Storm Water Program

California State University, Sacramento (CSUS)

University of California, Davis (UCD)

California Department of Transportation (Caltrans)

Design and Performance of Non-Proprietary Devices for Highway Runoff Litter Removal

Presented at:

American Society of Civil Engineers 9th International Conference on Urban Drainage, Portland, Oregon, September 8-13, 2002 (included in conference proceedings)

Authors:

Jeffrey D. Endicott, CDM, Ontario, California
Byron J. Berger, Caltrans Environmental Program
Shaun J. Stone, CDM, Ontario, California

Disclaimer:

Storm Water Program
CSUS Office of Water Programs
7801 Folsom Boulevard, Suite 102, Sacramento, CA 95826

PP031

Design and Performance of Non-Proprietary Devices for Highway Runoff Litter Removal

Jeffrey D. Endicott, P.E.*, Byron J. Berger, P.E.**, and Shaun J. Stone, P.E.***

*Associate, CDM, 2920 Inland Empire Blvd., Suite 108, Ontario, CA 91764; PH 909-945-3000; FAX 909-945-1333; E-Mail endicottjd@cdm.com
**Transportation Engineer, California Department of Transportation, Division of Environmental Analysis, 1415 11th St., MS-27, Sacramento, CA 95814; PH 916-653-8369; E-Mail byron_berger@dot.ca.gov
***Project Engineer, CDM, 2920 Inland Empire Blvd., Suite 108, Ontario, CA 91764; PH 909-945-3000; FAX 909-945-1333; E-Mail stonesj@cdm.com

Abstract

A Total Maximum Daily Load for discharges of trash to the Los Angeles River has been incorporated by the Regional Water Quality Control Board into the *Water Quality Control Plan – Los Angeles Region*. The California Department of Transportation operates highways and ancillary facilities served by storm drains discharging to the Los Angeles River and therefore must comply with the waste load allocation for discharges of trash in storm water. This paper presents the results of a pilot study investigation of the effectiveness of non-proprietary devices for removing trash from discharges of highway runoff.

Background

The California Regional Water Quality Control Board, Los Angeles Region (LARWQCB) has developed a Total Maximum Daily Load (TMDL) for discharges of trash to the Los Angeles River (LARWQCB, 2001a). The TMDL sets the maximum amount of trash that can be discharged to the Los Angeles River consistent with achieving the beneficial uses of the river designated in the *Water Quality Control Plan – Los Angeles Region* (Basin Plan) (LARWQCB, 2001b). The TMDL for discharges of trash to the Los Angeles River is set at zero.

The LARWQCB has identified storm drain systems discharging to the Los Angeles River as a major source of trash. In order to achieve the allowable TMDL for trash, the LARWQCB has assigned a waste load allocation to operators of storm drain systems discharging to the river. The waste load allocation calls for a phased reduction of trash from current levels to zero over a 10-year period ending September 30, 2013 (LARWQCB, 2001a).

The United States Environmental Protection Agency (USEPA) has also developed a TMDL for discharges of trash to the Los Angeles River (USEPA, 2001). The USEPA is taking this action in order to ensure that a trash TMDL for the Los Angeles River is established on or before the March 22, 2002 deadline set forth in a consent decree (*Heal the Bay, Santa Monica Baykeeper, et al. v. Browner, et al., No. 98-4825, March 22, 1999*). The USEPA has taken this action because the California State Water Resources Control Board might not establish the LARWQCB's trash TMDL before the deadline. The USEPA TMDL is substantially similar to the LARWQCB's TMDL, with the substantive difference being the elimination of the process to refine the default baseline waste load allocation by implementing a baseline monitoring program. Hereinafter, "TMDL" is a reference to both the LARWQCB's and USEPA's TMDL.

The California Department of Transportation (Caltrans) owns and operates highways and ancillary facilities served by storm drains discharging to the Los Angeles River and is therefore subject to the TMDL and has been assigned a waste load allocation. Caltrans has implemented a pilot study to design and test devices that can be incorporated into existing or future highway drainage structures for the purpose of removing trash from discharges of highway runoff. While a number of proprietary devices are being marketed for similar purposes, the pilot study focused on non-proprietary designs that could be designed, specified, bid, constructed, and operated without the constraints often associated with proprietary units.

Study Design

The objective of the pilot study was to pilot test devices that could be incorporated into existing or future highway drainage systems to remove trash from storm water discharges in order to meet the waste load allocation of the trash TMDL. The pilot study included conceptual design of trash removal devices, site selection, development of device design criteria, construction, monitoring, and assessment of the performance of each device. The pilot study schedule was as follows: conceptual designs were completed between January and April 2000; site selection and preliminary designs were completed between April and August 2000; final designs and construction were completed between August and December 2000; and initial monitoring and performance assessment were completed between December 2000 and June 2001. The second season of monitoring and performance assessment is currently underway.

Conceptual Design

The conceptual design effort focused on development of non-proprietary devices that could be incorporated into existing or future highway drainage systems for the purpose of removing trash from discharges of storm water. Non-proprietary designs were desirable because they ultimately provide for design, specification, bidding, construction, and operation without the constraints associated with proprietary units. Constraints that have been associated with proprietary units include competitive bidding statutes, royalty fees, replacement parts availability, and limited ability to modify units.

Four design concepts were initially developed and narrowed to three for pilot testing, including the Linear Radial, the Inclined Screen, and the Baffle Box. The fourth concept was not selected for pilot testing because it was primarily suited for use in detention basins and there were few detention basins for highway runoff in the Los Angeles River watershed.

