



# **DEBRIS-FLOW HAZARDS MITIGATION: Mechanics, Monitoring, Modeling, and Assessment**

**Edited by**  
**Jason W. Kean,**  
**Jeffrey A. Coe,**  
**Paul M. Santi, &**  
**Becca K. Guillen**

PROCEEDINGS OF THE SEVENTH INTERNATIONAL CONFERENCE ON DEBRIS-FLOW HAZARDS MITIGATION, GOLDEN, COLORADO, USA, JUNE 10-13, 2019

# DEBRIS-FLOW HAZARDS MITIGATION: Mechanics, Monitoring, Modeling, and Assessment

Edited by

Jason W. Kean  
US Geological Survey, Golden, Colorado

Jeffrey A. Coe  
US Geological Survey, Golden, Colorado

Paul M. Santi  
Department of Geology and Geological Engineering  
Colorado School of Mines, Golden, Colorado

Becca K. Guillen  
Continuing and Professional Education Services  
Colorado School of Mines, Golden, Colorado

ASSOCIATION OF ENVIRONMENTAL AND ENGINEERING  
GEOLOGISTS SPECIAL PUBLICATION 28

2019



DFHM logo by Alyssa Schwarz

On the Cover: Debris flow at the Chalk Cliffs monitoring site near Nathrop, Colorado. Photo taken by an automated monitoring camera, courtesy of Jeffrey Coe, US Geological Survey.

Authors granted permission to the organizers of the 7th International Conference on Debris-Flow Hazards Mitigation to release (publish) your paper online, with Open Access, on the AEG and Mountain Scholar websites.

Published by the Association of Environmental and Engineering Geologists  
Distributed by the Association of Environmental and Engineering Geologists and  
Mountain Scholar Digital Collections of Colorado & Wyoming

ISBN: 978-0-578-51082-8

## Preface

The Seventh International Conference on Debris-Flow Hazards Mitigation was held in Golden, Colorado June 10-13, 2019. The major objective of the conference was to provide a forum for international researchers, engineers, and policy makers to exchange ideas and promote communication to advance the scientific understanding of debris-flow hazards as well as approaches to assess and mitigate debris-flow risk to infrastructure and people. The conference agenda consisted of 14 keynote presentations, 38 shorter oral presentations, and 86 poster presentations. The conference sessions were preceded by a 1-day field trip to examine 2013 debris flows in Rocky Mountain National Park and followed by a 2-day field trip to the Chalk Cliffs debris-flow monitoring basin near Nathrop, Colorado.

This proceedings volume contains 134 papers from 17 countries that accompanied all three types of presentations. All papers underwent peer review, with each paper receiving at least one technical and one editorial review, and most receiving two technical and two editorial reviews. We acknowledge the critical role that reviewers played in assuring the high-quality of papers in this volume. Reviewer names and affiliations are given on the following pages.

Many people contributed to the success of the conference. The International Organizing Committee provided guidance to the Local Organizing Committee throughout the multi-year preparation period leading up the conference, as well as assisting with the review process and by serving as session moderators during the conference. The Colorado School of Mines Continuing and Professional Education Services group, led by Melody Francisco and including Becca Guillen, Jennifer Graser, and Andy Ledford, managed the massive job of creating and updating the conference website, corresponding with authors and attendees, wrangling manuscript submission and review logistics, and organizing meeting rooms, housing, and food arrangements for the conference. Emily Bongiovanni, the Colorado School of Mines Scholarly Communications Librarian, assured that this volume was posted on the Mountain Scholar website. Several organizations provided sponsorship through financial support. Their names are provided on the following pages. Our profound thanks goes out to all of these individuals and groups.

The Editors:

Jason W. Kean  
US Geological Survey

Jeffrey A. Coe  
US Geological Survey

Paul M. Santi  
Colorado School of Mines

Becca K. Guillen  
Colorado School of Mines

*International Organizing Committee*

Dieter Rickenmann	Swiss Federal Research Institute WSL, Birmensdorf, Switzerland
Elisabeth Bowman	The University of Sheffield, Sheffield, United Kingdom
Marcel Hürlimann	Universitat Politècnica de Catalunya, Barcelona, Catalunya
Mark Reid	US Geological Survey, Menlo Park, California, USA
Paul Santi	Colorado School of Mines, Golden, Colorado, USA
Yoshifumi Satofuka	Ritsumeikan University, Kyoto, Japan

*Local Organizing Committee*

Paul Santi	Colorado School of Mines
Jeffrey Coe	US Geological Survey
Jason Kean	US Geological Survey
Jonathan Godt	US Geological Survey

*Conference and Proceedings Management Team*

Colorado School of Mines, Continuing and Professional Education Services

Melody Francisco	Director
Jennifer Graser	Event Manager
Becca Guillen	Finance & Administrative Manager
Andy Ledford	Webmaster
Ed Mantz	Manager of Program Technology & Services

## Reviewers

The editors thank the following people who peer-reviewed manuscripts submitted to the conference:

Kate Allstadt	US Geological Survey (USA)
Muneyuki Arai	Meijo University (Japan)
Katherine Barnhart	University of Colorado (USA)
Rex Baum	US Geological Survey (USA)
Scott Beason	US National Park Service (USA)
Erin Bessette-Kirton	US Geological Survey (USA)
David Bonneau	Queen's University (Canada)
Elisabeth Bowman	The University of Sheffield (United Kingdom)
Miguel Cabrera	Universidad de los Andes (Columbia)
Nancy Calhoun	Oregon Dept. of Geology and Mineral Industries (USA)
Felix Camire	Town of Canmore (Canada)
Kerry Cato	California State University, San Bernardino (USA)
Hua-Yong Chen	Institute of Mountain Hazards and Environment (China)
Jian-Gang Chen	Institute of Mountain Hazards and Environment (China)
Shin-Kyu Choi	Korea Advan. Inst. Science and Tech. (Republic of Korea)
Jeffrey Coe	US Geological Survey (USA)
Velio Covello	Free University of Bozen-Bolzano (Italy)
Matt Crawford	Kentucky Geological Survey (USA)
Kahlil Fredrick Cui	Institute of Mountain Hazards and Environment (China)
Joanna Curran	Indicator Engineering (USA)
Tim Davies	University of Canterbury (New Zealand)
Alexander Densmore	Durham University (United Kingdom)
Litan Dey	National Cheng Kung University (China)
Vivian Dias	University of São Paulo (Brazil)
Junhan Du	Institute of Mountain Hazards and Environment (China)
Paul Duhart	Servicio Nacional de Geología y Minería (Chile)
Evan Friedman	Lithos Engineering (USA)
Masaharu Fujita	Disaster Prevention Research Institute (Japan)
Joe Gartner	BGC Engineering Inc. (USA)
Jonathan Godt	US Geological Survey (USA)
Christoph Graf	Swiss Federal Institute WSL (Switzerland)
Carlo Gregoretti	University of Padova (Italy)
Xiaojun Guo	Institute of Mountain Hazards and Environment (China)
Norio Harada	Mitsui Consultants Co. (Japan)
Yuji Hasegawa	Hiroshima University (Japan)
Junya Hina	Construction Technology Institute Co. (Japan)
Jacob Hirschberg	Swiss Federal Institute WSL (Switzerland)
Leslie Hsu	US Geological Survey (USA)

Yu-Charn Hsu	National Taiwan University (China)
Hongsen Hu	Institute of Mountain Hazards and Environment (China)
Kaiheng Hu	Institute of Mountain Hazards and Environment (China)
Li-Jeng Huang	National Kaohsiung University Science and Tech. (China)
Yi-Min Huang	Feng Chia University (China)
Johannes Hübl	University Natural Resources and Life Sciences (Austria)
Marcel Hürlimann	Universitat Politècnica de Catalunya (Spain)
Akihiko Ikeda	Sabo & Landslide Technical Center (Japan)
Fumitoshi Imaizumi	Shizuoka University (Japan)
Takahiro Itoh	Nippon Koei Co. (Japan)
Richard Iverson	US Geological Survey (USA)
Mattias Jakob	BGC Engineering Inc. (Canada)
Eranda Jayasekara	University of Peradeniya (Sri Lanka)
Roland Kaitna	University Natural Resources and Life Sciences (Austria)
William Kane	Kane Geotech Inc. (USA)
Jason Kean	US Geological Survey (USA)
Jeffrey Keaton	Wood (USA)
Masato Kobiyama	Federal University of Rio Grande do Sul (Brazil)
Viktoria Kurovskaia	St. Petersburg State University (Russia)
Dominique Laigle	Université Grenoble Alpes (France)
Jeremy Lancaster	California Geological Survey (USA)
Deuk-Hwan Lee	KAIST (Republic of Korea)
Kwangwoo Lee	Korea Railroad Research Institute (Republic of Korea)
Shuai Li	Institute of Mountain Hazards and Environment (China)
Dingzhu Liu	Institute of Mountain Hazards and Environment (China)
Fangzhou Liu	Georgia Institute of Technology (USA)
Jon Major	US Geological Survey (USA)
Tiago Martins	Federal University of São Paulo (Brazil)
Naoki Matsumoto	Nat. Inst. for Land and Infrastructure Management (Japan)
Kevin McCoy	Colorado Geological Survey (USA)
Scott McCoy	University of Nevada, Reno (USA)
Luke McGuire	University of Arizona (USA)
Abigail Michel	US Geological Survey (USA)
Kate Mickelson	Washington Geological Survey (USA)
Ben Mirus	US Geological Survey (USA)
Kuniaki Miyamoto	Nippon Koei Co. (Japan)
Chiara Morstabilini	Maccaferri Innovation Center (Italy)
Robb Moss	California Polytechnic State University (USA)
Naoto Nakamura	CTI Engineering Co. (Japan)
Kana Nakatani	Kyoto University (Japan)
Ba-Quang-Vinh Nguyen	Pukyong University (Republic of Korea)
Petter Nyman	University of Melbourne (Australia)
Nina Oakley	Desert Research Institute (USA)
Takehiro Ohta	Yamaguchi University (Japan)
Rosa Palau	Universitat Politècnica de Catalunya (Spain)
Jefferson Picanço	Unicamp (Brazil)

