Construction-Associated Solids Loads with a Temporary Sediment Control BMP

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Abstract: A highway construction site was monitored to determine the effectiveness of a temporary sediment control (rock-filter dam) that was part of the pollution prevention plan that protected storm water from leaving the site. Selected water quality parameters were monitored along with solids-specific parameters. The results were compared in a before-during-after approach and an upstream-downstream approach using a two-sample *t* test for differences in the mean values during the different construction phases or locations. Construction activity caused a six-fold increase in total solids leaving the construction site during construction, as compared to preconstruction values. Construction activity had an effect on the distribution of particles in a suspension leaving the construction site. The solids control device, a rock-filter dam, had an effect on the particle-size distribution of suspended particles, but—in upstream-downstream analysis—did not produce a significant difference in solids leaving the construction site.

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Introduction

The Clean Water Act prohibits storm water discharge from highway construction sites larger than a prescribed area, unless authorized by a National Pollutant Discharge Elimination System permit. Permittees provide a site description, identify sources of storm water contaminants and appropriate pollution control measures, and implement these measures. Collectively, the site description and measures are known as the facility's Storm Water Pollution Prevention Plan (SW3P).

The permit does not require performance measures, but states that total suspended solids (TSSs) can be used as an indicator parameter to characterize the control of other pollutants commonly found in storm water discharges. Therefore, solids control has been the focus of many SW3Ps.

Structural performance monitoring was conducted by the City of Austin (1990). They concluded that sand filtration and wet pond detention were effective controls for their conditions. These results are consistent with findings of other researchers (Urbonas and Stahre 1993; Shaver 1993). However, these best management practices (BMPs) are for permanent facilities (such as, an operating highway) and not for the short-term disturbances caused by construction. Structural controls were evaluated during construction by Barrett et al. (1995), but focused on sediment control fences.

Although the permit requires SW3Ps to be in place, it does not require any monitoring. Should monitoring become required, where, when, and what to measure will become important components of these SW3P technologies.

Study Description

This research monitored a drainage ditch, adjacent to a 2.3 mile construction site along NASA Road 1 in Harris County, Texas, to determine what effect highway construction activities have on solids transport to receiving waters and to evaluate the performance of a rock-filter dam as a pollution prevention device. Fig. 1 indicates the location of the project in relation to Houston, Texas.

The ditch was monitored before, during, and after highway construction. Two locations in the ditch were monitored: One immediately upstream of a rock-filter dam temporary sediment control (TSC), and another about 300 feet downstream of the TSC location. The construction project was to widen the road. The soil-disturbing activities included preparing the right of way, grading, excavation, storm sewer placement, utility adjustments, and topsoil replacement.

Figs. 2 and 3 are images of the upstream TSC location prior to construction activity and during construction activity. In these images, the utility pole foundation along the roadway and the electricity riser indicate that both images are of essentially the same location, even though the image angle is slightly different. The direct exposure of bare earth is obvious in these contrasting images.

The TSC operates by interception of solids-laden storm water

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solid_loads

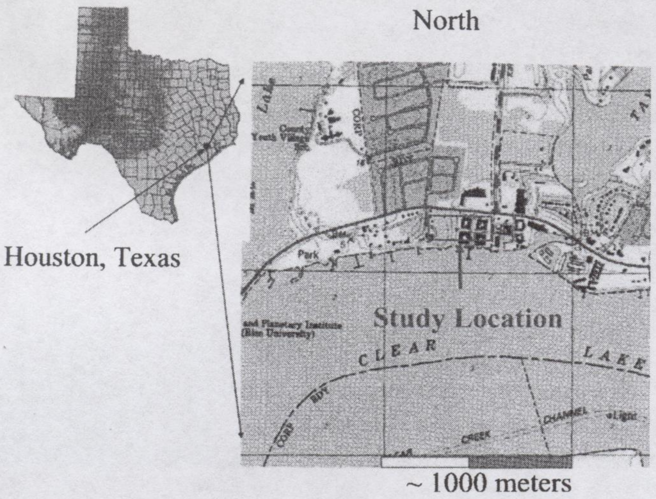

Fig. 1. Study location map. Images are from the Texas Natural Resources Information System (TNRIS 2005).

from disturbed areas, coincident reduction of flow speed, sedimentation and capture of the solids, and release of the water in a sheet flow (TxDOT 1993). Although the TSC is called a rock-filter dam, classical filtration (size exclusion, interception in the media, and cake formation) is not the intent of these devices.

