoring the BMPs. The unique challenges associated with siting, constructing, and monitoring BMPs on existing Caltrans facilities has been reflected in the BMP construction costs.

INTRODUCTION

This paper presents the lessons learned while siting, designing, constructing, operating, and monitoring 35 of the 39 BMPs retrofitted into Caltrans facilities in San Diego and Los Angeles Counties, as part of the Caltrans BMP Retrofit Pilot Program. The installation of the other four BMPs is still in progress. Many of the lessons applicable to a specific phase were discovered through experiences later in the implementation process These lessons will be included with the discussion of the applicable project phase. Siting, design, and construction practices available from literature are not presented, as they are already available. Table 1 contains a description the BMPs, the facilities where they're located, and their approximate costs.

The type and number of BMPs to be sited for this pilot study was pre-determined. The urban watershed in which they were to be sited was also known. Lessons learned applicable to siting regard space requirements, site requirements, and permitting requirements. The challenge was to find sites were the BMPs would function properly and where operations, maintenance and monitoring of the devices could be reasonably achieved. This is the reverse of normal BMP installation where the area to be treated is defined, and the challenge is to find a BMP amenable to that specific drainage area. In either case, the lessons presented may help avoid unforeseen problems with site specific conditions.

Table 1. Stormwater BMP Descriptions and Associated Retrofit Cost

Location: BMP type	Influent Sources [a]	Drainage Area (acres)	Approximate Construction Costs [b] (Thousand $s)
Los Angeles Sites			
I-605/SR-91: Infiltration Basin	91 westbound and cerritos MS	4.2	273
I-210 East of Orcas: CDS™ (hydrodynamic device)	Westbound I-210	1.1	30 (Est.)
I-210 East of Filmore:CDS™	E&W I-210, and SR118 connector	2.5	30 (Est.)
I-5/I-605: EDB (Extended Detention Basin)	I-605 and 5 to 605 connector	6.8	142
I-605/SR-91: Extended Detention Basin	Southbound 605	4.2	137
Paxton Park & Ride: Media Filter	Park & Ride	1.3	331 (Est.)
Metro MS: MCTT (Multi-Chambered Treatment Train)	Maintenance station	4.6	893 (Est.)
Alameda MS:Oil/Water Sep.	Maintenance station	0.8	178
Eastern MS: Media Filter	Maintenance station	1.5	341
Foothill MS: Media Filter	Maintenance station	1.8	479
Termination P&R: Media Filter	Park & Ride	2.8	450
Via Verde P&R: MCTT	Park & Ride	1.1	375
Lakewood P&R: MCTT	Park & Ride	1.9	456
Altadena: Biofilter Strip	Maintenance station	1.7	218
Altadena: Infiltration Trench	Inline w/strip	1.7	Built w/above
Foothill MS: Fossil Filter™ DII (Drain Inlet Insert)	Maintenance station	0.2	68 (including drainage reconstruction)
Foothill MS: Streamgaurd™ DII	Maintenance station	1.6	Built w/above
LasFlores MS: Fossil Filter™ DII	Maintenance station	0.2	88 (including drainage reconstruction)
LasFlores MS: Streamgaurd™ DII	Maintenance station	0.8	Built w/above
Rosemead MS: Fossil Filter™ DII	Maintenance station	0.3	65 (including drainage reconstruction)

Rosemead MS: Streamgaurd™ DII	Maintenance station	1.2	Built w/above
I-605/SR-91: Biofilter Strip	N.B. I-605	0.5	193
I-605/SR-91: Biofilter Swale	WB SR-91to SB I-605 connector	0.2	Built w/above
by Cerritos MS: Biofilter Swale	Westbound SR-91	0.4	59
I-5/I-605: Biofilter Swale	Sounthbound I-5	0.7	97
I-605/ Del Amo: Biofilter Swale	Northbound I-605	0.7	124
San Diego Sites			
I-5/SR-56: Extended Detention Basin	SB I-15, SR78, and connector	5.3	166
I-15/SR-78: Extended Detention Basin	SB I-5, 56/5 connector	13.4	855
I-5/La Costa (West): Infiltration Basin	SB I-5, & off ramp	3.2	241
I-5/La Costa (East): Wet Basin	Northbound I-5	4.2	694
I-5/Manchester (East): Extended Detention Basin	Northbound I-5, Man. Offramp	4.8	369
Kearney Mesa MS: Media Filter	Maintenance station	1.5	340
Escondido MS: Media Filter	Maintenance station	0.8	451
La Costa P&R: Media Filter	Park & Ride	2.8	242
SR-78/I-5 P&R: Media Filter	Park & Ride	0.8	231
Melrose Ave/SR-78: Biofilter Swale	Eastbound SR 78	2.4	156
I-5 Palomar Airport: Biofilter Swale	Southbound I-5	2.3	142
Carlsbad MS: Biofilter Strip	M.S. (0.7 acres bypasses trench)	2.4	196
Carlsbad MS: Infiltration Trench Trench inline w/ 1/2	Trench inline w/ 1/2 of Bio Strip	1.7	Built w/above

