Table of Contents

Chapter 1:	Fires, Floods and Mitigation	1
1.1	The global importance of fire	1
1.2	A redefinition of "flow" processes for fire areas	1
1.3	Fires and the urban/wildland interface in California	2
1.4	The Southern California "fire-flood" model	2
1.5	Runoff and erosion after fires in Southern California	3
1.6	Runoff and erosion after fires in the Western United States	. 12
1.7	Runoff and erosion after fires in other Mediterranean climates	. 15
1.8	Erosion and sediment yield after fire	. 20
1.9	History of post-fire mitigation	. 20
Chapter 2: Th	ne Oakland Firestorm	. 24
2.1	The fire	. 24
2.2	Oakland: erosion hazard potential	. 25
2.3	Mitigation efforts after the firestorm	. 26
2.4	Perception of the post-fire erosion hazard in the Oakland Hills	. 27
2.5	General observations from October, 1991, to April, 1992	. 28
2.6	Plot monitoring program: methods	. 30
2.7	Channel response	. 32
2.8	Surface runoff response at monitoring plot sites	. 33
2.9	Flow paths	. 34
2.10	Erosion by splash and overland flow	. 36
2.11	Bioturbation	. 37
2.12	Soil moisture and post-fire landslide potential	. 38
2.13	Artificial rainfall experiments	. 39
2.14	Sprinkler experiments: the apparatus	. 40
2.15	Sprinkler experiments: the plot	. 43
2.16	Sprinkler experiments: runoff rates and processes	. 43
2.17	Sprinkler experiments: erosion rates and processes	. 45
2.18	Summary of the Oakland Hills response to fire	. 47
Chapter 3: A	dditional Field Studies	. 50
3.1	Introduction	. 50
3.2	Field methods	. 50
3.3	Australia: the Sydney fires of 1994	. 51
3.3a	Previous field studies - Royal National Park	. 52
3.3b	Observations following the January 1994 fires in Sydney	. 52
3.4	Laguna Beach Fire: 1993 - 1995	. 54
3.4a	Rill development	. 56
3.4b	Erosion rates and flooding	. 57
3.5	Old Topanga Fire: 1993 - 1995	. 59
3.5a	Post fire runoff and erosion process	. 60
3.5b	Rill development	. 61
3.6	Highway 41 Fire: San Luis Obispo, 1994-1996	. 62

	3.6a	Upper Tassajera Creek study site	63
	3.6b	Highway 41 Fire: erosion rates for Tassajera Creek watershed	63
	3.6c	Rill monitoring (methods)	
	3.6d	Rill Monitoring: processes and Rates	
	3.7	Rabbit Creek Fire - North Fork Boise River, Idaho, 1995	
	3.8	The link between soil cohesion, runoff and rilling	
	3.9	The effect of slope on sediment yield	71
	3.10	Rainfall distribution	
	3.11	Post-fire erosion model	
	3.12	Summary of general findings	
Chapt	er 4:	Performance of Erosion Control Measures Following Wildfire	es In Southern
	Califor	ornia	
	4.1	Introduction	
	4.2	Temporary sediment structures - straw bale and sand bag chec	k dams
	4.3	Debris fences	
	4.4	K-rails	
	4.5	The use of hydromulch as a post-fire mitigation technique	
	4.6	Seeding	
	4.6a	Seeding: germination success	
	4.6b	Post-fire seeding and the potential for hillslope failure	
	4.7	Discussion	
	4.8	Conclusion	
Chapt	er 5	Summary of Landscape and Management Response to Wildfin	es93
	5.1	Summary	
	5.2	Future research	
	5.3	Conclusion	
Refere	ences		
Apper	ndix I. T	Tables	
	Table	1.1 The cost of Wildland Fires in California	
	Table	1.2a Qualitative analysis of Northern California fire areas	
	Table	1.2b Effect of slope and fire intensity on erosion	
	Table	1.2c Effect of control-burning on erosion	
	Table	1.3 Watershed ratings to compute peak discharge	••••••
	Table	1.4 Peak discharges and annual erosion rates following but	rning
	Table	1.5 Equivalent soil loss for different fire areas	
	Table	2.1 Fire frequency in the Oakland/Berkeley Hills	· · · · · · · · · · · · · · · · · · ·
	Table	2.2 Watershed parameters for Southern California and the	Oakland Hills
	Table	2.3 Burned Areas in hectares for different vegetation types	by fire effects
	Table	2.4a Rainfall totals and intensities for three local ALERT st	ations
	Table	2.4b Rainfall totals and intensities for three local ALERT st	ations
	Table	2.5 Winter runoff and erosion plots for the Oakland Hills f	1re area
	Table	2.0a Geology of the Oakland fire area plot locations	

Table 2.6b	Particle size fraction and soil textures for Oakland Hills burn area sites
Table 2.7	Watershed parameters for monitored drainage basins.
