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Effectiveness of Straw Bale Dams for Erosion Control in the Oakland Hills Following the Fire of 1991

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Abstract. For abating post-fire erosion, insufficient attention was given to the particular nature of the Oakland Hills versus the southern California landscape. This lead to inappropriate erosion control efforts. Furthermore, use of straw bales in the Oakland Hills was not consistent with existing scientific guidelines that are available in erosion control manuals. After 5000 straw bales were installed as check dams and barriers for post-fire erosion control, we evaluated their performance in two different watersheds. In both watersheds, over 50% of the straw bale dams failed 3.5 months after their installation. The installation of the straw bales and the cumulative impacts of their failure amounted to nearly 50% of the sediment captured behind the bales in one site. We suspect a similar condition at the other study site, but a large proportion of sediment was also associated with unprotected dirt roads. Straw bale barriers placed on landslides and along steep runout pathways of debris flows increased potential hazards rather than abating them. Straw bale berms placed along road cuts to reduce sediment supply to streams may have been the most effective use of bales. Short-term erosion control from the temporary check dams placed in intermixed urban and wildland landscape did not necessarily meet the objectives of the remediation.

Keywords: Check dams; erosion; erosion control; sedimentation; wildfire.

Introduction

The October 1991 Oakland Hills Fire provided an unusual opportunity to both increase our knowledge of how wildfire affects local erosion and to evaluate the effectiveness of post-fire, erosion control methods in an intermixed urban and wildland landscape. To assess the watershed response to fire, the sediment captured behind straw bale check dams and barriers was quantified and cross sections of a gully network were repeatedly surveyed. To evaluate the performance of erosion control methods we rated the condition of straw bale dams in gullies, on hillsides, landslides, and an alluvial fan. We made frequent observations throughout the first rainy season of straw bale berms located along road cuts and at storm drain inlets. The use of straw bale check dams and barriers for extensive, post-fire erosion control in intermixed urban and wildland communities appear to be increasing in popularity. Yet their effectiveness in situations other than construction sites has not been sufficiently monitored or evaluated.

Pre-existing Guidelines for Straw Bales

It must be kept in mind that there are published guidelines that give recommendations on how to maximize performance of straw bales. A standard erosion control manual should be consulted for this practical information. We referred to *Erosion and Sediment Control Handbook* (Goldman et al. 1986).

Traditionally, straw bales have been used as temporary sediment barriers to intercept and filter small volumes of runoff from disturbed areas such as construction sites. The primary purpose of a sediment barrier is to trap sediment from sheet flow on hillsides before it enters a channel, whereas the primary purpose of a check dam is to prevent channel erosion by slowing the velocity of flowing water. Sediment capture is considered a secondary function for check dams. Goldman et al. recommend that straw bale dams should be used for: (1) substitution for channel lining in temporary swales (they do not suggest this as a preferred approach); and (2) for protection of grass-lined channels during initial establishment of vegetation. The area draining a barrier should be less than 0.04 km^2 (~1 acre) and for a check dam it should be less than 0.08 km^2. Among the other standard guidelines in the handbook, Goldman et al. (1987) discuss that:

1. Straw bales typically last only 3 months when wet;
2. they will float until they are thoroughly wetted;
3. they should be inspected and repaired after each rainfall;
4. when placed across a swale, barriers should not receive more than 0.3 m^3s flow;
5. when the area upslope has stabilized, bales should be removed,
6. when sediment is 1/2 the dam height, it should be removed;
7. and, when barriers fail, there is frequently more damage than if no barrier had been installed.

The Post-fire Action Plan

The rawness of the landscape and the exposed pre-existing erosional scars amplified the perception of a landscape that would fall apart. An additional factor motivating the aggressive erosion control in Oakland may have been the mounting public concern and media attention about the potential for a second disaster of mudslides and extensive sedimentation from a fire-flood sequence, typical of landscapes in southern California but not for this region (for a discussion of differences in landscape response see Booker et al. 1995). The bottom line motivating factor, however, is often the concern over legal liabilities (if nothing was done). But in order to respond to concerns and avoid unnecessary actions or expenditures it is imperative to apply the state of the science pertinent to the region.

Concern for accelerated erosion of the denuded Oakland Hills prompted the cities and local agencies to pervasively apply erosion control remedies to a combined 728 ha of urban and wildland terrain. The total cost for the entire erosion control effort was nearly $5 million. The Oakland Firestorm Erosion and Sediment Control Plan, Phase I Action Plan (Woodward Clyde, 1991) recommended a myriad of temporary surface erosion control techniques to be installed on areas "which posed imminent hazard to houses and properties which survived the fire". Locations upslope and adjacent to significant drainage areas and water conveyance structures were identified as priority sites. An objective of the aggressive erosion control was to reduce damage to downstream water bodies and storm drains. Remediation techniques involved pervasive aerial seeding, hydraulic seeding and soil sealing; placement of 1700 straw bale dams within drainages and landslides; placement of straw bale berms along urban road cuts; scattering of straw mulch along road sides; construction of debris barriers and silt fences; and application of erosion control blankets on steep, unstable hillslopes above remaining structures.