The conceptual design process was primarily targeted at removal of trash from storm water as required by the TMDL. Trash is defined in the TMDL as litter and particles of litter that are retained by a 5-mm mesh screen (LARWQCB, 2001a). The TMDL defines litter per California Government Code Section 68055.1(g):

"Litter means all improperly discarded waste material, including, but not limited to, convenience food, beverage, and other product packages or containers constructed of steel, aluminum, glass, paper, plastic, and other natural and synthetic materials, thrown or deposited on the lands and waters of the state, but not including the properly discarded waste of the primary processing of agriculture, mining, logging, sawmilling or manufacturing…"

The storm drain system is known to carry both trash as defined in the TMDL and other materials such as vegetable matter from natural vegetation and landscaping, and sediments deposited after being eroded by wind or water. Because these materials are intricately commingled, this paper will refer collectively to this mixture of material as "gross solids."

Linear Radial (Figure 1). This device utilizes a modular and linear screen cage constructed of rigid mesh or louvered well casing contained in a vault. Gross solids are retained within the screen cage. Key design and operational concepts are as follows:

- Flows enter the device through a screen cage aligned parallel to the direction of flow.
- Flows exit the device by passing radially through the cage screen and into the vault.
- The screen has a smooth, solid bottom section to facilitate movement of gross solids towards the downstream end of the screen cage.
- The screen cage open area and interior volume are sized to accommodate the design storm discharge from the tributary drainage area and a once-per-year gross solids removal cycle.
- The vault has sufficient volume to reduce flow velocities to allow solids to settle.
- The vault is sloped towards the outlet to provide positive drainage.
- The vault can be configured with grates or covers, traffic or non-traffic rated, depending upon location within the right-of-way.

The linear configuration of this device and low head requirements make it ideal for many typical highway right-of way applications.

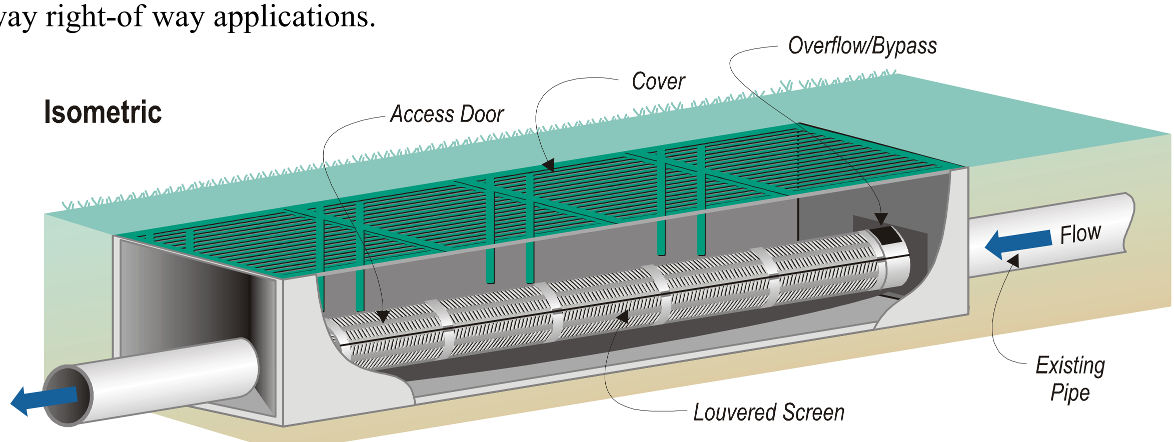

Figure 1. Linear Radial Gross Solids Removal Device

Inclined Screen (Figure 2). This device utilizes an inclined screen constructed of parallel wires or bars contained in a vault. Gross solids are retained in a storage area of the vault located at the bottom of the inclined screen. Key design and operational concepts are as follows:

- Flows enter the device through a trough and weir which distribute inflow across the top of the inclined screen. The trough captures the heavier solids such as gravel and sand.
- Flows exit the device by passing through the inclined screen.

- The screen has a smooth surface which allows water flowing down the screen to push gross solids downward towards the vault's gross solids storage area.
- The inclined screen open area is sized to accommodate the design storm discharge from the tributary drainage area.
- The gross solids storage area is sized to accommodate a once-per-year removal cycle.
- The influent trough is drained through a series of weep holes. The gross solids storage area is sloped towards a grate-covered drainpipe.
- The vault can be configured with grates or covers, traffic or non-traffic rated, depending upon location within the right-of-way.

The compact footprint of this device facilitates retrofit siting in space-constrained highway right-of-ways, especially fill sections with sufficient head to provide a drop, usually 0.9 m (3 ft) across the inclined screen.