Methods

The TSC evaluation was based on results of chemical and physical analyses from 142 sampling visits—from March 25, 1997 through July 9, 1998; about every three days. Of these visits, 27 during preconstruction, 58 during construction, and 11 postconstruction yielded paired storm and nonstorm samples. During some visits, storm samples were not collected because there were no recent storms before the visit, but at all visits, a nonstorm sample was collected. The storm samples were collected using a ball-valve-type 3-liter mechanical sampler. The storm sampler is a first-flush-type sampler, and collected samples from runoff-producing rainfall during the study period. Nonstorm samples were grab samples adjacent to the mechanical sampler.

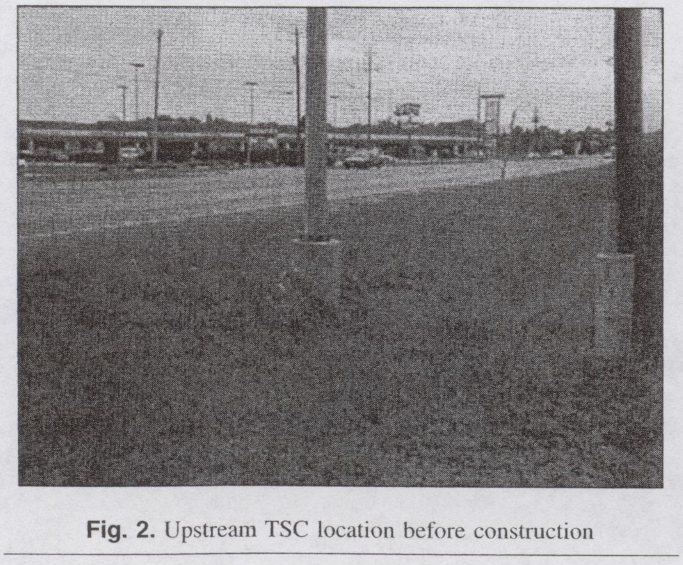

Fig. 2. Upstream TSC location before construction

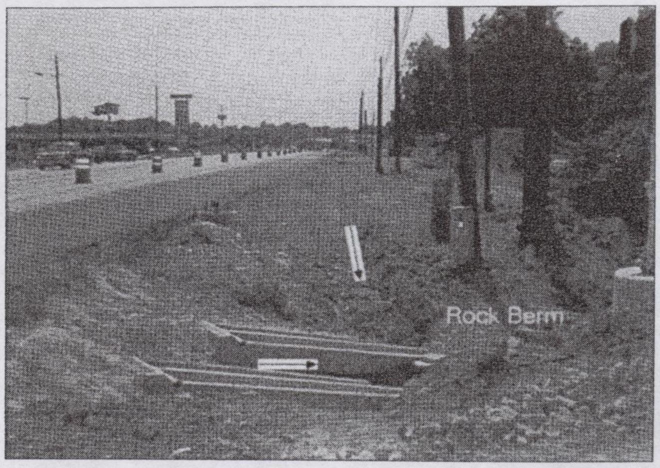

Fig. 3. Upstream TSC location during construction

Rainfall was measured on-site using a tipping-bucket rain gauge with a cumulative depth data logger. In Fig. 4, rainfall from this on-site gage is compared to a nearby continuous gauge—about one-mile away operated by the Harris County Office of Emergency Management (HCOEM 2005). The cumulative rainfall pattern at each gauge is about the same; exact agreement is not expected. The average rainfall intensities were 0.007 in./h, 0.004 in./h, and 0.009 in./h for the preconstruction, during-construction, and postconstruction monitoring phases, respectively. The largest incremental rainfall depths in the three phases were about 3 in., 5 in., and 4 in. These summary statistics indicate that the rainfall behavior is about the same for the three construction phases. The authors estimate that a 0.4-in. incremental rainfall depth produced enough runoff to fill the storm sampler.

Table 1 is a list of the solids and water quality measures collected during this research. These data were categorized as solids measures [turbidity, TSS, and total solids (TS)], nutrient measures (NO_3, NO_2, NH_4, and PO_4), and solids-size characteristics (D_{10}, D_{50}, D_{90}, and the fraction smaller than 75 μm). The particle-size