The Action Plan indicated that over 5000 individual bales were needed for sediment retention (Woodward Clyde 1991). The Plan also specified that "for areas where elevated water flows were anticipated" bales were to be placed into shallow ~10 cm deep trenches. Specifications for backfilling of trenches, disposal of excavated sediment, clean-out, inspection, repair, or removal of dams were not given. Based upon our observations, most of the check dams were abutted ~10 cm into gully walls (David Jaramillo, California Conservation Corps, personal communication) to provide a buttressing effect. In deep gullies, excavated sediment was not removed from the channel (based upon observations and verbal communication from ground crews installing bales in Claremont Canyon Regional Preserve). We observed that spoils were frequently left in loose unconsolidated piles. The treacherous working conditions within some of the gullies that had steep or high vertical banks made removal of sediment from the gullies difficult. Specifications for maximum drainage area, volume of flowing water, slope length or gradient were not given in the Action Plan. We note that scores of straw bale check dams were placed in channels that had drainage areas greater than 0.08 km^2. Guidelines for theuse of straw bales on landslides have not been found. In the Oakland Hills many of the existing recommendations for the use of straw bales (i.e., Goldman et al. 1986) were apparently not followed.

Landscape of the burn area

Within the burn area maximum relief is 457 m, average hillside gradient is 35%, many upland slopes are greater than 60% and predominant aspect is west-facing. The general geology of the burn area has been described by Spittler (1993) and soils have been described by Welch (1981). Fire-related hydrophobicity has been discussed by Booker et al. (1993, 1995).

The intermittent ephemeral channels of the steep upland hills are frequently crossed by roads and intercepted by culverts that drain the intermixed urban and wildland landscape. The fire exposed an abundance of pre-existing surficial erosion and slope stability problems that had been developing concurrently with hillside urbanization: deeply incised gullies emanating from nearly every upland storm drain and culvert; numerous natural and road-related landslide features sculpting the topography and encroaching upon urban infrastructure; and pathways loom former debris flows directed toward charred foundations. The entrenched drainages that have formed a network of gullies are where much of the straw bale remediation was focused.

At the base of the Oakland Hills, water and sediment are routed through an extensive subterranean storm drain system that extends through the heavily urbanized lowlands to the San Francisco Bay. Water that flows from the southern portion of the burn area flows first into Lake Temescal (a public park used for recreational swimming and fishing) before it proceeds to San Francisco Bay. These water bodies were identified in the Action Plan for resource protection.

Prior to 1991, the East Bay Area was in its sixth year of drought. Conversely, during the previous 1981-82 and 1982-83 winters, precipitation, landsliding and flooding peaked. Many upland channels incised to bedrock and much of the stored supply of sediment may not have been substantially replenished during the drought years.

Since the turn of the century, at least 14 notable fires have burned the local landscape in the vicinity of the 1991 fire (Amphion Environmental 1994). Post-fire seeding was performed along portions of Claremont Canyon following a fire in 1970 (Division of Forestry 1971), but for the other fires, recovery of native and mostly fire-adapted vegetation was otherwise natural. There are no known reports of post-fire erosion problems from these fires.

Winter rainfall

Published rainfall records from local newspapers, as well as data from our 5 gages in the burn area, indicated that the 1991-92 rainfall was about the same as the mean annual precipitation of 559 mm. Individual winter storms that occurred once the bales were installed were not characterized by any extreme amounts or intensities (Booker et al. 1993). The bales were installed in time to moderate sediment from all but one storm that occurred in late October.

Study Sites and Methods

Two watersheds located in Claremont Canyon Regional Preserve (CCRP) and above the North Oakland Sports Center (NOSC) were monitored throughout the rainy season (Fig. 1). Bedrock units of chert, shale and

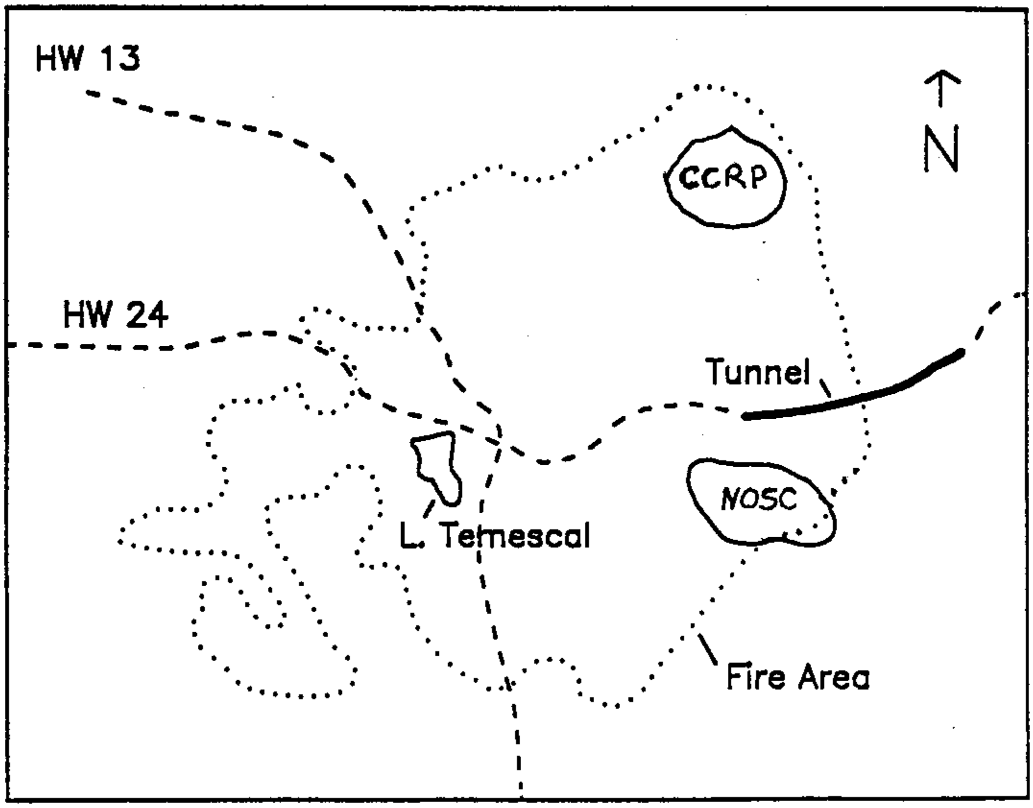

Figure 1. Map of the burn area showing approximate locations of the study site watershedsof Claremont Canyon Regional Preserve (CCRP) and the North Oakland Sports Center (NOSC).

sandstones have a similar distribution in both watersheds. Both sites have a relatively natural landscape except for an urban boundary along their upper perimeters. Drainage areas for each site were calculated above the lowest downstream check dam.