Marina Pirulli	Politecnico di Torino (Italy)
Guillaume Piton	Université Grenoble Alpes (France)
Sara Rathburn	Colorado State University (USA)
Mark Reid	US Geological Survey (USA)
Francis Rengers	US Geological Survey (USA)
Dieter Rickenmann	Swiss Federal Research Institute WSL (Switzerland)
Yuichi Sakai	University of Tokyo (Japan)
Paul Santi	Colorado School of Mines (USA)
Claudia Vanessa Santos Corrêa	Cemaden (Brazil)
Nicoletta Sanvitale	University of Sheffield (United Kingdom)
Luca Sarno	University of Salerno (Italy)
Katherine Scharer	US Geological Survey (USA)
Manfred Scheikl	ALPINFRA (Austria)
Kevin Schmidt	US Geological Survey (USA)
Vinod Sharma	Geological Survey of India (India)
Stephen Slaughter	Washington Geological Survey (USA)
Joel Smith	US Geological Survey (USA)
Dongri Song	Institute of Mountain Hazards and Environment (China)
Eu Song	Seoul National University (Republic of Korea)
Alex Strouth	BGC Engineering Inc. (USA)
Kiyotaka Suzuki	PASCO Corporation (Japan)
Takuro Suzuki	Forestry and Forest Products Research Institute (Japan)
Brian Swanson	California Geological Survey (USA)
Matt Thomas	US Geological Survey (USA)
Ting-Chi Tsao	Sinotech Engineering Consultants (China)
Haruka Tsunetaka	Forestry and Forest Products Research Institute (Japan)
Taro Uchida	Nat. Inst. for Land and Infrastructure Management (Japan)
Bianca Vieira	University of São Paulo (Brazil)
Thad Wasklewicz	East Carolina University (USA)
Shih-Chao Wei	National Taiwan University (China)
Michaela Wenner	ETH Zürich (Switzerland)
Jia Yang	Institute of Mountain Hazards and Environment (China)
Shun Yang	Institute of Exploration Technology (China)
Kousuke Yoshino	Asia Air Survey Co. (Japan)
Ann Youberg	Arizona Geological Survey (USA)
Sophia Zubrycky	University of British Columbia (Canada)

## **Keynote Speakers**

Some keynote speakers do not have papers in this volume

### *Processes and Mechanics*

Nico Gray (United Kingdom)

Anne Mangeney (France)

### *Monitoring, Detection, and Warning*

Kate Allstadt (USA)

Brian McArdell (Switzerland)

### *Experiments and Modeling*

Liz Bowman (United Kingdom)

Dave George (USA)

### *The Role of Disturbance*

Fumitoshi Imaizumi (Japan)

Luke McGuire (USA)

### *Case Studies and Hazard Assessments*

Jeremy Lancaster (USA)

Alex Densmore (United Kingdom)

Mike Chard (USA)

Mattias Jakob (Canada)

### *Engineering and Mitigation*

Johannes Huebl (Austria)

Ken Ho (China)

## **Sponsors**

The conference was financially supported by:

Access Limited Construction

Association of Environmental and Engineering Geologists

BGC Engineering Inc.

Geobrugg North America

KANE Geotech Inc.

MACCAFERRI Inc

US Geological Survey

## Table of Contents

### *Processes and Mechanics*

Numerical investigation of particle size segregation in saturated granular flows using CDF-DEM coupling approach .....	2
<i>Cui, K.F.E., Zhou, G.G.D.</i>	
Erosion by experimental debris flows: particle size effects .....	10
<i>Ghasemi, A., Kaitna, R., Fritton, P., Blankenship, B.T., Feng, Q., Densmore, A., de Haas, T., Hill, K.M.</i>	
How does particle-size segregation affect the fluidity of multi-granular debris flows? .....	18
<i>Hotta, N., Iwata, T., Suzuki, T.</i>	
Valid debris-flow models must avoid hot starts .....	25
<i>Iverson, R.M., George, D.L.</i>	
The role of topography on the volume of material eroded by debris flows .....	33
<i>Kudo, T., Uchida, T., Sakurai, W.</i>	
Numerical investigation of deposition mechanism of submarine debris flow .....	38
<i>Liu, D., Cui, Y., Choi, C.E., Bazai, N.A., Yu, Z., Lei, M., Yin, Y.</i>	
Compressibility of solid phase of debris flow and erosion rate .....	46
<i>Miyamoto, K., Itoh, T., Kisa, H.</i>	
Commonalities between debris flows and flow failures .....	54
<i>Moss, R.E.S.</i>	
Soil characteristics of long-traveling landslides and a hybrid model to predict travel distance ...	61
<i>Usuki, N., Toshino, K., Mizuyama, T.</i>	
The research on the movable solid materials under seepage flow effect in debris-flow source area .....	69
<i>Yang, S., Ou, G., Pan, H., Xie, Z., Yang, D.</i>	

