Literature Review

Compost Use for Erosion Control

And Improved Stormwater Quality

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Draft Interim Literature Review for
Model Guided Specification for Using Compost and Mulch to Promote
Establishment of Vegetation of and Improvement in Stormwater Quality
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Social, political and regulatory environment

Under Phase II of the National Pollution Discharge Elimination System (NPDES) 2003, to acquire a permit for any land disturbing activity over 1 acre, a storm-water management plan must be in place. In California, the SWRCB is the responsible agency for granting these permits. The primary objectives of the general permit plan are: reduce erosion, minimize or eliminate sediment in storm-water discharges, prevent materials used at a construction site any contact with storm-water, implement a sampling and analysis plan if storm-water does come in contact with construction materials, implement appropriate measures to reduce potential impacts on waterways both during after construction of projects, eliminate unauthorized non-storm-water discharges from the construction sites, and establish maintenance commitments on post-construction control measures (California Storm-water BMP Handbook, 2003, 1.3.2) The BMPs that the handbook lays out are hydraulic mulch, hydro-seeding, soil binders, straw mulch, geotextiles and mats, and wood mulching. Thus, using compost for these

activities seems to be within the spirit of these regulations, though not explicitly stated.

Large scale utilization of composts has an intrinsic benefit for CA in that it helps reduce the pressure on landfills. The CA state legislature passed AB939 in 1989. This act required the state's landfills to reduce their incoming volume by 50% by the year 2000. County landfills reduced the inflow volume into the landfills by composting organics. Thus, the use of these composted materials for erosion control and soil restoration benefits the landfill reduction efforts. The use of composted organics for erosion control and storm-water management is not unique to California. In fact, in 1997 it was reported that departments of transportation (DOTs) in 34 states were either studying and / or utilizing composts for erosion control purposes (Mitchell, 1997).

Field effects of compost use for sediment reduction

Numerous studies have shown that composts and mulches applied as blankets can be very effective in reducing runoff and sediment losses from disturbed slopes, when compared to bare slopes, or treated slopes without a mulch cover (Demars et al., 2000, Persyn et al., 2004; Faucette et al., 2004; Grismer and Hogan, 2005). All cover treatments protect the soil surface from the kinetic impact energy of rain; which reduces the potential for sediment detachment and surface crusting, roughens the surface which impedes overland flows, and allows for slower percolation of rain down into the soil. Persyn et al.,

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(2004) presented portions of the following table that outlines the results of past studies concerning varying surface protection amendments.

Table 1. Summary of results of compost use.

Citation	Experimental Conditions	Results
Meyer et al., 1972	Slope: 12%. Simulated rainfall: 63 mm h-1. Straw mulch of 2.3 t ha-1, 10 cm topsoil application.	Straw mulch soil loss <22 t ha-1. Topsoil soil loss of 69 t ha-1.
Storey et al., 1996	Slope: 33%. Simulated rainfall: 1, 2, and 5 year storms. Compost and wood mulch with synthetic chemical tackifiers applied between 76 to 101 mm depth.	Compost and wood mulch plots met Texas sediment loss standards on clay (12.21 kg/10 m2) and sandy soil (0.34 kg/10 m2).
Agassi et al., 1998	Slope: 5%. Simulated rainfall: 40 mm h-1. Solid waste compost, soil control.	85% infiltration for compost, <52% for control
Demars et al., 2000	50%. Natural rainfall. Wood waste materials.	Effective at reducing runoff for storms <12.7 mm h-1, effective at controlling erosion for mulch thickness of 1.9 cm or greater.
Block, 2000	Slope: 50%. Natural rainfall. Composted yard waste, wood mulch, straw thick.	Erosion more than 10 times any composted treatment on control plots.
Risse et al, 2001	Slope: 10%. Simulated rainfall: 167 mm h-1. Compost, wood mulch, poultry litter at 5 cm depths compared to bare soil.	Total solids loss significantly less on compost treatments (between 96 and 215 g) and on mulch treatments (between 71 and 124 g) compared to soil (766 g).