Table 2.8	Rainfall & Runoff for fire area monitoring sites January - April, 1992
Table 2.9	Sediment loss at winter monitoring sites
Table 2.10	Sediment loss due to bioturbation on winter erosion plots in the Oakland
f	ire area
Table 2.11	Sediment loss due to bioturbation on summer sprinkler plots in the
	Oakland Hills.
Table 2.12	Summer sprinkler runoff and erosion plots
Table 2.13	Summer sprinkler runoff and erosion plots
Table 2.14	Sprinkler experiment nozzle characteristics.
Table 2.15	Percent frequency distribution of natural and simulated raindrops
Table 2.16	Regression analysis of the mean of natural raindrop size frequencies
Table 2.17	Oakland hills runoff and erosion sprinkler experiment parameters
Table 2.18	Runoff comparisons for sites monitored both for winter storms and
	summer sprinkler experiments.
Table 2.19a.	Discharge by overland flow and through-flow during sprinkler
	experiments
Table 2.19b	Percent runoff for sprinkler experiment sites.
Table 2.20	Thickness of the wettable layer overlying a hydrophobic horizon
Table 2.21a	Sediment loss during sprinkler experiments on Oakland erosion plots
Table 2.21b	Sediment yield during sprinkler experiments on Oakland erosion plots.
Table 2.22	Sprinkler experiment suspended sediment concentrations
Table 2.22	Plot response to overland flow
Table 3.1	Particle size fraction and soil textures for Laguna Beach burn area
Table 3.2	Rill depths at Laguna Beach fire area monitoring sites
Table 3.3a	Rainfall records for the Laguna Beach fire area
Table 3.3h	Rainfall recorded by the City of Laguna Beach
Table 3.4	Estimated erosion rates for Laguna Beach fire area
Table 3.5a	Runoff and rainfall for Laguna Canyon between 1974 and 1995
Table 3.5h	Laguna Beach monthly rainfall totals (mm) runoff (mm) and the runoff to
14010 5.50	rainfall ratio for the five wettest years
Table 3.6	Rainfall for January 1995 which resulted in flooding in Laguna Beach
Table 3.7	Correlation between neak flow runoff and rainfall totals
Table 3.7	Dravious fires that have occurred within portions of the gree burned by the
1 able 5.8	1005 Old Topongo Eiro
Table 2.0	Derticle size fraction and soil textures for Old Tonange hum area mud
1 able 5.9	torrents
T_{a} = 10	Dill notwork normation for the Old Tanan of fine area (Malibu)
Table 3.10	Rill network parameters for the Old Topanga fire area (Manbu)
Table 3.11a	Chame Creek Deinfell Decende 1004 1005 (Mehlin 1005)
	Chorro Creek Rainfall Records 1994 - 1995 (Manin, 1995)
1 able 3.12	Highway 41 fire sediment sources and volumes for four catchments,
T-11 2 12	Dill Densites for Transient C. 1. C. (11) (11) (11)
Table $3.13a$.	Kill Density for Tassajera Creek Catchments, Highway 41 Fire area
Table 3.13b	Rill Density for Tassajera Creek Catchments, Highway 41 Fire area,
Dece	mber 8, 1997

Table 3.14	Shear Strength for the Vision and Calabasas Fire Areas
Table 3.15	Los Angeles County debris basin data (Los Angeles County, 1997)
Table 4.1	Fire areas visited (1993 - 1996).
Table 4.2	Effectiveness of in-channel straw bale and sand bag check dams within the
	Laguna Beach fire area.
Table 4.3	Summary of check dam effectiveness for three fire area locations
Table 4.4	Survey of Laguna Canyon debris fences in the Laguna Beach fire area.
Table 4.5	Basal cover provided by seeding and natural revegetation in the
	Tassaiera Watershed (Hwy 41 fire).