The CCRP watershed has a drainage area of 0.16 km². After the fire ~80% of the drainage area was treated with hydromulch and soil sealant. The vegetation is largely chaparral (predominantly *Baccharis pilularis*), northern coastal scrub (Ornduff 1974) and eucalyptus groves. A continuous gully emanating from road drains and extending through the entire watershed has deeply incised the intermittent channel (Fig. 2). In its upper reaches exposed bedrock indicated minimal sediment storage prior to bale installation. One dirt trail (~1 km) traverses the uppermost canyon below the urban boundary, but it has been abandoned since the early 1970's.

The NOSC watershed has a drainage area of 0.31 km². Treated soils covered ~95% of the drainage area. An extensive gully network has also formed in this watershed from problems associated with road runoff. The natural portion of the landscape is zig-zagged by ~2 km of dirt road that receives current use. Most of the vegetation is eucalyptus and to a lesser extent oak/bay woodland. In the central portion of the watershed

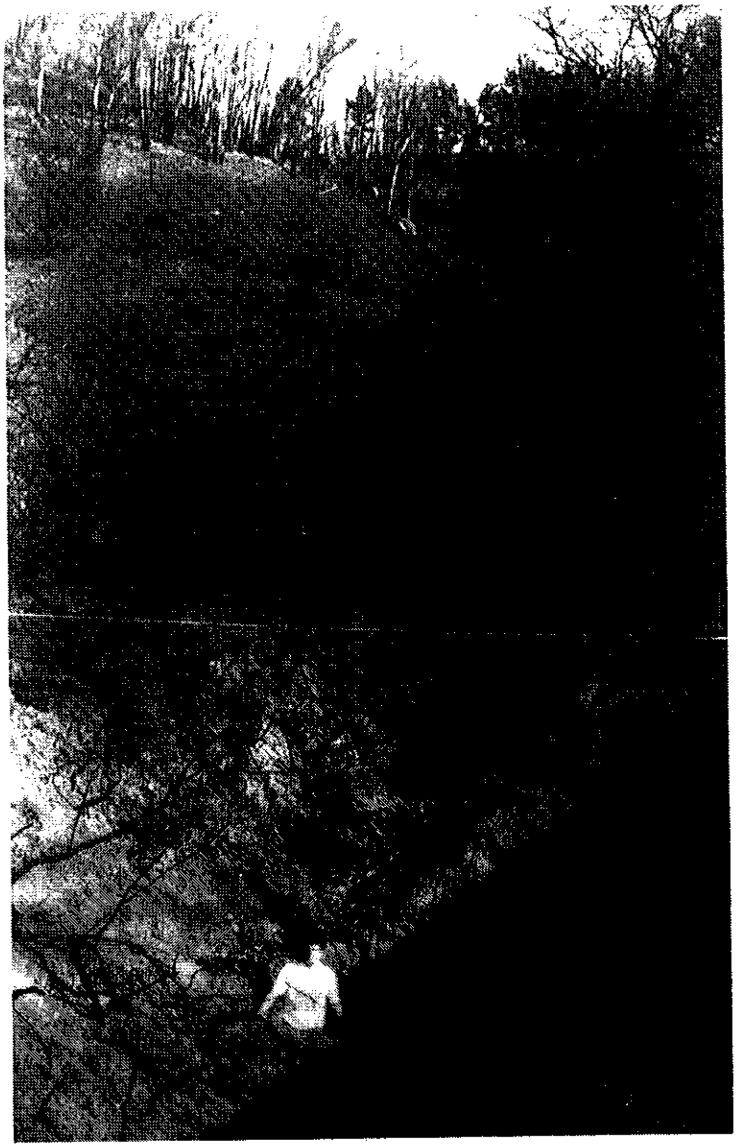

Figure 2. Photograph of gully in the CCRP site. The tape measure at the top of the gully indicates one of our cross sections.