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Persyn et al, 2004	Slope: 33%. Simulated rainfall: 100 mm h-1. Yard waste compost, yard waste compost mixed with a biosolid sludge, and yard waste compost mixed with bio-industrial sludge. Applied at 5 and 10 cm.	All compost treatments exhibited significantly lower steady state interrill rates as compared to control and topsoil treatments. The yard waste compost had the lowest steady state erosion rate. No statistical difference between compost depths.
Faucette at al, 2004	Slope: 10%. Simulated rainfall: 77.5 mm h-1. 11 treatments including 3 poultry litter composts, a municipal solid waste compost, a food waste compost, a yard waste compost, a biosolids/peanut hull compost, 3 grades of wood mulches. Applied to a depth of 5 cm. Soil depth (in flume) was 10 cm.	All of the treatments tested, except for the poultry litter treatment, reduced total solids lost compared to bare soil. The mulch treatments had lower total solids loss and less runoff than most of the composts (not statistically significant).
Grismer and Hogan, 2005	Slope: 50-60%. Simulated rainfall: 60 mm h-1. Pine needle mulch.	50% decline in sediment concentration, and 30% decline in sediment yield as compared to bare soil. Sediment values were still greater than from undisturbed sites.

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Compost use in Urban Settings

The goal of one urban study, the Portland Metro project, was to demonstrate that yard trimmings compost can be used effectively to control nonpoint-source pollution (Ettlin and Stewart, 1993; Metro, 1994) in urban environments. The project used both "coarse" compost materials (containing chunks of wood and branches up to 152 mm [6 in] in length) and "medium"

compost materials, the fraction remaining following screening of the coarse compost through a 16-mm (5/8-in) trommel screen. Leaf compost was collected from residential streets in the city of Portland.

Eight erosion control treatment plots were established at sites located at St. John's Landfill, Portland, OR. These sites measured 2.74 x 9.75 m (9 x 32 ft) on slopes of 34 percent (19 degrees). Surface runoff was collected on plastic sheeting at the base of the slope and collected in barrels. Treatments included three compost treatments applied as 7.6 ± 2.5 cm (3 ± 1 in) surface mulch layers: 1) 15 cm (6 in) minus "coarse" mixed yard debris compost, 2) 1.6 cm (5/8 in) minus "medium" screenings of the same material, or 3) 1.6 cm (5/8 in) screened compost made from leaf materials only. In an additional treatment, the "medium" and "leaf litter" composts were also shaped into 45 cm high and 100 m wide berms (18 x 39 inches) to act as sediment control barriers. A conventional treatment used a sediment fence (Amoco 2122 fabric) and a hydromulch treatment (wood fiber/tackifier mixture; Silva-Fiber Plus, Weyerhaeuser Co. Tacoma, WA), which were compared to an unamended control plot. The hydromulch was specified at 120 gal/ac of 36 – 48 lb of product per 100 gallons water, but on these field plots it was applied at an extra heavy rate by the contractor. During and after three storm events in March 1993, 364 samples were collected and tested for suspended solids, settleable solids, turbidity, total solids, metals, nitrate N, total N, and chemical oxygen demand. Total suspended solids is stated to be the most important single parameter to measure in evaluation of erosion control efficiency.

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The untreated control and the sediment fence yielded the highest average total suspended solids (8442 and 6348 mg/L). The compost barrier and the coarse-screened compost yielded 562 and 436 mg/L. The "leaf litter" compost (7.6 cm blanket application) yielded 380 mg/L and the hydromulch treatment yielded 341 mg/L. The "medium" mixed yard debris compost blanket yielded the lowest total suspended solids for the test period, producing 147 mg/L. Other compost effects, such as metals adsorption and other water quality data are also evaluated. The need for high-quality, mature compost was noted.

After this study, field plots were constructed in the Portland area utilizing compost as erosion control material. Objectives were to demonstrate use and to increase the market demand for yard trimmings compost materials. Three field sites were established on roadside, housing development, and mobile home park projects. All compost materials were applied to a depth of 76 to 102 mm (3 to 4 in). Materials were brought to the top of the slope by tractor bucket or backhoe. Materials were then spread by hand. The first site (Springwood Drive, Beaverton) had a 14-degree slope at the bottom and a 7.6 m (25-ft) slope length. The slope drains into an existing wetland. At the second site (Marylhurst, Lake Oswego), slopes ranged from 0 to 30 degrees. The third site (McLoughlin Boulevard, Portland) contained two areas with slope angles of 35 degrees and slope lengths of 3 to 18.3 m (10 to 60 ft). A third area had a slope angle of 15 degrees and a slope length of 4.6 m (15 ft), and a fourth area had a 1- to 5-degree slope and a slope length of 48.8 m (160 ft).