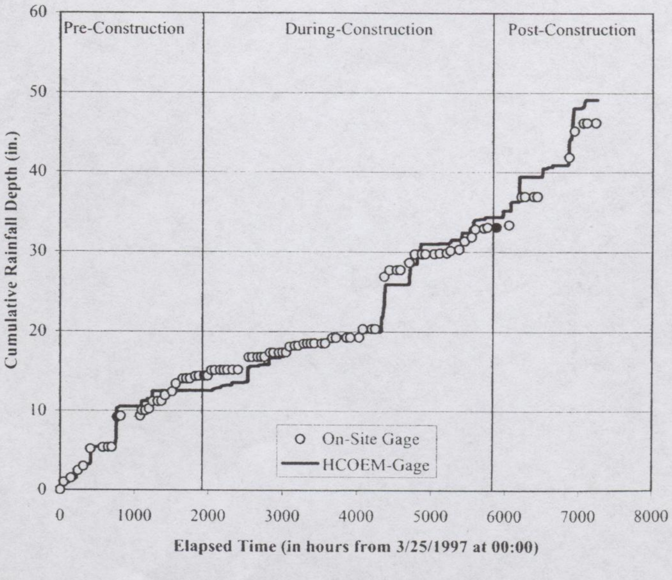

Fig. 4. Cumulative rainfall from on-site and from Clear Creek at Nassau Bay. (HCOEM Device ID=170).

Table 1. Constituents Analyzed for NASA Road 1 in Harris County, Tex

Parameter	Symbol	Range (mg/L)	Method
10th, 50th, and 90th percentile particle size	D_{10}, D_{50}, D_{90}	0–900 μm	Mastersizer
Clay fraction (75 μm)	%<75μ	0–100%	Mastersizer
Nitrate, MR	NO_3^-–N	0–4.5	8171[a]
Nitrite, LR	NO_2^-–N	0–0.300	8507[a]
Nitrogen, ammonia	NH_4–N	0–2.50	8038[a]
Phosphorus, reactive	P	0–2.50	8048[a]
Suspended solids[b]	SS	0–750	8006[a]
Total solids	TS		Standard methods
Total suspended solids	TSS		Standard methods
Cumulative rainfall	in.	0–9.99 in. (before reset)	Tipping-bucket rain gauge with cumulative datalogger

Note: MR=mid range; LR=low range

[a] Hach Company (1992). "Water Analysis Handbook." Hach Company, Loveland, Colo.

[b] Compared to total solids, gravimetric, EPA approved.

data were measured by a laser-diffraction instrument that assumed spherical particles.

The nonstorm samples were compared to storm samples during the three activity phases. Upstream and downstream comparisons were made during the construction phase. These comparisons were made using the mean value for a particular parameter from all data collected during that activity phase. The differences in these mean values were considered statistically significant if the p value for a two-sample t-test statistic associated with the particular pair of means was smaller than 0.05.

Results

The results from these analyses are summarized in Table 2. The results are stratified by activity phase—with the during-construction phase subdivided into upstream and downstream—to reflect the presence of the TSC during construction. Of the parameters analyzed, only TSS (and to a lesser extent TS), PO_4, and the size characteristics had statistically meaningful differences.

TSS from first-flush samples is more than three times larger than in nonstorm samples in the preconstruction phase. PO_4 is about two times larger in the first-flush samples in this phase. The other parameters did not exhibit significant differences.

TSS from first-flush samples is about ten times larger than in nonstorm samples in the during-construction phase. The size characteristics in first-flush samples differ in upstream-downstream analysis, as does PO_4. The other parameters did not exhibit significant differences. The TSS in first-flush samples in this phase of construction is about six times larger than in the preconstruction phase.

TSS from first-flush samples is ten times larger than in nonstorm samples for the postconstruction phase. The other parameters did not exhibit significant differences in this phase. The TSS in first-flush samples in this phase of construction is not significantly different than in the preconstruction phase.

TSS from first-flush samples in the during-construction phase is the same upstream and downstream of the TSC. Only PO_4 and size characteristic differences are significant in upstream-downstream analysis. The nonstorm size characteristics are coarser as compared to the preconstruction nonstorm samples; but finer for the storm samples upstream of the TSC.

Fig. 5 is a plot of the size characteristics represented as a distribution. The active-construction upstream storm data, having finer sizes as compared to the nonstorm samples, are different than either the preconstruction or postconstruction behavior. The cause for this difference is unknown; possibly due to some change in source distribution, or resuspension of previously deposited smaller particles. The upstream TSS during storm conditions is less than downstream, which might support the resuspension hypothesis, except that these differences are insignificant. The nonstorm samples demonstrate that the source distribution during construction has changed, but to coarser sizes. The particle-size distribution measures—increasing downstream of the TSC—suggest that the TSC is having an effect on the solids. The smaller

Table 2. Mean Water Quality Values at Downstream Sampling Location; nonstorm versus storm