a. The influent sources are portions of the areas listed in the table and may also include landscaped adjacent landscaped areas, especially roadside BMPs.

b. Approximate Construction Cost include cost associated with the construction items to allow monitoring of BMP performance.

Local Permits and Regulatory Restrictions

During siting, be aware of local and regional permit requirements and restrictions that could impact construction, operations, or maintenance. Identifying these requirements early will jump-start applying for the appropriate permits, and allow selecting BMPs that will have a reduced impact. Many of our

BMPs fell under the jurisdiction of the California Coastal Commission. Several sites had Coastal Zone Act Reauthorization Amendment (CZARA) permits administered by the local municipalities, and the municipality provided approval of the projects. An example of a significant impact was a biofilter swale at the Palomar Airport Road on Interstate 5. An existing permit for the site required impacted trees to be replaced at a five to one ratio. The biofilter was redesigned to avoid impacting three of the existing trees. This type of problem can be avoided by installing small footprint BMPs or by choosing sites to minimize impacting on existing trees.

Caltrans internal process requires certified biologist to assess the impact of projects to the environment. Impacts form construction of the device must be considered as well as impacts from the device itself. For instance, certain noise levels harass some species of concern. While all Caltrans pilot projects qualified for categorical exemptions, early coordination between the local Fish and Wildlife Service office and pilot team biologists assisted in establishing construction and maintenance schedules. The schedules were generally responsive to nesting periods of migratory birds and endangered species. If sensitive species are nearby, selecting a BMP relatively unattractive to those species may be a good strategy, as maintenance of the BMP could be impacted if the species utilize the BMP. Also, avoid BMPs with maintenance activities deemed harassing to nearby species. Alternative BMPs, such as those that can be covered or that have no vegetation or other attractive features, may be a better choice, as consistent maintenance is critical to the performance of structural BMPs.

Site Specific Requirements

During siting, it is also beneficial to talk to the local supervisor of the site as well as public works. Talking to people familiar with the site will often reveal undocumented information that affects the project. For instance, the City of San Dimas was responsible for the landscaping on Caltrans' right of way at the Via Verde Park and Ride, thus requiring coordination with the city. Communication with the permit inspector, who knew of the situation, during siting or design could have allowed coordination prior to construction.

When surveying a site, the space available must be calculated using safety setbacks required by existing standards. For Caltrans rights of way, a 30 ft minimum setback from the traveled way must be used for any device, obstruction, or drop-off that could damage an errant vehicle. When space doesn't allow for this setback, devices such as metal beam guard rail can be used to 'protect' the device. For example, the California Highway Patrol requested that a fiberglass monitoring cabinet be relocated to avoid vehicle impact. It was moved, and within weeks, a vehicle lost control and passed over the original location (unfortunately, another vehicle struck the relocated equipment, soon after).

General Siting Guidance

Proximity to wells, proximity to foundations, soil conditions, groundwater elevations, drainage area, and flood routing are other factors to consider during siting. Information on these factors is widely available so they are listed here for convenience in making a complete site survey.

DESIGN

The design phase should address as many of the challenges of implementing a BMP as possible. Lessons learned applicable to design were mainly discovered in the later phases of construction, operation, and maintenance. Design is the work between when a site has been selected and a contracted

is awarded for construction. This includes developing plans and specifications and writing the Notice to Contractors. Design lessons learned focus on initial investigation, coordination, on-going facility operations, design specifications, vendor coordination, public awareness, and documentation. Design changes and resulting lessons learned after the contract was awarded or ground was broken are discussed in the construction section of this paper.