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Results from the three demonstration projects suggest the following beneficial uses from compost application. A thick compost layer can provide a surface covering for foot or vehicle traffic onto soils that are otherwise too muddy and wet to support traffic. A compost layer at the exit of a site will reduce mud tracking onto local streets and into storm drains. A 76-mm (3-in) layer of compost was found to be effective. One demonstration site coordinator suggested using a specification of a “minimum” of 3 inches. Compost screened to 38 mm (1½ in) or less is recommended for erosion control on steeper slopes. Slopes of up to 35 degrees were effectively treated. The compost layer should be extended over the top of the slope for 0.6 to 1 m (2 to 3 ft) at a 300- to 450-mm (12- to 18-in) depth to diffuse ponded water entering the top of the slope. Compost that has been screened to 19 mm (¾ in) or less is recommended for slopes that are to be landscaped. A moisture content of less than 25 percent makes application most efficient and enables the compost layer to readily adsorb larger amounts of rainfall immediately after application. Mature compost will function to release nutrients into the soil more readily than immature compost. Contaminants (plastic, glass, undecomposed plant material) detract from the aesthetic benefits of compost amendment. As a result of the study and field plots, members of several local governments incorporated the use of compost into their specifications.

Use of compost for revegetation

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In addition to surface protection, compost treatments can restore disturbed soils and facilitate revegetation by increasing levels of organic matter (OM). Increasing or restoring soil OM increases soils' water holding capacities (WHCs), cation exchange capacity (CEC), and nutrient levels while decreasing soil bulk density (ρb) (Munshower, 1994). Re-establishing vegetation on disturbed soils provides long term soil erosion protection and stormwater buffering.

In 1998 the Texas DOT approved specifications for compost to be used for erosion control and vegetation establishment (Block, 2000). The DOT found that compost applications of up to 3 inch blankets were required to re-establish grasses on drastically disturbed slopes. The Texas DOT requires the compost particle sizes to be no more than 3 inches, with 70% being less than 2 inches. The compost must contain 40 to 60% organic content and no more than 5 mmohs cm^{-1} of soluble salts. This use of compost coupled with site specific mixtures of woodchips or other mulches has allowed for successful revegetation projects on previously, believed to be un-restorable sites.

Texas Transportation Institute field facility

Texas Transportation Institute's Hydraulics and Erosion Control Field Laboratory, affiliated with the Texas Department of Transportation and the Texas A&M University system, provides large, full scale experimental slopes for uniform testing of erosion control materials under field and controlled rainfall conditions. A study on compost application (Storey *et al*., 1996) tested three materials on 1:3 slopes with both clay and sandy loam textured soils. Plot size was 6.1 m wide by

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21.35 m downslope (1:3 slope plots). These materials included co-compost (mixed yard trimmings and municipal sewage sludge), shredded wood with polyacrylamide tackifier (6.75 kg/ha), and shredded wood with a hydrophilic colloid tackifier (56 kg/ha).

Treatments were amended with organic materials to a depth of 76 to 101 mm (3 to 4 in) over the plots. Soil textures on the plots were either clay or sandy loam (Storey *et al*., 1996) to sandy clay. Slopes were constructed at 2:1 and 3:1 (run:rise) angles. Soils were seeded with a standard warm-season revegetation grass mix selected for the central Texas area. Vegetation establishment criteria were to achieve a minimum coverage of 80 percent for the clay soils and 70 percent for the sandy loam soils within 6 months of seeding. Simulated rainfall was used to test for sediment loss from the plots at rates representing 1-, 2-, and 5-year storm events. These rates were designed to model events within the Houston/Dallas/Austin region and are equivalent to 30.2 mm/hr (1.2 in/hr), 145.5 mm/hr (5.7 in/hr) and 183.6 mm/hr (7.2 in/hr) (Landphair and McFalls, 2000b). The erosion control objectives were that the treatment should protect the seed bed from a short-duration, 1-year return frequency event (99 percent probability of occurrence within a given year) within the first month after installation, from a 2-year return frequency event (50 percent probability) within the first 3 months following installation, and from a 5-year return frequency event (20 percent probability) within the first 6 months of installation. To be included in the Texas Department of Transportation-approved Material List for Standard Specification

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Item 169 (Soil Retention Blanket), the sediment loss had to be 0.34 kg/10 m^2 or less from the clay soils and 12.21 kg/10 m^2 or less from the sandy loam soils.

Sediment loss from the compost-amended plots during simulated rainfall tests was right at the cutoff level of 0.34 kg/10 m^2 from the clay plots and was an acceptable 3.88 kg/10 m^2 for the sandy loam plots (Storey et al., 1996). Vegetation cover was 99 percent on the clay and 92 percent on the sandy loam. The two tackified wood chip treatments produced 0.15 and 0.30 kg/10 m^2 sediment loss on the clay soil and 11.27 and 10.97 kg/10 m^2 sediment loss on the sandy loam. Vegetation establishment was around 50 percent for several of the tackified wood chip treatments, disallowing them from approval under Texas Department of Transportation standards. The fact that much of the vegetative cover established in the compost treatment came from weed seed, not the applied seed mix, points out the need for quality control in compost products. Costs for the compost were below the average cost of synthetic or organic blankets tested by the facility.