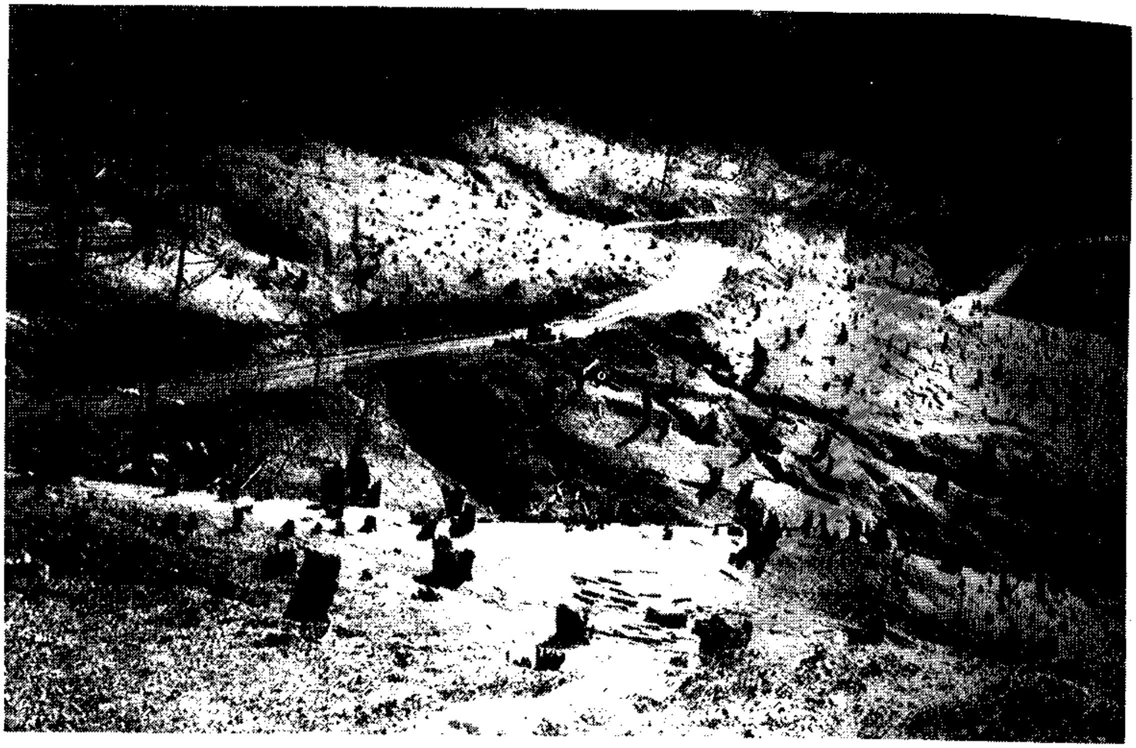

Figure 3. Central portion of the NOSC site. Note erosion associated with the dirt road, which was not protected with erosion control measures, even though most of the watershed was aerial seeded, seeded with hydromulch (mixed with soil sealand) and straw bales were added to all the gullies and landslides.

most of the eucalyptus trees were cut (but not killed) about two years prior to the fire (Fig. 3). The NOSC site has a broad flat valley that was created by fill from the excavation of Caldecott Tunnel. At the upper end of the valley fill, at the apex where upland gullies are intersected, a new alluvial fan has developed over the last few decades. Six rows of straw bale barriers (n = 112 bales) were placed on the fan to enhance natural sediment deposition, limit its spread onto the sports green at the lower end of the valley fill, and reduce downstream sedimentation to Lake Temescal.

Results and Discussion: Performance of Straw Bale Dams

We evaluated the different applications of straw bales after each major rain storm during the 1991-92 wet season. Sediment was never removed from any of the dams or barriers in either watershed or throughout much of the total burn area. Likewise, decomposing bales were not removed from the wildlands, but they were removed along the urban roadsides.

Gullies

In total, the conditions of nearly 440 straw bale check dams situated in channels and over 100 straw bale barriers located on landslides and steep slopes were evaluated during the middle and end of the rainy season (mid February and end of March). At both times their condition was rated as: (1) side cut (water flowed around the dam thereby minimizing sediment storage); (2) undercut (water flowed beneath the dam also minimizing sediment storage); (3) filled but cut (dam may have partially or totally filled with sediment but stored sediment was subsequently cut and remobilized); (4) moved (dam was blown-out by high flows, no sediment storage); (5) filled (considered functioning but unable to store any additional sediment); and (6) unfilled (also considered functioning). The filled and unfilled dams were combined as 'functioning properly', the others were combined as 'failed' (Fig. 4).

The results of the check dam analysis are shown in Figure 5a and b. By the third month after the bales were installed only 43% of the straw bale dams in CCRP and 46% in the NOSC were functioning to reduce the