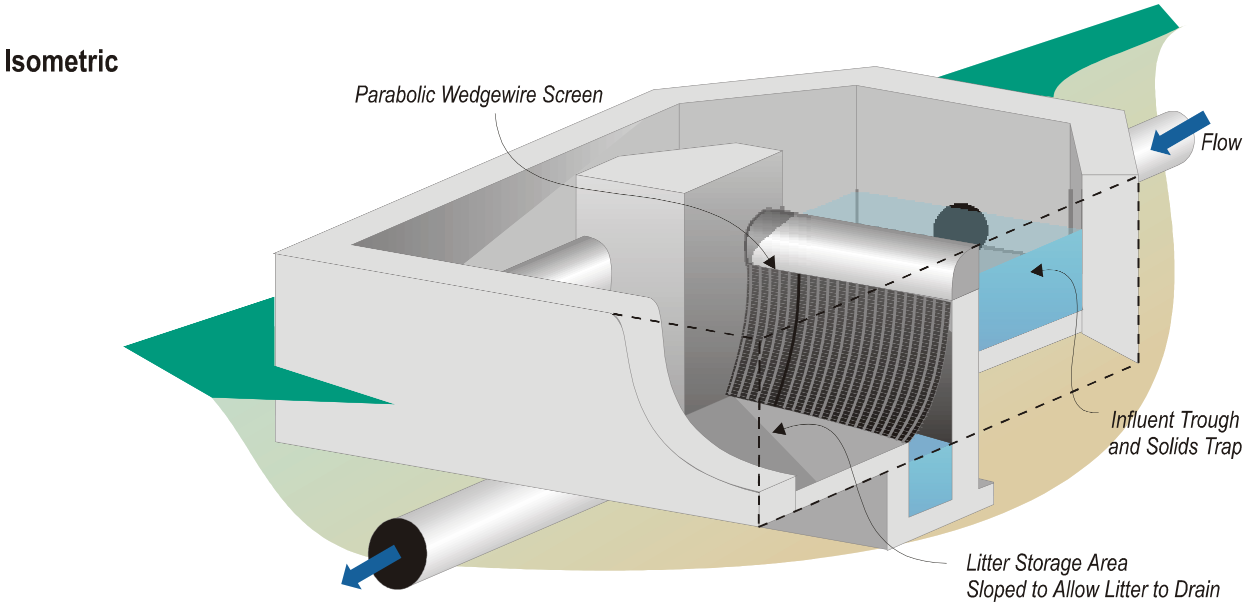

Figure 2. Inclined Screen Gross Solids Removal Device

Baffle Box (Figure 3). This device utilizes a two-chamber concept, with an underflow weir in the first chamber and a bar rack in the second chamber. Gross solids are retained in three storage areas: in the top and bottom of the first chamber for floatable and settled materials, respectively; and beneath the bar rack in the bottom of the second chamber. Key design and operational concepts are as follows:

- Flows enter the device through the first chamber. A weir wall and baffle create a standing pool. Flows continue through the unit to the second chamber by passing under the baffle and over the weir wall.
- Flows exit the device through the second chamber by passing upward through a bar rack.
- In the first chamber, the baffle wall prevents floatable gross solids from passing downstream, and the weir creates a quiescent volume sufficient to allow heavier particles to settle. As floating gross solids in the first chamber age, some are expected to sink and will be retained with the heavier solids near the bottom.
- In the second chamber, gross solids will be retained below the bar rack as flows proceed towards the effluent pipe.

- The baffle, weir, and screen are sized to accommodate the design storm discharge from the tributary drainage area and a once-per-year gross solids removal cycle.
- The second chamber of the device will be dewatered using drain holes or a sump pump.
- The vault can be configured with grates or covers, traffic or non-traffic rated, depending on the location within the right-of-way.

This device is suited to locations with sufficient space to accommodate a relatively large footprint, and having sufficient head to allow for gravity dewatering or having power available for a sump pump.

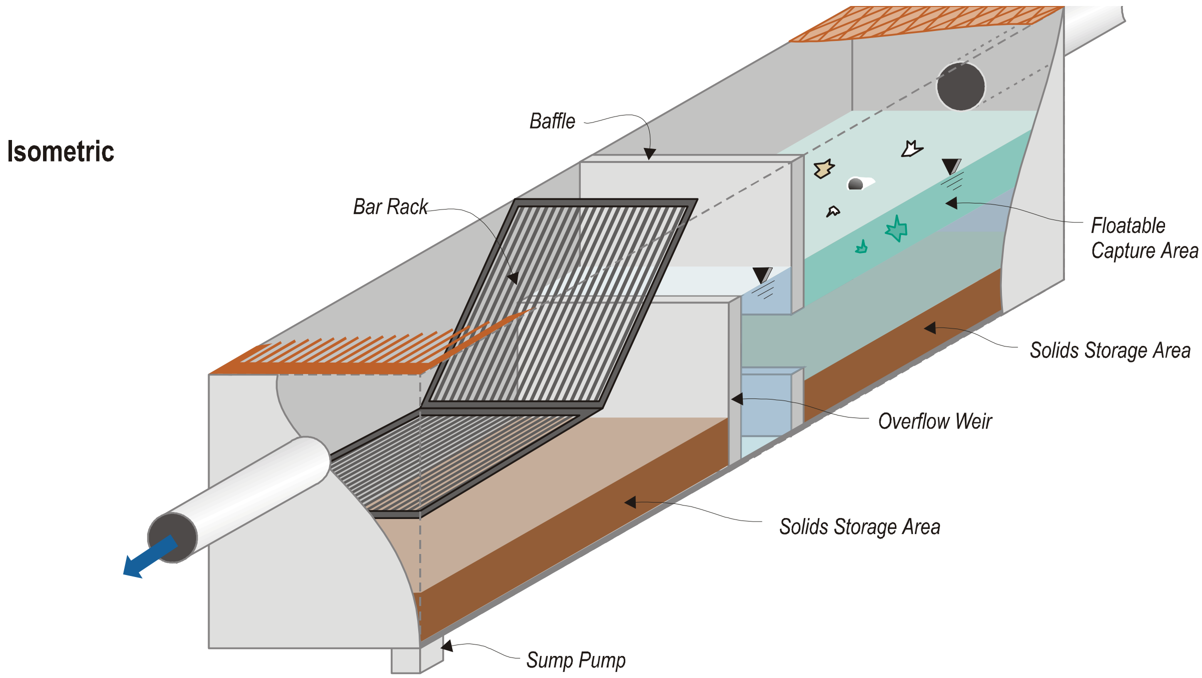

Figure 3. Baffle Box Gross Solids Removal Device

Site Selection

The objective of the site selection process was to identify locations in the Los Angeles River watershed where pilot gross solids removal devices could be implemented on a full-scale basis and their performance monitored. The site selection process began with development of site selection criteria designed to help identify candidate sites to accomplish pilot study objectives. Table 1 presents the site selection criteria. Additional site selection criteria included a relatively homogeneous drainage area, and sufficient space within the Caltrans right-of-way to construct the pilot project and to conduct monitoring activities. A final requirement was for each pilot site, during both construction and operation, to be in full compliance with Caltrans safety and traffic setback requirements (Caltrans, 1995).