In 2006, other researchers successfully revegetating a sandy clay loam slope (highly erodable soil, high K factor) in Athens, GA using compost treatments. Seven treatments (4 composts, 2 hydro-seeds, and bare soil) were applied and seeded with common Bermuda grass. The compost treatments included: 1) biosolids compost blanket; 2) a yardwaste compost blanket; 3) a municipal solid waste compost (MSW) and mulch blanket (2:1 compost to mulch ratio (by volume)); and 4) a poultry litter compost, mulch, and gypsum blanket (2:1 compost to mulch by volume with five percent gypsum addition by volume).

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The composts were all applied as blankets at a depth of 3.75 cm. The two hydroseed treatments included: one with a filter berm, and one with a silt fence. The hydroseed consisted of water, seed, paper fiber, lime, nitrogen, phosphorus, and potassium from 10-4.4-8.3 mineral fertilizer (commercially recognized as 10-10-10). This study found that the compost blanket treatments averaged 2.75 times more vegetative cover than hydroseed after three months. After one year, the compost and hydroseed treatments had similar cover percentages, but the hydroseed had significantly greater weed biomass than compost and a greater ratio of weed biomass relative to Bermuda grass biomass (Faucette et al, 2006).

Effect of compost quality or feedstock

Compost treatments have the potential to leach nutrients into stormwater runoff. If not managed properly, compost treatments can effectively create a point source of stormwater pollution. The type of compost utilized (ie. maturity, curing, feedstocks) greatly affects nutrient leaching potentials. Faucette et al. (2005) presented the cumulative losses in total N and P amongst 4 composts added to unvegetated test plots (aged poultry litter, biosolid treated, municipal waste, and yard waste). After three rainfall simulations, over a 12 month period, total N and P losses were approximately: 61 and 3.4 kg ha^{-1} for the biosolid, 27.1 and 0.75 kg ha^{-1} for the municipal waste, 13.6 and 1.7 kg ha^{-1} for the aged poultry litter, and 6.8 and 1.4 kg ha^{-1} for the yard waste. The authors state that compost curing levels and differences in organic versus inorganic N content most likely explain N and P loss differences among the separate treatments (Faucette et al.,

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2005). In a similar study (Glanville et al, 2004), nutrient levels in runoff from compost treated slopes (vegetated and un-vegetated) were measured. The compost treatments were: yard waste compost, yard waste compost mixed with a biosolid sludge, and yard waste compost mixed with bio-industrial sludge. All composts were applied as blankets at 5 and 10 cm depths. The study found that the soluble concentrations of P, K, and Zn were significantly ($p < 0.05$) greater in runoff from one or more of the composts than from the control plots. The N species, as well as 9 other metals, concentrations were below detection. The study also found that the control plots lost more nutrients in terms of total mass than the compost treated plots. This is due to the control plots having much greater volumes of runoff.

Field application methods

The method of application (blanket or incorporation), and soil preparation (tilled or non-tilled) influences the overall performance of compost treatments. Tillage treatments fracture soil crusts and soil compaction layers, thus allowing for deeper rooting depths. Incorporating compost into soil helps to stabilize soil structure by preventing reconsolidation / packing. Tillage management practices have been shown to increase surface pore size distribution (0-10 cm), increase infiltration and water holding capacities (Lipiec et al., 2006). This combined with surface roughening decreases overland surface flow. Compost incorporation also generates soil surface roughness, which increases depression storage and causes a delay in runoff (Govers et al. 2000). Muzzi et al. (1997) found, however,

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that surface amendments alone were not adequate to stop erosion and that, in most cases, tilling the ground before mulch application produced the most effective erosion control and plant growth.

When soils are compacted during disturbance, treatment by ripping improves hydraulic conductivity and reduces surface runoff and erosion (Luce, 1997). This type of physical treatment may not restore the natural hydraulic conductivity of an undisturbed slope, however, because the pores formed may not be continuous or may not persist through multiple soil saturation cycles such as with winter rains. Mulches protected the surface of a metamorphic material from sealing during rain events during this study, but did not prevent surface sealing of a granitic substrate. Water-stable aggregates, formed from organic matter and microbial residues, would help reduce the tendency to form surface seals and settling (subsidence and close packing) of the near-surface strata. Compost and mulch applications were recommended to preserve the open soil structure generated by ripping treatments (Luce, 1997).