Table 4.6	Ground cover provided by seeded grasses following fires in 1993 and 1994.
Table 4.7a	Landslides within the Highway 41 burn area in San Luis Obispo County
	following rains in March, 1995.
Table 4.7b	Landslides on unburned slopes adjacent to the Highway 41 burn area in
	San Luis Obispo County following rains in March, 1995
Table 4.8	Frequency of landslides in burned and unburned areas of San Luis Obispo
	County following heavy rains in March, 1995.
Appendix II. Figures	•••••••••••••••••••••••••••••••••••••••
Figure 1.1 Th	le global fire regime
Figure 1.2 Ca	lifornia fire history and costs
Figure 1.3 De	evelopment of a rill network due to hydrophobicity
Figure 1.4 So	uthern California storm zones
Figure 1.5 M	ean monthly soil loss for erosion plots in South Africa
Figure 1.6 Ra	infall and sediment yield in afforested catchments in Israel
Figure 1.8 So	il Loss and rainfall for Royal National Park, Australia
Figure 1.9 So	il loss and rainfall for adjacent canyons, San Gabriel Mountains
Figure 2.1a G	eneral location map of Oakland fire area
Figure 2.1b L	ocation map of fire area winter monitoring sites
Figure 2.1c C	Dakland fire area and distribution of burn intensity
Figure 2.2 Oa	kland fire area raingage network
Figure 2.3 Oa	kland fire area - runoff and rainfall relationships
Figure 2.4 W	ettable horizons and generation of overland flow
Figure 2.5 Se	diment loss for winter monitoring sites
Figure 2.6 Se	diment loss for winter monitoring sites
Figure 2.7 M	ean runoff and sediment loss
Figure 2.8 Cu	Imulative sediment loss
Figure 2.9 So	il moisture for treated and untreated sites
Figure 2.10a	Diagram of sprinkler apparatus
Figure 2.10b	Diagram of sprinkler apparatus
Figure 2.11a	Raindrop size frequency distribution
Figure 2.11b	Raindrop size frequency distribution
Figure 2.12	Flow for a single nozzle at different working pressures
Figure 2.13.a.	1 Runoff hydrograph and isohyetal map for CK1 run 1
Figure 2.13.a.	2 Runoff hydrograph and isohyetal map for CK1 run 2
Figure 2.13.b.	1 Runoff hydrograph and isohyetal map for CK2 run 1
-	

Figure 2.13.b.2 Runoff hydrograph and isohyetal map for CK2 run 2
Figure 2.13.b.3 Runoff hydrograph and isohyetal map for CK2 run 3
Figure 2.13.c.1 Runoff hydrograph and isohyetal map for CK3 run 1
Figure 2.13.c.2 Runoff hydrograph and isohyetal map for CK3 run 2
Figure 2.13.d.1 Runoff hydrograph and isohyetal map for CV1 run 1
Figure 2.13.d.2 Runoff hydrograph and isohyetal map for CV1 run 2
Figure 2.13.e.1 Runoff hydrograph and isohyetal map for GW2 run 1
Figure 2.13.e.2 Runoff hydrograph and isohyetal map for GW2 run 2
Figure 2.13.f.1 Runoff hydrograph and isohyetal map for M1 run 1
Figure 2.13.f.2 Runoff hydrograph and isohyetal map for M1 run 2
Figure 2.13.g.1 Runoff hydrograph and isohyetal map for VN1 run 1
Figure 2.13.g.2 Runoff hydrograph and isohyetal map for VN1 run 2
Figure 2.13.h.1 Runoff hydrograph and isohyetal map for GP1 run 1
Figure 2.13.i.1 Runoff hydrograph and isohyetal map for GP2 run 1
Figure 2.13.j.1 Runoff hydrograph and isohyetal map for FB1 run 1
Figure 2.13.j.2 Runoff hydrograph and isohyetal map for FB1 run 2
Figure 2.13.k.1 Runoff hydrograph and isohyetal map for OSC1 run 1
Figure 2.14.1a Mean throughflow and overland flow runoff
Figure 2.14.1b Throughflow as a function of wettable horizon thickness
Figure 2.14.1c Overland flow as a function of wettable horizon thickness
Figure 2.14.2a Sediment yield by overland flow (winter & sprinkler)
Figure 2.14.2b Sediment yield by overland flow (sprinkler)
Figure 2.15a Preferential flow path in a cohesive fine textured soil (VN1)
Figure 2.15b Preferential flow path in a coarse textured soil (GP2)
Figure 2.16 Active hillslope hydrology following the Oakland fire