Table 1. Key Site Selection Criteria for Pilot Gross Solids Removal Devices

GSRD Type	Site Selection Criteria				
	Upstream Drain Inlets #	Drain Pipe Diameter mm (in)	Depth to Pipe Invert m (ft)	Drain Pipe Slope (%)	Minimum Available Head Loss m (ft)
Linear Radial	≥ 5	≤ 900 (36)	≤ 2.5 (8)	≥1	N/A
Inclined Screen	≥ 5	≤ 900 (36)	≤ 2.5 (8)	≥1	> 0.9 (3)
Baffle Box	≥ 5	≤ 900 (36)	≤ 2.5 (8)	≥1	N/A

In total, reconnaissance was conducted on over 250 sites, with site selection checklists completed on approximately 200 sites. The inventoried sites were subjected to a three-step review process including: 1) compiling, screening, and reviewing available "As-Built" plans; 2) contacting Caltrans District staff to collect information on potential site locations and field constraints; and 3) detailed field review of candidate sites. Following the three-step review, 70 candidate sites were ranked, and 8 sites were selected for the pilot projects. Table 2 and Table 3 present details on the location and drainage area for the eight sites selected for pilot project implementation.

Table 2. Location Summary for Pilot Gross Solids Removal Devices

Site Name	Device Type	City	Route	Direction	Kilometer Post
I-10/Rosemead	Linear Radial	Rosemead	10	Westbound	44.1
I-210/Glenada	Linear Radial	La Crescenta	210	Eastbound	28.7
I-5/Garber	Linear Radial	Pacoima	5	Southbound	61.0
SR-170/Burbank	Inclined Screen	North Hollywood	170	Northbound	26.1
US-101/Gaviota	Inclined Screen	Encino	101	Eastbound	68.4
I-210/Orcas	Inclined Screen	Lake View Terrace	210	Westbound	13.5
I-405/Leadwell	Baffle Box	Van Nuys	405	Southbound	14.6
I-210/Christy	Baffle Box	Lake View Terrace	210	Eastbound	30.0

Table 3. Drainage Area Summary for Pilot Gross Solids Removal Devices

Site Name	Device Type	Watershed	Drainage Area ha (ac)	Roadway Runoff %	Drain Inlets Served
I-10/Rosemead	Linear Radial	Los Angeles River	1.5 (3.7)	100	6
I-210/Glenada	Linear Radial	Los Angeles River	2.5 (6.2)	100	12
I-5/Garber	Linear Radial	Los Angeles River	0.4 (0.9)	100	5
SR-170/Burbank	Inclined Screen	Los Angeles River	1.0 (2.5)	100	5
US-101/Gaviota	Inclined Screen	Los Angeles River	0.8 (2.1)	100	15
I-210/Orcas	Inclined Screen	Los Angeles River	1.4 (3.4)	100	4
I-405/Leadwell	Baffle Box	Los Angeles River	1.2 (3.0)	100	3
I-210/Christy	Baffle Box	Los Angeles River	0.9 (2.3)	100	3

Design Criteria and Approach

Governing criteria for the design of the pilot gross solids removal devices included the ability to remove litter as required by the trash TMDL and compatibility with existing highway infrastructure since compliance with the TMDL will require retrofit of existing drainage systems. The governing criteria were then subdivided into design criteria including: hydrology and hydraulics; public and maintenance personnel safety; operation and maintenance; vector control; and gross solids loading rates. A brief discussion of each design criterion is presented below.

Hydrology/Hydraulics. The existing drainage systems at the selected sites were designed to Caltrans standards which included the ability to convey the peak runoff generated by a 25-year storm event. Therefore, the ability to convey the peak runoff generated by a 25-year storm event was set as the minimum hydraulic design criteria for the pilot gross solids removal devices.

Standard Caltrans methodology (rational method for small watersheds) was used for the calculation of the peak discharge from the 25-year storm event. Soil classification and rainfall intensities were obtained from Los Angeles County Department of Public Works hydrologic maps. Five-minute peak intensity durations were used to calculate peak discharges for slopes greater than 10 percent and 10-minute peak intensities were used for slopes less than 10 percent. Runoff coefficients of 1.00 and 0.75 were used for paved and unpaved areas, respectively.

Drainage area boundaries were delineated using topographic maps, but when contour maps were unavailable, a 2 percent cross-slope typical of freeways was used. It was assumed that drainage inlets were positioned to intercept 100 percent of roadway runoff. Freeway layout, grading, inlet locations, and storm drain plan and profile were obtained from Caltrans record drawings and field reconnaissance.

Public Safety and Maintenance Personnel Safety. The pilot gross solids removal devices were required to comply with all applicable Caltrans safety standards to minimize or eliminate risks to the motoring public and Caltrans personnel. These criteria applied during construction, monitoring, and maintenance phases of the pilot study. Criteria included facility set backs from the traveled way equal to or greater than a standard shoulder width and maintenance of a clear recovery zone. Where feasible, non-freeway access was provided for maintenance and monitoring. Safety issues and other site-specific issues were identified and addressed on a case-by-case basis.