### *Monitoring, Detection, and Warning*

Overcoming barriers to progress in seismic monitoring and characterization of debris flows and lahars .....	77
<i>Allstadt, K.E., Farin, M., Lockhart, A.B., McBride, S.K., Kean, J.W., Iverson, R.M., Logan, M., Smith, J.B., Tsai, V.C., George, D.L.</i>	

Topographic change detection at Chalk Cliffs, Colorado, USA, using airborne lidar and UAS-based Structure-from-Motion photogrammetry .....	85
<i>Barnhart, K.R., Rengers, F.K., Ghent, J.N., Tucker, G.E., Coe, J.A., Kean, J.W., Smith, J.B., Staley, D.M., Kleiber, W., Wiens, A.M.</i>	
Forecasting and seismic detection of debris flows in pro-glacial rivers at Mount Rainier National Park, Washington, USA .....	93
<i>Beason, S.R., Legg, N.T., Kenyon, T.R., Jost, R.P., Kennard, P.M.</i>	
Deciphering sediment dynamics in a debris-flow catchment: insights from instrumental monitoring and high-resolution topography .....	103
<i>Coviello, V., Theule, J.I., Marchi, L., Comiti, F., Crema, S., Cavalli, M., Arattano, M., Lucía, A., Macconi, P.</i>	
Examining the impact force of debris flow in a check dam from small-flume experiments ....	111
<i>Eu, S., Im, S.</i>	
The vibrational characteristics of debris flow in Taiwan .....	116
<i>Huang, Y., Fang, Y., Yin, H.</i>	
Monitoring and modeling of debris-flow surges at the Lattenbach creek, Austria .....	124
<i>Huebl, J., Arai, M., Kaitna, R.</i>	
Monitoring of rainfall and soil moisture at the Rebaixader catchment (Central Pyrenees) ....	131
<i>Hürlimann, M., Oorthuis, R., Abancó, C., Carleo, L., Moya, J.</i>	
Debris flow monitoring using load cells and pressure sensors on Sakurajima Island .....	138
<i>Itoh, T., Fujimura, N., Katou, H., Tagata, S., Mizuyama, T.</i>	
Implementation of an integrated management strategy to deal with landslide triggered debris flows: the Valloire case study (Savoie, France) .....	146
<i>Laigle, D., Jongmans, D., Liebault, F., Baillet, L., Rey, E., Fontaine, F., Borgniet, L., Bonnefoy-Demongeot, M., Ousset, F.</i>	
Taking the pulse of debris flows: Extracting debris-flow dynamics from good vibrations in southern California and central Colorado .....	154
<i>Michel, A., Kean, J.W., Smith, J.B., Allstadt, K.E., Coe, J.A.</i>	
Observations on the development and decay processes of debris flows .....	162
<i>Murasawa, M., Imaizumi, F., Yokota, Y.</i>	
Monitoring of sediment runoff and observation basin for sediment movements focused on active sediment control in Jo-Gan-Ji River .....	170
<i>Nagayama, T., Furuya, T., Matsuda, S., Itoh, T., Fujita, M., Mizuyama, T.</i>	

Measurements of velocity profiles in natural debris flows: a view behind the muddy curtain .....	177
<i>Nagl, G., Huebl, J., Kaitna, R.</i>	
Debris-flow early warning system at regional scale using weather radar and susceptibility mapping .....	184
<i>Palau, R.M., Hürlimann, M., Berenguer, M., Sempere-Torres, D.</i>	
Real-time monitoring of debris-flow velocity and mass deformation from field experiments with high sample rate lidar and video .....	192
<i>Rengers, F.K., Rapstine, T.D., Allstadt, K.E., Olsen, M., Bunn, M., Iverson, R.M., Kean, J.W., Leshchinsky, B., Logan, M., Sharifi-Mood, M., Obryk, M., Smith, J.B.</i>	
Exploring controls on debris-flow surge velocity and peak discharge at Chalk Cliffs, Colorado, USA .....	199
<i>Smith, J.B., Kean, J.W., Coe, J.A.</i>	
Dynamic characteristics of extreme superelevation of debris flows observed by laser profile scanners in Sakura-jima volcano, Japan .....	207
<i>Takahashi, Y., Fujimura, N., Akita, H., Mizuno, M.</i>	
Monitoring and early warning of debris flow in an earthquake impacted area, Baishahe catchment, southwest China .....	214
<i>Tian, H., Yang, Z., Qiao, J., Shi, L.</i>	
Deciphering debris-flow seismograms at Illgraben, Switzerland .....	222
<i>Wenner, M., Walter, F., McArdell, B., Farinotti, D.</i>	
 <i>Experiments and Modeling</i>	
Reproducibility of debris-flow fan physical modeling experiments .....	231
<i>Adams, K., Wasklewicz, T., de Haas, T., Lecce, S., Gares, P.</i>	
Influence of momentum correction factor and friction factor on flow models of debris flow related to flow surface deformation .....	239
<i>Arai, M.</i>	
Constraining parameter uncertainty in modeling debris-flow initiation during the September 2013 Colorado Front Range storm .....	249
<i>Baum, R.L., Scheevel, C.R., Jones, E.S.</i>	
An evaluation of debris-flow runout model accuracy and complexity in Montecito, California: Towards a framework for regional inundation-hazard forecasting .....	257
<i>Bessette-Kirton, E.K., Kean, J.W., Coe, J.A., Rengers, F.K., Staley, D.M.</i>	