	Preconstruction		During construction				Postconstruction	
			Upstream		Downstream			
Parameter	Nonstorm	Storm	Nonstorm	Storm	Nonstorm	Storm	Nonstorm	Storm
Turb. (FTU)	88.1	121.2	95.6	141.1	71.9	159.2	45.6	171.9
TSS-Hach	71.2	131.3	96.6	184.7	65.8	229.2	32.9	270.1
TS-SM	232.9	361.0	559.7	1577.7	287.2	2018.7	262.4	405.1
TSS-SM	62.7	212.5	122.5	1227.1	57.3	1410.3	29.4	376.1
NO_3	0.33	0.45	0.40	0.38	0.38	0.42	0.38	0.33
NO_2	0.005	0.164	0.060	0.060	0.017	0.030	0.014	0.015
NH_4	0.81	1.32	0.73	0.82	0.74	1.12	0.74	1.21
PO_4	0.06	0.14	0.46	0.47	0.17	0.21	0.18	0.17
D_{10}	2.63	2.77	9.07	0.87	6.92	3.29	5.33	4.81
D_{50}	13.5	17.2	41.8	12.5	30.2	23.3	22.6	26.7
D_{90}	95.9	86.1	150.3	39.9	141.6	86.7	85.7	77.1
%<75μ	85.87	76.01	74.7	96.1	82.7	80.1	86.9	89.1

Notes on sample sizes: Preconstruction: 27 paired samples for solids; 10 paired samples for nutrients; 14 paired samples for size. During construction: Upstream: 19 paired samples for solids and nutrients; 10 paired samples for size; Downstream: 58 paired samples for solids and nutrients; 24 paired samples for size. Postconstruction: 11 paired samples for solids and nutrients; 4 paired samples for size.

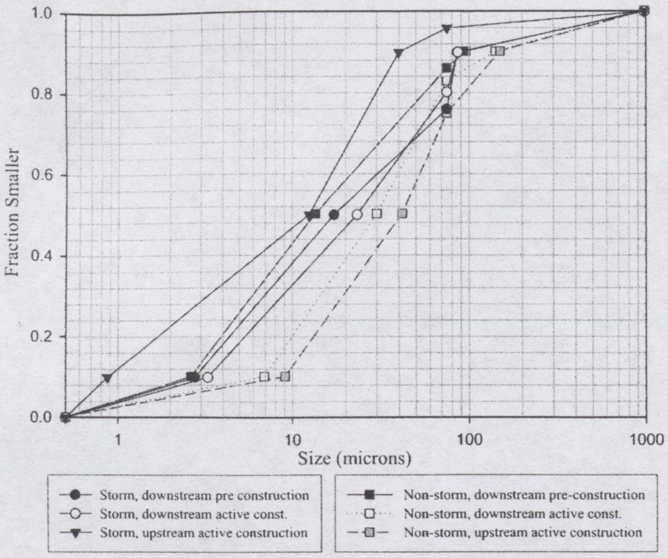

Fig. 5. Particle-size characteristics for nonstorm samples upstream and downstream of TSC during active construction phase

sizes remaining in suspension upstream are expected, as the flow velocities are supposed to be reduced by the TSC (and coarser-sized particles should be removed). This distribution shift is similar to those that have been observed in engineered storm water treatment systems (Pitt et al. 1999).

Conclusions

Construction activity increases the TSS concentrations; it about doubles for nonstorm samples and is about six times larger for storm samples. These increases are consistent with findings of other studies, but of lower magnitude (e.g., Wolman and Schick 1967; Vice et al. 1969). The postconstruction samples indicated that the storm water quality is returning to preconstruction behavior as expected.

TSS exhibited no statistically significant difference in upstream-downstream analysis. The particle-size distribution increased downstream of the TSC. This distribution shift, combined with the PO_4 reduction moving downstream, and combined with field notes of solids residuals trapped upstream of the TSC, suggest that some benefit was conferred by the TSC; but this benefit was not quantified.

The TSC studied in this research failed as a pollution control device for controlling TSS. The writers note that, during post-storm visits of the TSC, large volumes of solids were deposited upstream of the TSC that were subsequently removed by the construction company—as per the SW3P. These solids would have likely been discharged to the ditch without the TSC in place. For rock-filter dams and similar controls, future research should include measurements of the volume or mass of solids captured upstream of the TSC after a storm event, and report this volume or mass as an estimate of the solids removed by the TSC. These volumes or masses would demonstrate some benefit of the TSC as a pollution control device, and justify their continued use. Water quality sampling alone may not be adequate justification. Characterization of these residual solids should provide improved insight into the ability of such TSCs to provide pollution control.

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