Operation and Maintenance. Operation and maintenance criteria included consideration of maintenance frequency and safety of maintenance personnel. Design criteria to address operation and maintenance concerns included: adequate parking and access for maintenance and monitoring vehicles; no lane closures for servicing or monitoring a device; shoulder closures for major device maintenance activities were allowable but must be minimized; maintenance equipment limited to equipment commonly available in the Caltrans maintenance fleet; and an annual maintenance cycle for removal of accumulated gross solids.

The criterion for an annual maintenance cycle indirectly addresses multiple operation and maintenance criteria by reducing the number of times per year a device would need to be cleaned. The annual maintenance cycle required that each device be sized to hold the gross solids projected to accumulate over a one-year period.

Vector Control. Vector control authorities expressed concern over standing water in the devices as such conditions provide breeding grounds for mosquitoes. The criteria adopted to address mosquito breeding was that each device would need to completely drain within 72 hours following the end of a runoff event. In addition, each device was required to include appropriate features to allow for vector monitoring by vector control authorities during the pilot study.

Gross Solids Loading Rates. Early in the conceptual design process it was recognized that the technologies being considered for the pilot project would capture a combination of "litter" as defined by the TMDL as well as "other materials" that are commonly observed in storm water. Therefore, in lieu of a strictly litter design criteria, a gross solids design criteria was developed. The design criteria for gross solids loading rates were based on an analysis of data from two Caltrans studies: the *District 7 Litter Management Pilot Study* (Caltrans, 2000); and the *Solids Transport and Deposition Study* (Caltrans, 1999). Gross solids were then defined as a combination of litter and solids, with each component described below:

> "Litter is defined as anthropogenic waste material. It is assumed to include floating and suspended materials that will be trapped by a 5 mm (0.25 inch nominal) square screen mesh. Litter excludes sediments, oil and grease, and exotics. Solids include suspended materials that readily settle, similar to silt, sand, and grit. Gross Solids include litter solids and all of the naturally occurring organic materials that may be transported by storm water runoff." (Caltrans, 2000)

The *District 7 Litter Management Pilot Study* (Caltrans, 2000) reported a maximum gross solids capture volume of 0.33 m^3/ha/yr (4.7 ft^3/ac/yr), and the *Solids Transport and Deposition Study* (Caltrans 1999) reported an average gross solids accumulation in drain inlets of 0.39 m^3/ha/yr (5.6 ft^3/ac/yr). The gross solids loading rate design criteria for this pilot study was set between these loading rates at 0.35 m^3/ha/year (5 ft^3/ac/year). Due to the limited availability of data on gross solids loading rates and the variability of loading rates reported in the two Caltrans studies, a factor of safety of 2.0 was applied to the loading rate design criteria, resulting in an effective gross solids loading rate design criterion of 0.7 m^3/ha/yr (10 ft^3/ac/yr).

Design and Construction

The gross solids removal device design criteria, together with site-specific survey and field reconnaissance data, were then used to the guide design of the pilot gross solids removal devices. The key design element at each site was selection and design of the screen type and configuration. Table 4 summarizes key site details and the selected screen type and configuration for the eight pilot sites.

Construction of the pilot gross solids removal devices was commenced and completed on an accelerated schedule between November 2000 and January 2001. The construction time frame for the pilot devices ranged from 21 to 37 working days (31 working day average, 33/34 working day median) once final plans were approved and permits were secured. Construction costs for each device are presented in Table 5 and are exclusive of costs associated with installation of monitoring equipment.

Monitoring

Performance monitoring was a key part of the pilot project. The objective for monitoring the pilot gross solids removal devices was to determine their effectiveness at removing trash, defined in the TMDL as litter and litter particles retained on a 5-mm (0.25-in) mesh screen, from discharges of storm water from highways.

The monitoring program design began by defining the measure of effectiveness for the pilot devices. For this study, device effectiveness was defined as the percentage of total litter captured by the device. In order to calculate this percentage, it was necessary to measure the amount of *captured gross solids* as well as the *total gross solids loading* to each device, and then to manually separate the litter fraction from each component. The amount of *captured gross solids* was defined as the total mass and volume of gross solids removed from within the device during the annual cleaning or, if necessary, incremental cleanings. The *total gross solids loading* was defined as the sum of the *captured gross solids* and the *bypassed gross solids*. *Bypassed gross solids* were defined as gross solids that bypassed the gross solids removal device (by way of overflow or by material passing through the device screen) and that were captured in a mesh bag and/or mesh screen box located downstream of the pilot device.

Each pilot device was instrumented with the following monitoring equipment: tipping bucket rain gage; flow meter; bypass capture device; and automatic sampler. The rain gauge and flow meter collected data to develop estimates of runoff coefficients and to develop storm hydrographs. The bypass capture device allowed capture of gross solids bypassing the device. The automatic sampler collected aliquots to allow development of flow weighted composite water quality samples for laboratory analysis.