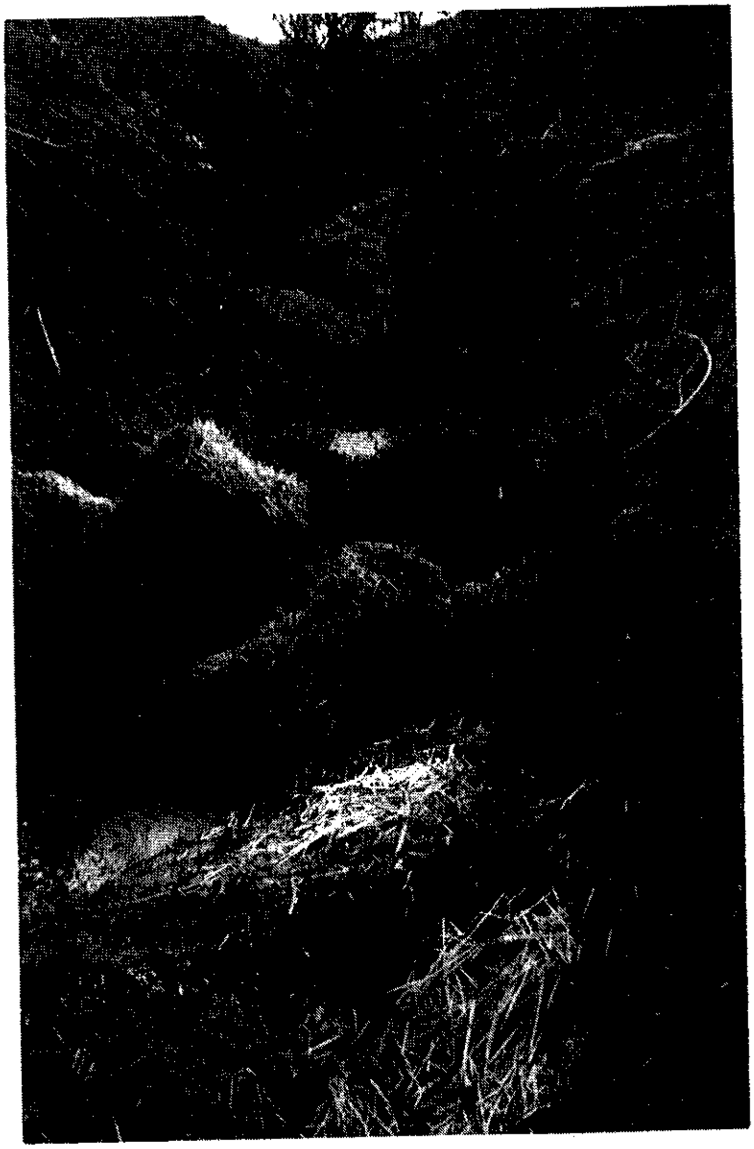

Figure 4. Photograph of straw bales in various conditions within the CCRP watershed.

erosion potential. About 60% (330 mm) of the total rainfall (since the bale installation) had already occurred. After 4.5 months (end of March) a respective 43% and 37% were functioning. The reason the number of functioning dams In CCRP did not change may have been due to the plugging of holes and repairing of dams by labor crews after the February storms. Repairs on other straw bale dams within gullies were not consistently observed In NOSC. Crews from the California Conservation Corps (CCC) inspected some of the bales in the gullies of NOSC in early February (David Jaramillo, CCC, personal communication) Some of the bales were replaced with sandbags at the dirt road crossings but repairs in gullies were minimal.

Alluvial fan

After 2.5 months the straw bale barriers on the alluvial fan showed significant deterioration. Others had been displaced by flows that exceeded the strength of the wooden stakes to hold them in place. They were

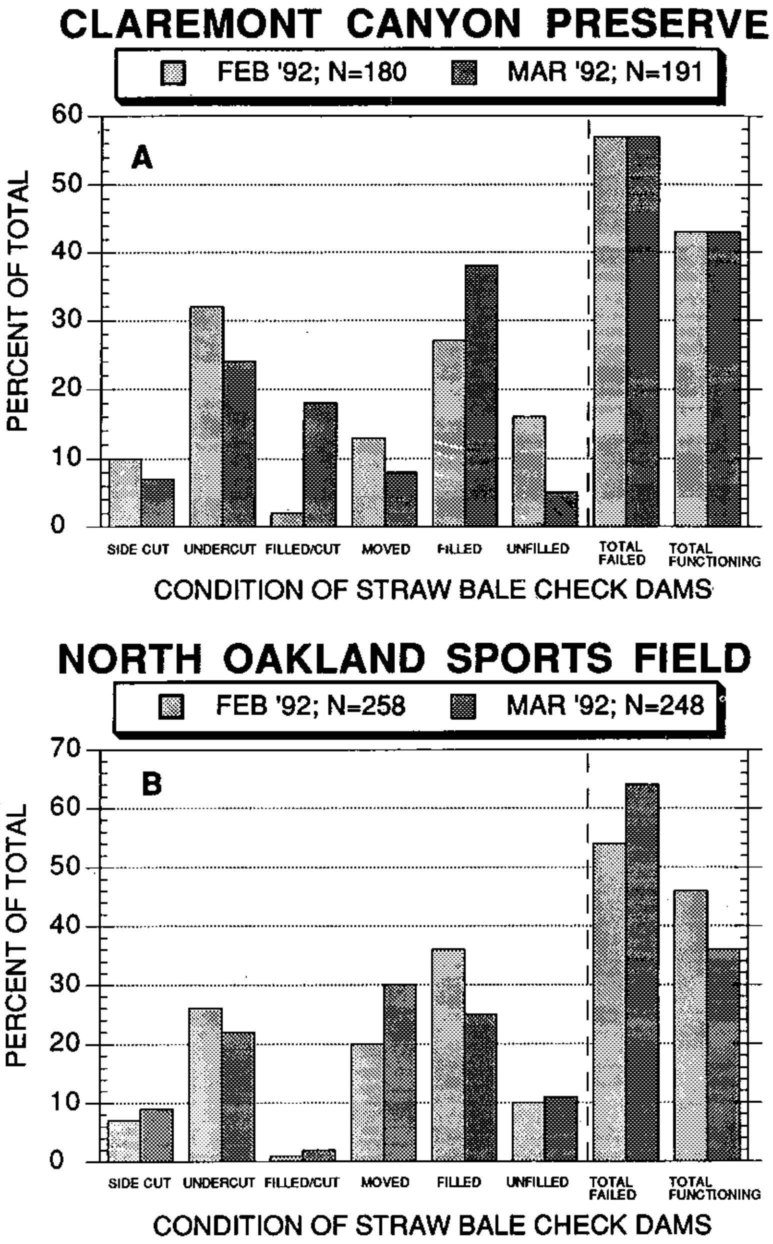

Figure 5a and b. Percentage of functioning and non-functioning straw bale check dams in the watersheds.

replaced with new bales in mid February. As a result, sediment was confined to a more limited area than if the bales had not been either used or replaced. We caution that although alluvial fans may appear to be obvious places to use straw bales (because they are sites of natural deposition), flow volumes are usually so large that other remedial options that provide greater structural integrity and less maintenance would be warranted.

It is worth noting that although flooding did not occur in the Oakland Hills, in Orange County following devastating fires in 1993, straw bales functioned as battering rams on residential structures that they were designed to protect when they floated downstream during flood flows (Dylan 1993).

Steep wildland soils

For the straw bale barriers that were located on both treated and untreated wildland soils, the amount of sediment that was captured was negligible. In most instances, indications of overland flow was not apparent upslope of the barriers. Conditions of the barriers, therefore, could not be tallied and evaluated since they had not been in contact with significant sheet flow.