Possibilities and limitations for the back analysis of an event in mountain areas on the coast of São Paulo State, Brazil using RAMMS numerical simulation .....	265
<i>Corrêa, C.V.S., Reis, F.A.G.V., Giordano, L.C., Cabral, V.C., Targa, D.A., Brito, H.D.</i>	
Discrete-element investigation of granular debris-flow runup against slit structures .....	273
<i>Du, J., Zhou, G.G.D.</i>	
A method for predicting debris-flow occurrence based on a rainfall and sediment runoff model .....	280
<i>Fujita, M.; Yamanoi, K.; Suzuki, G.</i>	
Seamless numerical simulation of a hazard cascade in which a landslide triggers a dam-breach flood and consequent debris flow .....	287
<i>George, D.L., Iverson, R.M., Cannon, C.M.</i>	
Woody debris blocking conditions at bridges in mountainous streams .....	294
<i>Hasegawa, Y., Nakatani, K., Satofuka, Y.</i>	
Flume experiments and numerical simulation focused on fine sediments in stony debris flow .....	301
<i>Hina, J., Uchida, T., Matsumoto, N., Sakurai, W., Nishiguchi, Y., Murakami, M.</i>	
On the regression of velocity distribution of debris flows using machine learning techniques .....	307
<i>Huang, L., Hsiao, D.</i>	
Experimental evaluation for peak and temporal changes in debris-flow initiation processes ...	315
<i>Itoh, T., Ikeda, A., Mizuyama, T.</i>	
Correlation between the slump parameters and rheological parameters of debris flow .....	323
<i>Jan, C., Yang, C., Hsu, C., Dey, L.</i>	
Concentration distribution in debris flow consisting of particles with two different sizes .....	330
<i>Kida, H., Iwao, M.</i>	
Debris-flow hazard investigation with Kanako-2D in a rural basin, Alto Feliz municipality (Brazil) .....	338
<i>Kobiyama, M. and Michel, R.D.L.</i>	
Numerical analysis on the behavior of the debris flow and impact force on check dam .....	346
<i>Lee, K., Jeong, S., Kim, H.</i>	
Impact load estimation on retention structures with the discrete element method .....	354
<i>Leonardi, A., Calcagno, E., Pirulli, M.</i>	

Debris-flow deposition: effects of fluid viscosity and grain size .....	361
<i>Li, S., Zhou, G.G.D., Chen, X., Song, D.</i>	
Regional-scale modelling of liquefaction-induced shallow landslides in unsaturated slopes ..	369
<i>Li, X., Song, Z., Lizárraga, J.L., Buscarnera, G.</i>	
Flume experiment on the influence of particle size distribution on sediment capturing efficiency of open-type steel Sabo dams .....	377
<i>Matsumoto, N., Uchida, T., Sakurai, W., Matsubara, T., Okuyama, R., Hina, J., Satofuka, Y.</i>	
Debris-flow behavior containing fine sediment considering phase shift .....	385
<i>Nakatani, K., Hasegawa, Y., Asano, Y., Satofuka, Y.</i>	
Long travel distance of landslide-induced debris flows .....	393
<i>Nishiguchi, Y., Uchida, T.</i>	
Effect of rheological properties on debris-flow intensity and deposition in large scale flume experiment .....	401
<i>Nguyen, B., Lee, J., Kim, Y., Lee, S., Kwon, T.</i>	
Long travel distance of landslide-induced debris flow .....	407
<i>Pinzón, G., Cabrera, M.A.</i>	
Small scale debris-flow experiments on run-up height .....	414
<i>Rickenmann, D., Karrer, T., McArdell, B., Scheidl, C.</i>	
Numerical simulation of debris flows focusing on the behavior of fine sediment .....	421
<i>Sakai, Y., Hotta, N.</i>	
Optical measurements of velocity and of solid volume fraction in fast dry granular flows in a rectangular chute .....	429
<i>Sarno, L., Carleo, L., Papa, M.N., Villani, P.</i>	
Debris flow behavior in super- and subcritical conditions .....	437
<i>Scheidl, C., McArdell, B., Nagl, G., Rickenmann, D.</i>	
Experimental examination for influence of debris-flow hydrograph on development processes of debris-flow fan .....	443
<i>Tsunetaka, H., Hotta, N., Sakai, Y., Nishiguchi, Y., Hina, J.</i>	
Numerical simulation for evaluating the phase-shift of fine sediment in stony debris flows ...	451
<i>Uchida, T., Nishiguchi, Y., McArdell, B., Satofuka, Y.</i>	
Run out processes of sediment and woody debris resulting from landslides and debris flow...	459
<i>Yamazaki, Y., Egashira, S.</i>	