Table 4. Design Summary for Pilot Gross Solids Removal Devices

Site Name	Device Type	Drainage Area ha (ac)	Inlets Served #	Screen Type and Configuration
I-10/ Rosemead	Linear Radial	1.5 (3.7)	6	Circular well screen with 5-mm (0.25-in.) nominal louvers. One unit installed horizontally. Gross solids captured and stored inside well screen.
I-210/ Glenada	Linear Radial	2.5 (6.2)	12	Rectangular rigid mesh housing supporting a nylon mesh bag with 5-mm (0.25-in.) openings. Three units installed horizontally. Gross solids captured and stored inside mesh bags.
I-5/ Garber	Linear Radial	0.4 (0.9)	5	Rectangular rigid mesh housing supporting a nylon mesh bag with 5-mm (0.25-in.) openings. Three units installed horizontally. Gross solids captured and stored inside mesh bags.
SR-170/ Burbank	Inclined Screen	1.0 (2.5)	5	Parabolic wedge-wire screen with 3-mm (0.125-in.) nominal openings. Two units installed with near vertical slope. Flow is perpendicular to wedge-wire slots. Gross solids washed to storage area at bottom of screen.
US-101/ Gaviota	Inclined Screen	0.8 (2.1)	15	Parabolic wedge-wire screen with 5-mm (0.25-in.) nominal openings. Single units installed nearly horizontal. Flow is parallel to wedge-wire slots. Gross solids washed to storage area at end of screen.
I-210/ Orcas	Inclined Screen	1.4 (3.4)	4	Parabolic wedge-wire screen with 5-mm (0.25-in.) nominal openings. Single units installed nearly horizontal. Flow is parallel to wedge-wire slots. Gross solids washed to storage area at end of screen.
I-405/ Leadwell	Baffle Box	1.2 (3.0)	3	Chain-link fence initial screen and perforated plate second screen with 5mm (0.25-in.) diameter circular perforations. Initial screen installed vertically and second screen installed horizontally. Gross solids trapped and stored beneath perforated plate.
I-210/ Christy	Baffle Box	0.9 (2.3)	3	Chain-link fence initial screen and perforated plate second screen with 5-mm (0.25-in.) diameter circular perforations. Initial screen installed vertically and second screen installed horizontally. Gross solids trapped and stored beneath perforated plate.

Table 5. Construction Costs for Pilot Gross Solids Removal Devices

Site Name	Device Type	Drainage Area Ha (ac)	Construction Cost[1] $	Construction Cost[1] $/ha ($/ac)
I-10/Rosemead	Linear Radial	1.5 (3.7)	48,300	32,200 (13,054)
I-210/Glenada	Linear Radial	2.5 (6.2)	155,935	62,374 (25,151)
I-5/Garber	Linear Radial	0.4 (0.9)	94,388	235,970 (104,876)
SR-170/Burbank	Inclined Screen	1.0 (2.5)	82,800	82,800 (33,120)
US-101/Gaviota	Inclined Screen	0.8 (2.1)	135,263	169,079 (64,411)
I-210/Orcas	Inclined Screen	1.4 (3.4)	134,351	95,965 (39,515)
I-405/Leadwell	Baffle Box	1.2 (3.0)	113,348	94,457 (37,783)
I-210/Christy	Baffle Box	0.9 (2.3)	119,555	132,839 (51,980)

[1]Excludes costs associated with features or equipment for monitoring.

Each pilot device was periodically observed throughout the 2000-01 wet season, with rainfall data, flow data, and water quality samples retrieved and analyzed after each runoff event. Gross solids were removed at the end of the wet season except where a device was judged to be sufficiently clogged to make bypass imminent, wherein the device was cleaned mid-season. Gross solids were then analyzed in the laboratory, including manual separation of the vegetation and litter components. The laboratory recorded the wet weight and volume for total gross solids and vegetation, and wet and dry weight and volume for litter. Table 6 and Table 7 summarize key results of device monitoring and laboratory analysis on a mass (weight) and volume basis, respectively. For comparison purposes, loadings are also expressed in terms of loading per unit of drainage area and loading per unit of drainage area per unit of rainfall.

Performance Evaluation

The pilot gross solids removal devices removed a combination of gross solids, including solids, vegetation, and litter. Removal efficiencies for gross solids ranged from approximately 82 to 100 percent on a wet mass (weight) basis (Table 8), and from approximately 55 to 100 percent on a wet volume basis (Table 9). Removal efficiencies for litter ranged from approximately 66 to 100 percent on a dry mass (weight) basis (Table 8), and from approximately 66 to 100 percent on a dry volume basis (Table 9).

Six of the pilot devices (Linear Radials at I-10/Rosemead and I-5/Garber; Inclined Screens at SR-170/KP 26.1 and I-210/Orcas; and Baffle Boxes at I-405/Leadwell and I-210/Christy) were operational during the first monitored runoff event on January 10, 2001. This event lasted approximately 18 hours and produced from 81-mm (3.2-in) to 140-mm (5.5-in) of rainfall. Based on historical records, this was a 10-yr to 25-yr storm event. Subsequent storms in January 2001 blinded the Linear Radial at I-5/Garber, Inclined Screen at I-210/Orcas, and Baffle Boxes at I-405/Leadwell and I-210/Christy, and required that the devices be cleaned of accumulated