Surface mulch studies

A study of surface applied composts (as mulches) compared to hydromulches was done by Morris, 2007. Composts perform at least as well as hydromulching, and significantly lowered runoff. Compost produced higher concentration of TSS, total N, total P, but because of the low runoff, the total load was estimated to be lower from compost treatments than from hydromulch.

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Binders in the hydromulch made no difference in performance. Some decrease in plant density was noted, although the decrease was not of concern.

The use of shredded brush as erosion control mulch was reviewed by Texas Transportation Institute staff (Storey *et al*., 1996). Shredded wood mulch provides physical benefits because it adsorbs rainfall energy, slows water flow over the surface, reduces crusting allowing increased infiltration, moderates soil temperature and wind speeds at the soil surface, and reduces evaporative loss of soil moisture. The decomposable carbon materials in the compost stimulate microbial activity, facilitate generation of water-stable aggregates, and provide a variety of microclimates for improved seed germination. Fiber lengths of 10 to 20 cm (4 to 8 in.) are stated to be adequate for loose straw, while wood fiber lengths for coarse compost mulches are about 7.6 cm (3 in), with application rates of 9 to 13.5 Mg/ha (8,000 to 12,000 lb/ac) for composts or 0.9 to 1.3 kg/m^2 for wood chips.

Caltrans tested surface mulch applications of composted mulch/chipped green waste in a study in District 3 (Sacramento area) and District 11 (San Diego area) (Pollock and Moreno, 1993). Mulch depths evaluated included 15, 30, and 45 cm (6, 12, and 15 in). The mulch layers did not completely control weeds, even at the 30 cm depth at the Sacramento (District 3) location, but in the San Diego trials (District 11) weed growth on the 30 cm deep mulch plots was suppressed. The shallower 15-cm depth plots had 50 to 60 % of the weed growth as the control plots, which were densely covered with weeds. A lag time between the start of rainfall and the moistening of the soil was observed, with a

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greater lag time associated with greater mulch depths. Pooling of water at the soil level killed some of the trees on the plots. Drainage and weed growth is somewhat dependent on the percent of fine materials in the compost. The best material of those used was stated to be that with uniform sized 6 mm (1/4 in) particles with fewer larger and smaller sized particles. At the San Diego site, illegal dumping of chipped material from private contractors increased as soon as chipped material for the project began to be delivered to the site. Wood waste chips were recommended to be less than 15 cm.

The most efficient method of application turned out to involve five or six workers and a single tractor with a front bucket. Using this combination, a field crew could place 80 to 100 cubic yards of compost per day. Larger crews increased potential for accidents because of crowding and reduced productivity because of worker inactivity. Bed widths of 10 m (30 feet) were able to be constructed with the most even depths. Use of larger equipment (articulated front loader) had the effect of incorporating soil into the compost during loading and moving, which increased weed growth the subsequent season.

Overall, plant growth was improved with mulch treatment, as a result of greater retained moisture, less extreme temperatures and improved soil conditions. The green waste compost was noted as providing little, if any nutrient benefit during the period of the study. The study period was noted as being too short to evaluate the long-term effects of compost mulch treatments on landscape plantings and soil chemistry.

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Another study titled "Evaluation of Compost and Co-compost Materials for Highway Construction" was completed by Caltrans (Sollenberger, 1987) but the materials actually tested were at least 80 % municipal solid waste derived materials mixed with biosolids, not yard waste composts, as is the focus of the current study. No tests of erosion control effectiveness were made in this study.

Conclusions

Composts have been well documented to provide superior control of erosion and sediment loss, and they typically have low nutrient losses. Use and evaluation of these materials, however, should be considered in the context of the site conditions. Specifically, if composts are applied to impermeable substrates, the water flow through the compost (applied as a mulch) will more extensively leach out nutrients and dissolved organics than if the soil had greater infiltration rates. Further, the type of material, whether well cured or not and feedstock type, greatly influence the potential for nutrient loss, which may or may not be realized depending on site conditions. Lastly, the ability of the compost to increase vegetative establishment (seed germination as well as growth) has great ability to influence nutrient losses.

Few studies integrate these components that are none-the-less common to all field site conditions and that will determine the ultimate performance of a generic compost application under storm conditions. These various conditions

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should be at least evaluated during test construction, if not controlled or manipulated.

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