Comparison of an empirical and a process-based model for simulating debris-flow inundation following the 2010 Schultz Fire in Coconino County, Arizona, USA.....	467
<i>Youberg, A.M., McGuire, L.A.</i>	

### *The Role of Disturbance*

The impact of global warming on the formation of debris flows in an alpine region of southeastern Tibet .....	476
<i>Cui, P., Yang, J., Liu, D.</i>	
Relationship between rainfall intensity and debris-flow initiation in a southern Colorado burned area .....	484
<i>Friedman, E.Q. and Santi, P.M.</i>	
Effects of terrain on temporal changes in susceptibility of debris flows and associated hydrogeomorphic processes after forest harvesting .....	492
<i>Imaizumi, F.</i>	
Overview of geotechnical effects of the January 9, 2018, debris-flow and flash-flood disaster in Montecito, California .....	500
<i>Keaton, J., Oriz, R.M., Turner, B., Alessio, P., Gartner, J., Duffy, J., Parker, G., Smilovsky, D., Watts, T.</i>	
The debris flows and mitigation systems after the 2008 Wenchuan earthquake .....	508
<i>Liu, F., Frost, J.D., Xu, Q., Huang, R.</i>	
Looking through the window of disturbance at post-wildfire debris-flow hazards .....	516
<i>McGuire, L.A., Rengers, F.K., Kean, J.W., Staley, D.M., Tang, H., Youberg, A.M.</i>	
Conceptual framework for assessing disturbance impacts on debris-flow initiation thresholds across hydroclimatic settings .....	524
<i>Mirus, B.B., Staley, D.M., Kean, J.W., Smith, J.B., Wooten, R., McGuire, L.A., Ebel, B.A.</i>	
A novel approach for determining risk of water supply disruptions due to post-wildfire debris flows .....	532
<i>Nyman, P., Yeates, P., Langhans, C., Schärer, C., Noske, P.J., Lane, P.N.J., Haydon, S., Sheridan, G.J.</i>	
Rainfall intensity limitation and sediment supply independence of postwildfire debris flows in the western U.S. ....	539
<i>Santi, P.M., MacAulay, B.</i>	

## *Case Studies and Hazard Assessments*

Debris flows in the North Pacolet River valley, Polk County, North Carolina, USA - case studies and emergency response .....	549
<i>Bauer, J.B., Wooten, R.M., Cattanach, B.L., Fuemmeler, S.J.</i>	
Characteristics of debris flows just downstream the initiation area on Punta Nera cliffs, Venetian Dolomites .....	557
<i>Bernard, M., Berti, M., Crucil, G., Simoni, A., Gregoretti, C.</i>	
Characterizing debris transfer patterns in the White Canyon, British Columbia with terrestrial laser scanning .....	565
<i>Bonneau, M., Hutchinson, D.J., McDougall, S.</i>	
Simulation of the debris flow occurred the 15 August 2010 on Rio Val Molinara Creek (northeast Italian Alps) .....	573
<i>Boreggio, M., Bernard, M., Alberti, R., Gregoretti, C.</i>	
Post-fire rockfall and debris-flow hazard zonation in the Eagle Creek fire burn area, Columbia River Gorge, Oregon: A tool for emergency managers and first responders.....	581
<i>Calhoun, N.C., Burns W.J., Hay, S., Staley, D.M., Kean, J.W.</i>	
Hydrogeomorphology and steep creek hazard mitigation lexicon: French, English and German .....	589
<i>Camiré, F., Piton, G., Schwindt, S.</i>	
Debris flow in southeast Brazil: susceptibility assessment for watersheds and vulnerability assessment of buildings .....	597
<i>Vieira, B.C., de Souza, L.M., Alcalde, A.L., Dias, V.C., Bateira, C., Martins, T.D.</i>	
Complexity of a debris-flow system at Forest Falls, California .....	605
<i>Cato, K., Goforth, B.</i>	
A 4000-year history of debris flows in north-central Washington State, USA: preliminary results from trenching and surficial geologic mapping at the Pope Creek fan .....	613
<i>Coe, J.A., Bessette-Kirton, E.K., Slaughter, S.L., Rengers, F.K., Contreras, T.A., Mickelson, K.A., Taylor, E.M., Kean, J.W., Jacobacci, K.E., Hanson, M.A.</i>	
Modeling frequent debris flows to design mitigation alternatives .....	621
<i>Curran, J.C., Flanagan, P.</i>	
Application of knowledge-driven method for debris-slide susceptibility mapping in regional scale .....	629
<i>Das, R., Nandi, A.</i>	