Figure 2.17 Model of rill initiation by debris flow
Figure 3.1 Diagram of a shear vane
Figure 3.2 Location map of Royal National Park
Figure 3.3 Location map of the Laguna Beach fire
Figure 3.4a Location of Laguna Beach monitoring sites
Figure 3.4b Location of Laguna Beach monitoring sites
Figure 3.5 Degradation of hydrophobic horizon
Figure 3.6 Location of Laguna Beach erosion and check dam sites
Figure 3.7 Laguna Canyon hydrograph, January 1995
Figure 3.8 Laguna Beach, rainfall and runoff, 1973-1995
Figure 3.9 Laguna Beach, Peak annual flows, 1973-1995
Figure 3.10a Location map of Old Topanga fire
Figure 3.10b Old Topanga fire monitoring sites
Figure 3.11 Fire history for Malibu area
Figure 3.12a Las Flores Creek incision, cross section 1
Figure 3.12b Las Flores Creek incision, cross section 2
Figure 3.12c Las Flores Creek incision. cross section 3
Figure 3.13 Location map of Highway 41 fire area
Figure 3.14 Tassajera Creek study site
Figure 3.15 Tassajera Creek sediment vield catchments
Figure 3.16 Tassaiera Creek rill and vegetation density cross sections
<i>G G G G G G G G G G</i>

Figure 3.17a General Location map of Rabbit Creek fire
Figure 3.17b Rabbit Creek fire area
Figure 3.18 Wren Creek tributary cross sections
Figure 3.19 Shear strength of rilled and unrilled soils for five fire areas
Figure 3.20a Location map of the Mt. Vision fire
Figure 3.20b Shear strength of soils at nine sites within the Mt. Vision fire area
Figure 3.21a Location map of the Calabasas fire
Figure 3.21b Shear vane sites within the Calabasas fire area
Figure 3.21c Shear strength of soils at three sites within the Calabasas fire area
Figure 3.22 Mean sediment yield for 108 debris basins in Los Angeles County
Figure 3.23 Sediment yield for debris basins with slopes greater than 35 degrees
Figure 3.24 Sediment yield as a function of geology for slopes greater than 35 degrees
Figure 3.25 Sediment yield as a function of fire history
Figure 3.26a Distribution of storm types in the Western United States
Figure 3.26b Time distribution of rainfall within storm types
Figure 3.27a Model of hydrologic and erosional response to intense rainfall
Figure 3.27b Model of hydrologic and erosional response to moderate rainfall
Figure 4.1a Two year event rainfall intensities for California fire areas
Figure 4.1b Two year event rainfall intensities for California fire areas
Figure 4.2 Laguna Beach channel mitigation
Figure 4.3 Laguna Beach check dam sites
Figure 4.4 Excavation of check dams leads to failure
Figure 4.5 Area - failure relationship for in-channel check dams
Figure 4.6 Debris fences, a design for failure
Figure 4.7 K-rail structures as used in Laguna Beach
Figure 4.8a Laguna Beach, Vet Canyon cross section, station 107 meters
Figure 4.8b Laguna Beach, Vet Canyon cross section, station 148 meters
Figure 4.9 Laguna Beach, Vet Canyon cross section, station 306 meters
Figure 4.10 Laguna Beach, location of hydromulch treatment
Figure 4.11a Erosion as a function of ground cover in the West
Figure 4.11b Erosion as a function of ground cover in Utah
Figure 4.11c Erosion as a function of ground cover in Montana
Figure 4.11d Erosion as a function of ground cover in subalpine Montana
Figure 4.11e Erosion as a function of ground cover in New South Wales, Australia
Figure 4.11f Erosion as a function of ground cover for three California forest Districts
Figure 4.12 Highway 41 fire area and raingage network
Figure 4.13a Landslide map of San Luis Obispo Quad
Figure 4.13c Landslide map of Morro Bay South Quad
Figure 4.13d Landslide map of Morro Bay North Quad
Figure 4.13e Landslide map of Atascadero Quad
Figure 4.14 Typical landslide morphology
Figure 4.15 Percent cover provided by seeded grasses, 1956-1972