Initial Investigation and Coordination

When a site is selected for installation of a BMP, all on-going and planned construction activities in the area should be determined. Coordinating BMP construction to coincide with redevelopment or new construction can save on costs such as mobilization. Also, smaller jobs like BMP installation may not be attractive to many contractors, and getting competitive bids will be easier if combined with other work. Recently installed drainage works could require removal to construct the BMP. Coordinating with other projects on the site could also allow expansion of the BMP drainage area so runoff from a larger area could be treated. If time had permitted, coordination at the 5/78 Park and Ride could have reduced construction cost of a sand filter. Had construction been coordinated, shoring and landscaping costs would have been reduced. To avoid demolition of a section of the upper portion of the Park and Ride, shoring was required that would not have been had the BMP been constructed first. Also, recently planted palm trees in the area required for the shoring operation would not have been dug up and replanted if the BMP was built with the larger improvement project. Finally, drainage from the upper portion of the park and ride could have been diverted to the BMP. Currently only the lower half of the park and ride is treated.

If a thorough site investigation cannot be performed before beginning construction, requiring the contractor to accomplish this investigation should be the first work performed. Preliminary excavation (pot-holing) should be used to determine the accuracy of 'as builts' as well as to discover other items that could require relocation of the device or increase excavation costs. Having this knowledge before excavation may allow for adjustments and cost savings. At the Altadena Maintenance Station in Los Angeles County, the pavement was only an inch thick in the excavation area. The edge of the original pavement cut could not stand up to the equipment traffic and a change order was required at the end of the project to re-cut past the damaged area and repave a larger amount than was previously anticipated. The thin pavement could have been discovered during siting or design by simply investigating the pavement with a pickaxe, and the additional work could have been included in the original work order. Depending on the terms of the change order, this may not save construction costs, but it should save administrative time and prevent disputes of the additional work.

Site Specific Requirements and On-going Facility Operations

Provisions to allow for the on-going operation or function of the site to be retrofitted should also be included in the original work order. For example, material storage bins at the Altadena and Foothill maintenance stations were located where the BMP was to be built. The yard operators requested the contractor construct the new bins specified in the plans before the old ones were removed. This schedule change would have added costs for the contractor and required a change order. Since the contractor was working on 8 different sites, he was able to re-schedule by switching demolition crews to other unaffected sites. Because this may not always be the case, the work plan should include a work schedule that allows vital operations to continue. Other examples include the Via Verde Park and

Ride where site operators required a bicycle storage shed be relocated, so as not to affect commuters who ride bikes to the park and ride. Similarly, the sand filter at 5/78 required shoring not originally specified. Construction without the shoring would require the removal and re-construction of a portion of the upper parking lot. The need to maintain use of those parking spots and not disturb the recently constructed lot should have been identified early, and reflected in the work description.

BMP Specifications and Vendor Coordination

Besides water quality performance goals, product reliability and consistency, product availability, product flexibility, vector control, hydraulic performance and maintenance requirements can influence the design specifications of BMPs. Early consideration of these factors should allow for more efficient BMP implementation.

1) Product Reliability and Consistency

Begin ordering materials with long lead times as soon as possible (i.e. once the design is far enough along to determine items that must supplied to or ordered by the contractor). Some products have long lead times and others may have unanticipated delivery or fabrication problems. For example, at a San Diego site the designer determined that the flumes specified for flow monitoring would not be available before the expected project completion date. The BMP designer researched and specified an alternative cutthroat flume. However, the cutthroat flume performance was insufficiently verified and didn't perform to standard. Additionally, the flumes were built on-site from concrete which resulted in measurement precision much less than that obtainable with fiberglass flumes. Follow-up investigation revealed that even if the flumes could be calibrated, they didn't work very well on the low flows (< 0.1cfs) being monitored. These flumes were later replaced, months after construction was completed. The lesson here is don't specify an alternative product, regardless of delivery problems of the original, unless adequate performance of the alternative can be verified. Similarly, some BMP installations in Los Angeles specified concrete monitoring pads that were smaller than the fiberglass equipment enclosures that arrived later. A change order to widen the pads was required. Once again, checking the specifications of the product ordered would have resulted in the correct pad dimensions in the original plans.