Landslides

Reactivation of naturally oocurring landslides did not occur in the burn area, but there were some problems along road cuts and areas effected by urbanization. No new slides occurred at either site, but in CCRP a pre-existing earthflow (caused by road runoff) was reactivated enough to alter topography and shift the direction of potential overland flow. The bales became nonfunctional. Numerous tension cracks also reduced the potential for sheet flow. When slope stability is a concern or when mitigation is being performed to reduce the potential for landslide reactivation, priority is usually given to actions that reduce the opportunity for saturating soils or elevating the ground water table. In this regard, the use of straw bale barriers on landslides was inappropriate because infiltration and saturation of the unstable soil mass was promoted.

Some straw bales had been placed at the apex of steep colluvium-filled hollows (zero order basins). These locations are significant source areas for debris flows. We noticed that some of the dams persisted until after the second winter because they did not intercept flowing water. During the second summer, these barriers completely filled with debris that raveled from the hillsides during a goat grazing project that was impremented to reduce fuel loads from seeded and recovering vegetation. Placement of the bales in these steep hollows effectively increased the potential for debris flows by promoting saturation, and sediment loading increased the potential for downstream damage by storing additional amounts of sediment that can be subsequently mobilited in the event of failure.

Road cuts and drop inlets

We made some general observations about straw bales used along road cuts and inlet protection of storm drains. Rows of straw bale berms placed along cut banks of urban roads functioned well. We observed sediment capture behind most. Many that stayed in place for two years filled completely. Road cuts in the Oakland Hills probably supply a significant proportion of the normal, yearly sediment load directly to streams along their inboard drainage ditches. Under both normal conditions and after the fire, road cuts have had the most common incidence of shallow mudslides and ravelling of loose debris. We expect that to reduce sediment supply to streams, the retention of sediment along road cuts was the most immediately effective remediation performed with bales.

Bales placed around inlets tended to over protect the drains to the extent that water completely bypassed many of the drains during the first storms. This was commonly due to too little space left between the bales to accommodate flowing water from the road surfaces. The resulting indiscriminate discharge of runoff diverted from the inlets caused erosion of road fill. By the middle of the rainy season many of the bales around inlets were replaced with sandbags. In the Lake Temescal watershed we observed that bales blown-out from an upstream gully entirely blocked an inlet, causing the creek to flood its banks, and water and sediment to flow down residential streets. Loose straw from decomposing bales can also clog inlets, which increases the need for routine maintenance.

Sediment: How Much and Where Did it Come From?

At the end of the rainy season total stored sediment caught behind check dams in gullies of CCRP and NOSC was 56 m^3 and 54 m^3, respectively. At the NOSC site, an additional 124 m^3 was deposited on the alluvial fan amounting to a total volume of 178 m^3. At the end of the second winter, when there was good vegetative cover from herbs and grasses, sediment deposition on the fan amounted to an additional 230 m^3, 30% more than the previous year.

CCRP site

The data show that no substantial changes from landsliding, bank collapse, or wall erosion occurred along the gullies in CCRP. Throughout the length of the main gully and its tributary confluences, 9 permanent cross sections were repeatedly surveyed by standard leveling techniques. For the reach of gully effected by check dams, the average respective width and depth were 5.4 m and 2.9 m (Fig. 2 shows one of the cross sections). Some reaches were as much as 6 m deep. Surveys indicated that net bed erosion and aggradation was fairly evenly split. The range of either process was only a few centimeters, even at the cross sections downstream of the straw bale dams. Erosion of the gully walls averaged about 1 cm along the bottom of the walls and negligible change was indicated along the top half. The significance of these differences is small because the resolution of survey error was ±0.5 cm. Our observations beyond the discrete cross sections confirmed our conclusion that erosion of gully walls did not contribute large quantities of sediment to the channel.

Similarly, erosion of wildland soils contributed to a very small percentage of the captured load. Postfire soil erosion rates from winter field measurements averaged 0.1 mm/year on untreated sites and 0.01 mm/year on treated sites (Booker et al. 1993). The amount actually transported to channels cannot be determined, but we expect that much of it remained on the hillsides. Rills did not form on either treated or untreated soils, except for a short distance below some large diameter eucalyptus trees from concentrated stem flow. These rills did not intercept a channel.

After considering that (1) our cross sections and observations In CCRP indicated minimal change from the soils and gully walls, (2) no natural rilling was observed to link hillslope erosion directly to channels, and (3) average maximum erosion rates, as determined by Booker et al. (1993), did not even exceed 0.1 mm yr^{-1}, then the obvious question becomes what was the source of sediment captured behind the dams? We emphasize that these sediment totals should be considered minimal estimates, because suspended loads moved through the watershed and were not quantified.

We found that a minimum of 41% of the sediment captured in CCRP was directly related to the spoils generated by trenching and abutting the bales during their installation. Based upon our measurements of total sediment captured by bales in CCRP (Table 1a), a hypothetical sediment budget can be developed to use as a tool to estimate proportion of sediment loom the different sources (Table 1b). In both watersheds the most common dams were comprised of three bales (Fig. 6) with two up-ended on the sides of the middle bale (Fig. 7). The combined width is the same as two bales placed end to end. Therefore, if we assume that an average dam width was 2 bales, and consider the excavated sediment from the ~10 cm deep trenches, then an additional 27% of the sediment volume was from 191 dams. Furthermore, abutting the bales into the gully walls involved cutting a trench at least ~10 cm deep. We have conservatively sized the wall trenches for the least bale dimensions (not accounting for some to be up-ended) and calculate an additional 14% of the total volume. For erosion of the gully walls (from cross section surveys) average erosion of 1 cm accounts for 36% of the total, measured sediment volume. This is a generous estimate because we included the entire height of gully walls. After the fire an average erosion rate of 0.01 mm/yr for treated hillsides (80% of the area) and 0.1 mm/yr for untreated slopes (20%) accounts for an additional 9% of the total measured load. This could also be a generous estimate because the proportion of sediment actually transported to the gully system is unknown. The tally of values of erosion from these latter sources leaves unaccounted a remaining 14% of the total sediment.