Making sense of avulsions on debris-flow fans .....	637
<i>Densmore, A.L., de Haas, T., McArdell, B., Schuerch, P.</i>	
The morphology of debris-flow deposits from a 1967 event in Caraguatatuba, Serra do Mar, Brazil .....	645
<i>Dias, V.C., Martins, T.D., Gramani, M.F., Coelho, R.D., Dias, H.C., Vieira, B.C.</i>	
The Santa Lucía landslide disaster, Chaitén-Chile: origin and effects .....	653
<i>Duhart, P., Sepúlveda, V., Garrido, N., Mella, M., Quiroz, D., Fernández, J., Moreno, H., Hermosilla, G.</i>	
Debris-flow risk management in practice: a New Zealand case study .....	661
<i>Farrell, J., Davies, T.</i>	
Post-fire debris-flow hazard analysis for interstate 80, Truckee River Canyon, near the California-Nevada state line, USA .....	669
<i>Felling, G., Myers, A., McCoy, S.W.</i>	
Debris-flow risk assessment and mitigation design for pipelines in British Columbia, Canada .....	677
<i>Gartner, J.E., Jakob, M.</i>	
An overview of a decade of applied debris-flow runout modeling in Switzerland: challenges and recommendations .....	685
<i>Graf, C., Christen, M., McArdell, B.W., Bartelt, P.</i>	
Analysis of rainfall and runoff for debris flows at the Illgraben catchment, Switzerland .....	693
<i>Hirschberg, J., McArdell, B.W., Badoux, A., Molnar, P.</i>	
Debris-flow assessment from rainfall infiltration induced landslide .....	701
<i>Hsu, Y., Liu, K., Shu, H.</i>	
Study of prediction methods of debris-flow peak discharge .....	709
<i>Ikeda, A., Mizuyama, T., Itoh, T.</i>	
Debris-flow hazard assessments -- a practitioner's view .....	716
<i>Jakob, M.</i>	
Evaluation of shallow landslide-triggering scenarios through a physically based approach: A case study from Bulathsinhala area, Sri Lanka .....	724
<i>Jayasekara, E.I., Weerasekara, N.K., Jayathissa, H.A.G., Gunatilake, A.A.J.K.</i>	
Hydro-meteorological trigger conditions of debris flows in Austria .....	732
<i>Kaitna, R., Prenner, D., Braun, M., Hrachowitz, M.</i>	

Weather-radar inferred intensity and duration of rainfall that triggered the January 9, 2018, Montecito, California, disaster .....	740
<i>Keaton, J.R.</i>	
Review of contemporary terminology for damaging surficial processes – stream flow, hyperconcentrated sediment flow, debris flow, mud flow, mud flood .....	748
<i>Keaton, J.R.</i>	
Evaluation of slope stability of Taebaeksan Mountain National Park using detailed soil map .....	758
<i>Kim, Y., Jun, K., Jun, B., Lee, H., Kim, S., Jang, C.</i>	
Estimation of debris-flow volumes by an artificial neural network model .....	766
<i>Lee, D., Lee, S., Jeon, J., Park, J., Kim, Y.</i>	
Post-fire debris flows of 9 January 2018, Thomas Fire, southern California: Initiation areas, precipitation and impacts .....	774
<i>Lukashov, S.G., Lancaster, J.T., Oakley, N.S., Swanson, B.J.</i>	
Debris-flow susceptibility mapping in Colorado using Flow-R: calibration techniques and selected examples .....	782
<i>McCoy, K.M.</i>	
Landslides and debris flows in volcanic rocks triggered by the 2017 Northern Kyushu heavy rain .....	790
<i>Ohta, T., Eguchi, S.</i>	
Debris-flow occurrence in granite landscape in south-southeast Brazil .....	798
<i>Picanço, J., Vieira, B., Martins, T., Gramani, M., Faccuri, G., Silva, M.</i>	
Hillslope evaluation in the vicinity of the Wolsong nuclear power plant after 12th September 2016 Gyeongju earthquake, South Korea.....	808
<i>Pradhan, A.M.S., Lee, J., Lee, S., Kwon, T., Kim, Y.</i>	
Historical debris-flow occurrence in Rocky Mountain National Park, Colorado, USA .....	816
<i>Rathburn, S.L., Patton, A.I., Bilderback, E.L.</i>	
Debris-flow initiation promoted by extension of a slow-moving landslide .....	824
<i>Reid, M.E., Brien, D.L.</i>	
Regional level debris-flow hazard assessment for alpine infrastructure facilities using the 3D numerical high-performance simulation tool FIMT .....	832
<i>Scheikl, M., Powell, D.</i>	