Table 6. Gross Solids Monitoring and Mass (Weight) Loading Summary

Device Type	Site Name	Total Gross Solids (wet) kg (lbs)	Total Litter (dry) kg (lbs)	Total Area ha (ac)	Total Period Rainfall mm (in)	Total Gross Solids (wet) kg/ha (lbs/ac)	Total Gross Solids (wet) kg/ha/mm (lbs/ac/in)	Total Litter (dry) kg/ha (lbs/ac)	Total Litter (dry) kg/ha/mm (lbs/ac/in)
Linear Radial	I-10 at Rosemead	111.9 (246.7)	9.5 (20.9)	1.5 (3.7)	367 (14.45)	74.6 (66.7)	0.2 (4.6)	6.3 (5.6)	0.02 (0.4)
	I-210 at Glenada	410.2 (904.3)	6.6 (14.6)	2.5 (6.2)	270 (10.63)	164.1 (145.8)	0.6 (13.7)	2.6 (2.4)	0.01 (0.2)
	I-5 at Garber	191.6 (422.4)	6.2 (13.7)	0.4 (0.9)	344 (13.54)	479.0 (469.3)	1.4 (34.7)	15.5 (15.2)	0.04 (1.1)
Inclined Screen	SR-170 at KP 26.1	97.6 (215.2)	16.7 (36.8)	1.0 (2.5)	483 (19.02)	97.6 (86.1)	0.2 (4.5)	16.7 (14.7)	0.03 (0.8)
	I-210 at Orcas	134.4 (296.3)	6.2 (13.7)	1.4 (3.4)	346 (13.62)	96.0 (87.1)	0.3 (6.4)	4.4 (4.0)	0.01 (0.3)
	SR-101 at Gaviota	308.4 (679.9)	10.0 (22.0)	0.8 (2.1)	271 (10.67)	385.5 (323.8)	1.4 (30.3)	12.5 (10.5)	0.05 (1.0)
Baffle Box	I-405 at Leadwell	531.3 (1171.3)	29.8 (65.7)	1.2 (3.0)	372 (14.65)	442.8 (390.4)	1.2 (26.6)	24.8 (21.9)	0.07 (1.5)
	I-210 at Christy	413.2 (910.9)	20.1 (44.3)	0.9 (2.3)	378 (14.88)	459.1 (396.0)	1.2 (26.6)	22.3 (19.3)	0.06 (1.3)

gross solids to prevent overflows. The Linear Radial at I-10/Rosemead and the Inclined Screen at SR-170/KP 26.1 did not require mid-season cleanings to prevent overflows.

Pilot site loading rates for the January to April monitoring season ranged from 0.13 to 0.92 m^3/ha (1.9 to 13.0 ft^3/ac) for gross solids and from 0.02 to 0.21 m^3/ha (0.3 to 3.0 ft^3/ac) for litter (Table 7). These loading rates bracket the design annual gross solids loading rate of 0.35 m^3/ha/yr (5 ft^3/ac/yr) and the annual loading rate with a factor of safety of 2.0 of 0.70 m^3/ha/yr (10 ft^3/ac/yr).

Observations during the monitoring period revealed that screen blinding was the most frequent cause for uncontrolled device bypass. Device designs that provided considerable allowances for screen blinding in addition to gross solids storage (Linear Radial at I-10/Rosemean and Inclined Screen at SR-170/KP 26.1) were projected to achieve the annual cleaning cycle: other devices required mid-year maintenance to prevent screen blinding and subsequent uncontrolled bypasses.

Table 7. Gross Solids Monitoring and Volumetric Loading Summary

Device Type	Site Name	Total Gross Solids (wet) m³ (ft³)	Total Litter (dry) m³ (ft³)	Total Area ha (ac)	Total Period Rainfall mm (in)	Total Gross Solids (wet) m³/ha (ft³/ac)	Total Gross Solids (wet) m³/ha/mm (ft³/ac/in)	Total Litter (dry) m³/ha (ft³/ac)	Total Litter (dry) m³/ha/mm (ft³/ac/in)
Linear Radial	**10 at Rosemead**	0.39 (13.78)	0.12 (4.24)	1.5 (3.7)	367 (14.45)	0.26 (3.7)	0.0007 (0.3)	0.08 (1.1)	0.0002 (0.08)
	I-210 at Glenada	1.10 (38.87)	0.05 (1.77)	2.5 (6.2)	270 (10.63)	0.44 (6.3)	0.0016 (0.6)	0.02 (0.3)	0.0001 (0.03)
	I-5 at Garber	0.18 (6.36)	0.04 (1.41)	0.4 (0.9)	344 (13.54)	0.45 (7.1)	0.0013 (0.5)	0.10 (1.6)	0.0003 (0.12)
Inclined Screen	**SR-170 at KP 26.1**	0.36 (12.72)	0.21 (7.42)	1.0 (2.5)	483 (19.02)	0.36 (5.1)	0.0007 (0.3)	0.21 (3.0)	0.0004 (0.16)
	I-210 at Orcas	0.18 (6.36)	0.03 (1.06)	1.4 (3.4)	346 (13.62)	0.13 (1.9)	0.0004 (0.1)	0.02 (0.3)	0.0001 (0.02)
	SR-101 at Gaviota	0.44 (15.55)	0.13 (4.59)	0.8 (2.1)	271 (10.67)	0.55 (7.4)	0.0020 (0.7)	0.16 (2.2)	0.0006 (0.20)
Baffle Box	**I-405 at Leadwell**	1.10 (38.87)	0.22 (7.77)	1.2 (3.0)	372 (14.65)	0.92 (13.0)	0.0025 (0.9)	0.18 (2.6)	0.0005 (0.18)
	I-210 at Christy	0.45 (15.90)	0.03 (1.06)	0.9 (2.3)	378 (14.88)	0.50 (6.9)	0.0013 (0.5)	0.03 (0.5)	0.0001 (0.03)

Table 8. Summary of Gross Solids and Litter Removal Efficiency by Mass (Weight)