Table 1a, b, and c: (a) Amount of sediment captured behind straw bales; (b) sediment budget estimates for each watershed and (c) qualitative assessments of additional sources accounting for remaining sediment in budget estimates.

Total Measured Seciment Captured in Straw Bale Dams

CCRP	NOSC
56 m^3 (in gullies)	178 m^3 (54 in gullies; 124 on fan)

Sediment Budget as Proportion of Total Measured Sediment.

Source Feature	CCRP (56 = 100%)	NOSC (178 = 100%)
gully walls	20 (36%)	unknown
hillside soils	5(9%)	4 (2%)
gully bed trench	15 (27%)	20 (11%)
gully wall trench	8 (14%)	11 (6%)
alluvial fan trench	not applicable	5 (3%)
Subtotal	48 (86%)	40 (22%)
remaining sediment	8 (14%)	138 (78%)

Qualitative Assessment of Possible Additonal Sources to Account for Remaining Sediment of Budget Estimates

Possible Source	CCRP	NOSC
gully walls	as estimated	moderate
roads protected by dams	very minor	very minor
roads not protected by dams	very minor	major
soil disturbance (foot traffic, bale dragging)	minor	minor
undercut and sidecut dams	moderate (n=76 dams)	major (n=96 dams)
displaced dams and related downstream erosion	minor (n=23 dams)	moderate (n=77 dams)
gully wall trenches (if larger than assessed)	unknown	unknown

If we qualitatively account for this remaining amount and add it to the 41% generated by trench spoils (Table 1c), the analysis suggests that nearly 50% of the sediment captured could be associated with the bales in CCRP. A large proportion of the remaining 14% could have been created by the combined effects of soil disturbance from foot traffic and dragging of the bales, the 42% of dams that were undercut and side cut, cumulative downstream erosion from 14% of the dis-

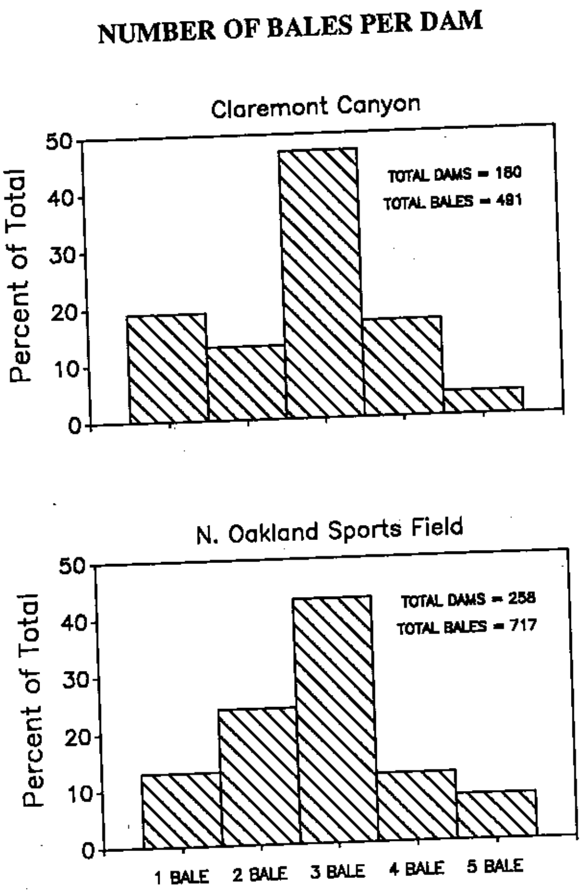

Figure 6. Number of bales per dam in each watershed.

placed bales, and wall trenches that were larger than the assumed dimensions. We assumed that the erosion coming from urban roadcut banks was very minor because they were lined with straw bale berms and we did not observe 'new' erosional features along the abandoned trail.

NOSC site

The analysis for NOSC suggests that a high proportion of sediment is also associated with the bales, but that the dirt road was also a major contributor. Although dirt roads are known to be major sources of sediment, erosion control measures were never applied to the one in NOSC. If we make similar assumptions for a sediment budget in NOSC, then a possible 2% accounts for hillside soil erosion (Table 1b). A minimum of 20% accounts for combined sediment generated by gully, fan, and abutment trench spoils. This leaves a remaining 78%, some of which must be attributed to natural erosion of gully walls. Since cross sections were not established in NOSC, we do not have an estimate of gully dimensions or amount of wall erosion. We assume that because of the greater length of the gully network, the walls generated a moderate amount of sediment as compared to a minor amount at CCRP. We expect that predominant sources contributing to the remaining sediment were erosion from the prism of the dirt road network, the 35% of bales that were side cut and undercut, and cumulative erosion from 30% of the bales that were displaced. The incidence of moved bales was much higher in NOSC than at CCRP because the former had much greater flows due to its larger drainage area. We also observed cumulative downstream erosion from blown-out bales. Erosion from foot traffic during bale installation and from gully wall trenches that could have been larger than assumed, may have contributed only a minor proportion to the remaining 78%. The total proportion of erosion associated with straw bales could be close to 50%, since roughly a third of the remaining 78% could have been caused by the bales and at least 20% was caused by the trench spoils.