Guidelines on the acceptance of the quality of material should also be included in the specifications. For example, the plant material for the biofilters in both Los Angeles and San Diego, was grown in flats at a nursery. When the sod was delivered, the construction crews found two problems: First, the area of each flat was miscalculated by measuring the dimensions of the grass and not the flat. Second, most of the sod had poor coverage with many of the flats having no plant material. These problems could have been prevented if the height and coverage of the plant material was specified and if the sod area was determined properly at the time of planting at the nursery.

2) Product Availability

Use care when specifying proprietary devices and materials. The compost media for the Kearny Mesa media filter was in a canister configuration. The manufacturer delivered a different media, claiming it would work better. The media was accepted, but specifying proprietary devices may force one to accept revised technologies or maintenance methods that may change the practicality of the device.

3) Product Flexibility

Avoid using pre-cast units. Typically, the elevations in as-builts are not reliable enough to order pre-cast units with pre-set orifices to tie into the existing drainage system. Cast-in-place features allow the contractor to make adjustments necessary because of both the actual field conditions and changes resulting from the construction process. For instance,Pre-cast G2 inlets at the Rosemead, Foothill, and Los Flores Maintenance Stations had to be modified and grouted because of differences between design and field conditions. This resulted in added time and expense.

4) Vector Production

A vector borne disease control expert reviewed each BMP design. Initially, the biofilter devices were considered a low threat for mosquito production, and no design changes were recommended. However, during operations it was discovered that the energy dissipaters and flow spreaders were very effective mosquito incubators. Subsequently, these structures were grouted in and rip-rap was set in the grout to perform the function of the shallow recesses. This reduced the need to abate mosquito larva in these devices. Future design of BMPs should avoid standing water for longer than the incubation period of mosquitoes, 72 hours.

Vector experts also required that BMPs with potential for breeding mosquitoes, such as basins, be designed to incorporate access to the site for inspection and abatement of vectors. The method of abatement uses control material broadcast from a truck. The distance from the access road to any part of the BMP had to be within the broadcast range of the equipment used by the local vector control authority. Easy access to the BMP also makes maintenance easier and safer.

5) Hydraulic Performance

Flow spreader and similar BMP features should not be designed for one specific flow rate, as storm water flows vary greatly within an event as well as between events. The flow spreader at the Carlsbad maintenance station infiltration trench was designed to spread flow from the target treatment volume. Smaller, more frequent flows, were not spread properly, and caused water to concentrate on one side of the infiltration trench.

6) Maintenance Requirements

Railings, ladders, steps, and vehicle access to sedimentation chambers of sand filters should be included in the original BMP designs. These basins have vertical drops to save space, while cost prevented them being covered. Railings should be provided to avoid accidents in what could be considered an attractive nuisance. Ladders were added later as a change order, but steps and railing would be better. Vehicle access would ease sediment removal, inspections, and vector treatment.

Public Notification

Prior to construction, the community should be educated on the purpose and potential impact of the project. Prior knowledge can avoid confusion and unnecessary public reaction. At the Via Verde Park and Ride installation of a Multi-Chambered Treatment Train, the public was concerned that all the spaces used during the construction of the device would be lost completely. When it was explained that many spaces would be returned following completion of construction the public's concerns were substantially relieved.

Pre-construction Documentation

Pre-construction photography of the site should be done to document existing site conditions. Disputes can arise with contractors regarding damage done during construction. Also, if the work description requires the contractor to return the landscaping or other site feature to their existing condition, photographs will reduce or eliminate disputes. Photographs of landscaping prior to sand filter installation at Termination Park and Ride and the MCTT installation at the Via Verde Park and Ride could have eliminated such disputes.

CONSTRUCTION

Many of the lessons learned during construction were included in the design section, as action taken in the design phase could prevent problems during construction. Lessons specific to construction will help resolve or avoid disputes, save time and money, and improve initial BMP performance. As with the previous phase, site photographs taken throughout construction may help resolve disputes with the contractor.