Using satellite radar interferometry to delineate burn area and detect sediment accumulation, 2018 Montecito disaster, California .....	840
<i>Smilovsky, D., Keaton, J.R.</i>	
Quantitative risk management process for debris flows and debris floods: lessons learned in Western Canada .....	847
<i>Strouth, A., McDougall, S., Jakob, M., Holm, K., Moase, E.</i>	
Semi-automated regional scale debris-flow and debris-flood susceptibility mapping based on digital elevation model metrics and Flow-R software .....	855
<i>Sturzenegger, M., Holm, K., Lau, C., Jakob, M.</i>	
Study on methods for assessing sediment disaster inundation zone in regions with insufficient data: Case study of the Aranayake disaster in Sri Lanka .....	863
<i>Suzuki, K., Uchida, T., Matsumoto, N., Nakatani, K., Jayathissa, G.</i>	
Application of an MPS-based model to the process of debris-flow deposition on alluvial fans .....	871
<i>Suzuki, T., Hotta, N., Tsunetaka, H., Sakai, Y.</i>	
Numerical modeling of debris flows and landslides triggered by extreme rainfall event .....	879
<i>Tsai, Y., Syu, F., Lee, S., Shieh, C.</i>	
Debris-flow building damage level and vulnerability curve – A case study of a 2015 Typhoon event in northern Taiwan .....	887
<i>Tsao, T., Hsu, C., Yin, H., Cheng, K.</i>	
Estimating mechanical slope stability to predict the regions and ranges of deep-seated catastrophic landslides .....	895
<i>Yoshino, K., Uchida, T.</i>	
Multi-scale hazard assessment of debris flows in eastern Qinghai-Tibet Plateau area .....	903
<i>Zou, Q., Cui, P., Zhang, G., Wang, D.</i>	
Preliminary calibration of a numerical runout model for debris flows in Southwestern British Columbia .....	911
<i>Zubrycky, S., Mitchell, A., Aaron, J., McDougall, S.</i>	
<i>Engineering and Mitigation</i>	
Predicting debris-flow scour depth downstream from a check dam .....	920
<i>Chen, H., Chen, Z., Chen, J., Tang, J.</i>	

Debris-flow mitigation measures and an application case in a small-scale watershed in China .....	928
<i>Chen, J., Chen, X., Zhao, W., You, Y.</i>	
Roles of barrier location for effective debris-flow mitigation: assessment using DAN3D .....	936
<i>Choi, S., Kwon, T., Lee, S., Park, J.</i>	
Scour and erosion experience with flexible debris-flow nets .....	941
<i>Feiger, N. and Wendeler, C.</i>	
Steel stakes to capture debris-wood on an impermeable type sabo dam .....	949
<i>Harada, N. and Satofuka, Y.</i>	
Debris-flow mitigation – research and practice in Hong Kong .....	957
<i>Ho, K.K.S., Koo, R.C.H., Kwan, J.S.H.</i>	
Flume investigation of the interaction mechanisms between debris flow and slit dams .....	965
<i>Hu, H.S., Zhou, G.G.D., Song, D.</i>	
Empirical model for assessing dynamic susceptibility of post-earthquake debris flows .....	973
<i>Hu, K., Wang, Z., Chen, C., Li, X.</i>	
From practical experience to national guidelines for debris-flow mitigation measures in Austria .....	981
<i>Huebl, J., Nagl, Georg</i>	
Flexible debris-flow nets for post-wildfire debris mitigation in the western United States .....	988
<i>Kane, W.F., Jones, M.A.</i>	
Laboratory tests of an innovative check dam .....	996
<i>Morstabilini, C., Boschini, I., Zambrini, F., Menduni, G., Deana, M.L., Zorzi, N.</i>	
Application of an innovative, low-maintenance weir to protect against debris flows and floods in Ottone, Italy device .....	1004
<i>Morstabilini, C., Deana, M.L.</i>	
Numerical study of debris flows in presence of obstacles and retaining structures: A case study in the Italian Alps .....	1012
<i>Pirulli, M., Manassero, M., Terriotti, C., Leonardi, A., La Porta, G.</i>	
Design of a debris retention basin enabling sediment continuity for small events: the Combe de Lancey case study (France) .....	1019
<i>Piton, G., Mano, V., Richard, D., Evin, G., Laigle, D., Tacnet, J., Rielland, P.</i>	

Review of the mechanisms of debris-flow impact against barriers .....	1027
<i>Poudyal, S., Choi, C.E., Song, D., Zhou, G.G.D., Yune, C.Y., Cui, Y., Leonardi, A., Busslinger, M., Wendeler, C., Piton, G., Moase, E., Strouth, A.</i>	
Small scale impact on rigid barrier using transparent debris-flow models .....	1035
<i>Sanvitale, N., Bowman, E., Cabrera, M.A.</i>	
Estimation of temporal changes of debris flows and hydraulic model tests of channel works with multi-drop structures .....	1043
<i>Watabe, H., Ikeshima, T., Nishi, Y., Nagarekawa, Y., Matsuda, S., Nakayama, T., Itoh, T., Mizuyama, T.</i>	
<i>Author Index</i> .....	1051