Device Type	Site Name	Captured Gross Solids (wet) kg (lb)	Bypass Gross Solids (wet) kg (lb)	Total Gross Solids (wet) kg (lb)	Gross Solids Removal Efficiency, %	Captured Litter (dry) kg (lb)	Bypass Litter (dry) kg (lb)	Total Litter (dry) kg (lb)	Litter Removal Efficiency, %
Linear Radial	**I-10 at Rosemead**	110.13 (242.79)	1.80 (3.97)	111.93 (246.76)	98.4	9.27 (20.44)	0.19 (0.42)	9.46 (20.86)	98.0
	I-210 at Glenada	398.00 (877.42)	12.20 (26.90)	410.20 (904.32)	97.0	6.20 (13.67)	0.40 (0.88)	6.60 (14.68)	93.9
	I-5 at Garber	179.60 (395.94)	12.00 (26.46)	191.60 (422.40)	93.7	5.60 (12.34)	0.56 (1.23)	6.20 (13.67)	90.3
Inclined Screen	**SR-170 at KP 26.1**	97.61 (215.19)	0.00 (0.00)	97.61 (215.19)	100.0	16.69 (36.79)	0.00 (0.00)	16.69 (36.79)	100.0
	I-210 at Orcas	111.20 (245.15)	23.18 (51.10)	134.40 (296.30)	82.7*	4.15 (9.15)	2.05 (4.52)	6.20 (13.67)	66.9*
	SR-101 at Gaviota	265.70 (585.76)	42.70 (94.14)	308.40 (679.89)	86.2*	8.12 (17.90)	1.88 (4.14)	10.00 (22.04)	81.2*
Baffle Box	**I-405 at Leadwell**	494.60 (1090.39)	36.70 (80.91)	531.30 (1171.30)	93.1*	26.00 (57.32)	3.75 (8.27)	29.80 (65.70)	87.2*
	I-210 at Christy	411.60 (907.41)	1.64 (3.62)	413.20 (910.93)	99.6*	19.70 (43.43)	0.40 (0.88)	20.10 (44.31)	98.0*

*Denotes possible lost gross solids due to overflow.

Table 9. Summary of Gross Solids and Litter Removal Efficiency by Volume

Device Type	Site Name	Captured Gross Solids (wet) m^3 (ft^3)	Bypass Gross Solids (wet) m^3 (ft^3)	Total Gross Solids (wet) m^3 (ft^3)	Gross Solids Removal Efficiency, %	Captured Litter (dry) m^3 (ft^3)	Bypass Litter (dry) m^3 (ft^3)	Total Litter (dry) m^3 (ft^3)	Litter Removal Efficiency, %
Linear Radial	**I-10 at Rosemead**	0.39 (13.7)	0.01 (0.4)	0.40 (14.1)	97.5	0.11 (3.9)	0.01 (0.4)	0.12 (4.2)	91.7
	I-210 at Glenada	0.61 (21.6)	0.49 (17.3)	1.10 (38.9)	55.4	0.04 (1.4)	0.01 (0.4)	0.05 (1.8)	80.0
	I-5 at Garber	0.18 (6.4)	0.02 (0.7)	0.20 (7.1)	90.0	0.03 (1.1)	0.01 (0.4)	0.04 (1.4)	75.0
Inclined Screen	**SR-170 at KP 26.1**	0.36 (12.7)	0.00 (0.0)	0.36 (12.7)	100.0	0.21 (7.4)	0.00 (0.0)	0.21 (7.4)	100.0
	I-210 at Orcas	0.12 (4.2)	0.06 (2.1)	0.18 (6.4)	66.7*	0.02 (0.7)	0.01 (0.4)	0.03 (1.1)	66.7*
	SR-101 at Gaviota	0.34 (12.0)	0.10 (3.5)	0.44 (15.5)	77.3*	0.10 (3.5)	0.03 (1.1)	0.13 (4.6)	76.9*
Baffle Box	**I-405 at Leadwell**	0.90 (31.8)	0.14 (4.9)	1.10 (38.9)	81.8*	0.15 (5.3)	0.07 (2.5)	0.22 (7.8)	68.2*
	I-210 at Christy	0.43 (15.2)	0.02 (0.7)	0.45 (15.9)	95.6*	0.03 (1.1)	0.00 0.0	0.03 (1.1)	100.0*

*Denotes possible lost gross solids due to overflow.

Conclusion, Key Findings, and Lessons Learned

The pilot gross solids removal devices tested in this pilot study showed that non-proprietary designs can be useful and *effective* to *very effective* in removing litter from discharges of highway storm water runoff. For compliance with the trash TMDL for the Los Angeles River, a device must incorporate a screen of adequate size to prevent blinding and possible litter bypass during overflow events.

Key findings and lessons learned resulting from this pilot study include the following:

- Gross solids removal devices are sensitive to gross solids loading rates.
- Design loading rates must consider total gross (solids, vegetation, and litter) as the simple screening technologies utilized in these devices do not automatically segregate the litter component regulated under the TMDL from overall gross solids.

- Litter is a relatively small component of gross solids on both a total mass and total volume basis.
- Gross solids loading rates require further study to define the average and range of expected values.
- Screen blinding and subsequent bypass is the most common cause for a device to exhibit a low level of effectiveness for litter removal.
- Gross solids storage and screen blinding prevention must be individually considered during design.

References

California Department of Transportation (Caltrans). (1995). "Highway Design Manual Metric." Topic 309 – Clearances.

California Department of Transportation (Caltrans) (1999). "Solids Transport and Deposition Study." Caltrans report CTSW-RT-99-024.

California Department of Transportation (Caltrans) (2000). "District 7 Litter Management Pilot Study." Caltrans report CTSW-RT-00-013.

California Regional Water Quality Control Board, Los Angeles Region (LARWQCB). (2001a). "Trash Total Maximum Daily Loads for the Los Angeles River Watershed," January 25.

California Regional Water Quality Control Board, Los Angeles Region (LARWQCB). (2001b). "Water Quality Control Plan – Los Angeles Region," amended by Resolution No. 01-013, September 19.

United States Environmental Protection Agency (USEPA). (2001). "Public Review Draft – Total Maximum Daily Load for Trash for Los Angeles River Watershed," December 5.