Installation Specifications

Proprietary devices may come with installation instructions. These instructions should be viewed as guidelines, or results in the field may not be satisfactory. For the drain inlet inserts, two types of inserts were installed. The fabric insert called for removal of the inlet grate, placing of the fabric, and replacement of the grate. This technique allows for water to seep past the edge of the grate. Also, the fabric tends to slip into the drain inlet when the weight of water and accumulated sediment pull it down. The solution was to rip strips of wood to wedge the fabric against the walls of the drain inlet. This allowed better flow through the device and added resistance to help prevent slipping. The other type of inlet insert required the installation of a framework that held rectangular canisters containing a filtering media. The framework and canisters had to be ordered to the size of the inlet to be retrofitted. The tolerances in fabrication resulted in installations that had gaps up to 0.1" at the Rosemead Maintenance Station installation. Though small, this did allow a small portion of stormwater runoff to bypass the device untreated. The solution was to use silicon caulk and/or shims to prevent water from bypassing the device. In both cases, specifying a 'water-tight installations by use of shims or caulk' will have the drain inlet inserts off and running and avoid re-installation. In general, always specify that all connections are sealed and bypass is not allowed, except for where bypass features are included for flood routing purposes.

Quality Control

Quality control during the surveying and construction is critical because many BMPs in a retrofit environment require tight tolerances due to available hydraulic head. Adjustments were required at the 605/91 Infiltration Basin inlet/outlet/overflow structure. Also, the diversion structure for the influent to the Lakewood Park and Ride was partially removed and re-grouted at the proper elevation. Many other sites, such as at the I-5/SR-56, I-15/SR-78, and the I-5/I-605 extended detention basins, had minimal available hydraulic head and construction was successfully controlled to achieve the design requirements.

For future reference and as a resource for BMP operation and maintenance crews, accurate as-builts

should be submitted. In the case of the wet basin at I5/La Costa in San Diego County, the maintenance program for vegetation management is tied to the 'as-constructed' condition. The maintenance crews use the plans as a reference. Also, future changes to a BMP require accurate knowledge of existing conditions, and existing conditions are rarely reflected in the original plan set because of adjustments required during construction.

At the Lakewood Park and Ride, the contractor tied into existing electrical power on site. During construction, it was determined that the voltage to the MCTT for operating it's two pumps was insufficient. The contractor tried to pull the wiring, but it 'wouldn't budge.' Because construction was already behind schedule, the problem was left for the operation and maintenance crews to deal with and the contractor was released from the job. The operation crew had a voltage booster installed. The resulting performance was improved, but still less than ideal. It would have been better to force the original contractor to supply adequate power. The added delay in construction could make up for downtime due to insufficient performance of an inadequately constructed BMP.

CONCLUSIONS

Siting and design are the most critical phases of BMP implementation. Problems addressed early within these processes can save time and money, and result in better BMP performance. As a whole, the lessons learned in this BMP pilot study present a lesson in itself. That is, the phase most rushed will be the phase with more mistakes or oversights. Also, a mistake or oversight in early phases may plaque the subsequent stages including operation and maintenance of the BMP.

Siting should start contacting agencies and internal management of the sorrounding area to use them as a resource in early identification of conflicts. On average, additional investigation and coordination,seems to pay for itself in later phases of the project. However, the cost of added investigation must be weighed by the potential cost savings. In the case of the sand filter at I-5 and La Costa Ave. Park and Ride, there existed sufficient flexibility in space that potholing to determine the exact location of the 24" discharge pipe would be meet or exceed the cost to modify the design during the construction process. In this case, exploration costs were reduced because of sufficient flexibility.

Design of the BMP devices should be responsive to maintenance, on-going facility operations, vector and safety concerns. Poor design will result in poorly functioning BMPs, or in BMPs that create safety and public health liabilities. Proper work plan preparation can minimize impact to on-going facility operations and minimize conflicts between facility operators and the contractor.

Even proper siting and design can not guarantee against challenges with construction. Following good construction management practices will avoid most problems identified. For retrofit construction, allow a time contingency to deal with unforeseen challenges. This would allow time for detailed inspection and correction of any insufficient work items.

For each phase of BMP implementation, the tradeoff between time and quality will hold true. If time is tightly constrained, some amount of inefficiency (cost increase) is expected. The goal, however, is to have the most efficient process that is constrained by the project's available resources and time.