The volume of sediment transported to the channel networks may have been substantially reduced by the effective placement of straw bale berms at the base of road cuts along miles of urban roads. It is interesting to speculate on how the total volume of captured sediment may have changed if these berms had not been installed.

The total volume of sediment deposited on the alluvial fan at NOSC during the second winter (1992-93) represented a 30% increase from the previous year, even though vegetative cover was more abundant on the hillsides. This increase is attributed to the release of stored sediment from decomposing bales, new erosion caused by more bales being blown-out, increased rainfall and higher discharge amounts, new gully development on road treads, removal of bales along some road cuts, and the beginning of construction in the upper watershed. We have no estimate of how sediment storage changed in the gully system.

Gullies and construction sites in general

Gullies accounted for substantial sediment production long before the fire ever happened. For example, during the last 60 years, the entire gully network in CCRP has deposited into San Francisco Bay a volume equivalent to 850 fully loaded, six to seven ton dump trucks (~5,350 m^3). The reported post-fire volume of sediment would have to be more than tripled yearly for 60 years to produce an equivalent volume. If sediment production from all the gullies in the hills was calculated, the total volume from road-related erosion becomes overwhelming. Even though gullies comprise a very small amount of total hillside area, they create

Figure 7. Check dam with two edge bales placed on end.

disproportionately large impacts to downstream resources and habitats by their direct supply and transport of large quantities of sediment. Likewise, their short-term sediment remediation with bales has accrued a disproportionately large amount of expense compared to resolving long-term sediment production. The 'ideal' solution is to fix the road runoff problems that are causing the erosion. But when such long-term solutions cannot be funded, rather than using bales for temporary sediment abatement, semi-permanent sediment basins (with access for clean-out) could provide a more cost-eftective solution to deal with both long and short-term erosion associated with roads, fire, and post-fire construction.

Erosion from construction sites in the Lake Temescal watershed during the 1970's was reported as 46.0 mm per site (East Bay Regional Park District 1981). This implies that during the several years of post-fire reconstruction, erosion rates could be significantly greater than those just following fire. Clearly, intensive erosion control at construction sites is prudent, especially when hundreds of structures are being rebuilt within a single watershed and when these activities are permitted throughout the rainy season to hasten community recovery. We considered sediment production and downstream impacts to be more severe during the second winter from the combined effects of construction erosion and released sediment from thousands of decomposing bales.

Wildlands and Construction Sites: Where are Straw Bales Appropriate?

The standard use of straw bales has typically been for construction sites where they can effectively provide an inexpensive means to temporarily maintain sediment on site and restrict it from channels. Usually, access for supplying and cleaning-out bales at construction sites is easily accommodated, future landscaping is pending, and sediment retention basins are engineered to capture sediment missed by temporary measures. In wildland sites, however, access for supplying straw bales may be hampered by remoteness of the site, lack of roads, and steep rugged terrain. In Orange County for example, straw bales were dropped to ground crews by helicopter, because there was no other feasible access into the wildlands. The cost of transport alone could be prohibitively expensive in other regions. In Oakland, hundreds of bales were dragged by hand for thousands of feet straight down steep hillsides to remote gullies. Their installation was labor intensive.

The time and labor involved to install straw bale dams must be weighed against the longevity and cost-effectiveness of their benefits. The expense of rigorous maintenance, clean-out and eventual removal should be incorporated into action plans. If bale removal is rejected as an option, then consideration should be given to second year problems when cumulative impacts from failing bales and construction-related erosion could overwhelm downstream resources.

Were Remediation Objectives Met?

The remediation objectives to reduce downstream damages to water bodies and storm drains could not be substantially accomplished without following provisions for replacement, clean-out, repair and removal of straw bales. Their primary function is to slow water and reduce channel bed erosion, but close to 50% of the captured sediment may have been related to the installation and the failure of the dams. The secondary function, to capture sediment, was successful on the fan but less than 50% effective in the gullies. Eventually all the bales decayed and sediment was subsequently remobilized. The highest priority for remediation was aimed at reducing imminent hazards to houses and properties that survived the fire. Straw bale barriers placed on landslides and debris flow source areas performed contrary to the intended objective: they increased potential hazards by increasing infiltration and by loading temporary check dams with sediment.

Conclusions

1. In the Oakland Hills, we suggest that straw bales for post-fire erosion control were pushed beyond their intended design and functional capacity. If standard guidelines are not rigorously observed, bales may not be cost-effective in intermixed urban and wildland landscapes. Our data support the conclusions by Goldman et al. (1986), that failure of straw bales can cause more damage than if no barriers had been installed.

2. The most effective application of straw bales was along road cuts.

3. Straw bale barriers were mostly unnecessary on the wildland soils because erosion rates on both treated and untreated soils were quite low.

4. Straw bale barriers on landslides and on steep, colluvium-filled-hollows were inappropriate because they inch soil moisture by promoting infiltration, and sediment loading inch the amount of material that could be mobilized if failure occurred.

5. During the second year following fire, release of sediment from decaying straw bales may augment the already high sediment yields associated with post-fire reconstruction activities.

6. Other measures such as sediment retention basins could be more cost-effective and provide long-term benefits.

Recommendations for Future Fires

Immediately following the Oakland Fire a team of interagency managers and local experts was assembled by the Soil Conservation Service to identify the needs for erosion control and re-vegetation of the hills. This was a commendable action, but in the future, a science advisory council should be formed to oversee the selection and use of technical methods for field assessments, remediation and monitoring. The main focus should be on long-term resource recovery and public welfare.

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