

Annual Report for Period:09/2008 - 08/2009**Submitted on:** 06/23/2009**Principal Investigator:** Anderson, Suzanne P.**Award ID:** 0724960**Organization:** U of Colorado Boulder**Submitted By:****Title:**

CZO: Boulder Creek Critical Zone Observatory--Weathered Profile Development in a Rocky Environment and Its Influence on Watershed Hydrology and Biogeochemistry

Project Participants**Senior Personnel****Name:** Anderson, Suzanne**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Suzanne has been working with landowners to establish permission for our field project; working with team members to site stream gages, met towers and other instrumentation; organizing regular meetings of project members during the academic year; coordinating logistics for non-local project members; giving talks about the CZO objectives; recruiting students and staff members.

Name: Anderson, Robert**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Bob is planning CRN sampling for the summer (first field sampling tomorrow), and has been overseeing glacier modeling efforts of post-doc Miriam Duhnforth. Bob is beginning to think about weathering front propagation and interactions between fracture networks, hydrology and chemical weathering. Bob has helped with graduate student recruitment. He is running our first Boulder Creek CZO meeting in August.

Name: Sheehan, Anne**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Anne is coordinating the geophysical surveying component of the project. She has made ties with HMF-geophysics and established collaboration with Dennis Harry (CSU). She is bringing in connections with UNAVCO, specifically obtaining training and access to GPS and T-LiDAR for several students this summer. These will be used in the CZO project. She has recruited a grad student to the project, and has several summer interns involved in project. Participated in our first snow survey.

Name: Tucker, Gregory**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Greg has started working on developing landscape models relevant to the CZO landscapes. He has helped with graduate student recruitment, and LiDAR planning.

Name: Fierer, Noah**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Noah is developing microbial community assessment tools for application in the project, recruiting graduate students, planning and implementing soil sampling.

Name: McKnight, Diane**Worked for more than 160 Hours:** No**Contribution to Project:**

Planning field work; recruiting graduate student; supervising a post-doc; planning Dissolved Organic Matter (DOM) workshop as a cross-CZO activity.

Name: Williams, Mark**Worked for more than 160 Hours:** No

Contribution to Project:

Planning field work; designing field instrumentation; recruiting graduate student; coordinating with Niwot LTER and NEON activities

Name: Caine, Nel

Worked for more than 160 Hours: Yes

Contribution to Project:

Planning field work; designing and locating stream gauges; supplying insight from decades of work in Green Lakes Valley; aiding graduate student recruitment

Name: Wobus, Cam

Worked for more than 160 Hours: Yes

Contribution to Project:

Planning field work; preliminary analysis of topography in Green Lakes Valley from LiDAR; work on fluvial bedrock incision; writing on incision of the Great Plains (which drives fluvial rejuvenation of lower Boulder Canyon). Helped with snow survey.

Name: Dethier, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Wrote successful Keck grant to bring 3 undergrads to Boulder Creek CZO for summer 2008; assisting with topographic analysis of watersheds; handling GIS

Name: Voelkel, Joerg

Worked for more than 160 Hours: Yes

Contribution to Project:

Recon geophysical suveys (summer 2007), and planning for geophysical surveys at all field sites. Will be in the field summer 2008.

Name: Leopold, Matthias

Worked for more than 160 Hours: Yes

Contribution to Project:

Recon geophysical suveys (summer 2007), and planning for geophysical surveys at all field sites. Will be in the field summer 2008.

Name: Murphy, Sheila

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinating with BASIN website; developing relationship with City/County officials; planning water sampling

Name: Blum, Alex

Worked for more than 160 Hours: No

Contribution to Project:

Planning field work, water sampling, and drilling; helped with snow survey.

Name: Loague, Keith

Worked for more than 160 Hours: No

Contribution to Project:

Will begin working on hydrologic simulations of Green Lakes Valley summer 2008.

Post-doc

Name: Duhnforth, Miriam

Worked for more than 160 Hours: Yes

Contribution to Project:

Working with Bob Anderson on CRN sampling and analysis for Green Lakes Valley. Is developing model of glacier occupation of Green Lakes Valley.

Name: Miller, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Matthew completed his PhD in 2008 on nutrient fluxes in Green Lakes Valley and their relationship to hydrology and impact on diatom *Didymosphenia geminata*. He worked as a post-doc for the CZO and Niwot LTER from August-December 2008, before moving to a post-doc with Beth Boyer at the Penn State CZO.

Name: Hinckley, Eve-Lyn

Worked for more than 160 Hours: No

Contribution to Project:

NSF Earth Sciences Post-doctoral fellow

Name: Barnes, Becca

Worked for more than 160 Hours: Yes

Contribution to Project:

Dr. Barnes has an NSF Earth Sciences post-doctoral fellowship, and is based at the USGS in Boulder. Her original project on in-stream processing of nitrogen in coal bed methane discharge became unnecessary because of changes in regulations on water discharge in these extraction operations. She has revised her project to study in-stream processing of nitrogen and its relationship to dissolved organic matter in Boulder Creek and the tributaries that are foci in the Boulder CZO.

Graduate Student

Name: Kandel, Cary

Worked for more than 160 Hours: Yes

Contribution to Project:

New (2008) student work with Suzanne Anderson (Geography), who decided to leave graduate school in her first term.

Name: Huber, Juliane

Worked for more than 160 Hours: No

Contribution to Project:

Graduate student (PhD) at Technical Univ. Munich who will conduct a thesis on CZO geophysical surveys. Will spend >1 month in field this summer.

Name: Eilers, Kathryn

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student working with Noah Fierer (EBio) on soil microbiology in the CZO.

Name: Gray, Chris

Worked for more than 160 Hours: No

Contribution to Project:

New graduate student will work with Noah Fierer (Ebio) on CZO soil microbiology, funded from other sources.

Name: Cowry, Rory

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student with Mark Williams (Geography) working on hydrology and ecology.

Name: Befus, Kevin

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student with Anne Sheehan (Geology), working on seismic refraction surveying of CZO sites.

Name: Gabor, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student with Diane McKnight (Civil Eng), who will work on hydrology and dissolved organic matter.

Name: Daferner, Johannes

Worked for more than 160 Hours: No

Contribution to Project:

Diplom student from Technical Univ. Munich, working as field assistant with Voelkel and Leopold, summer 2008. Will use data from CZO in his Diplom thesis.

Name: Doetterl, Sebastian

Worked for more than 160 Hours: No

Contribution to Project:

Student from Technical Univ. Munich, working as field assistant with Voelkel and Leopold, summer 2008.

Name: Riggins, Susan

Worked for more than 160 Hours: No

Contribution to Project:

Worked on understanding regolith formation.

Name: McLaughlin, Aimee

Worked for more than 160 Hours: No

Contribution to Project:

Thesis is on relationships between environmental conditions in Boulder Creek and invasive diatom *Didymosphenia geminata*. Conducted fieldwork.

Name: Hill, Ken

Worked for more than 160 Hours: No

Contribution to Project:

Completed MA thesis in 2008 on Green Lakes Valley hydrology, analyzing 26 years of observations.

Name: Nielson, Ashley

Worked for more than 160 Hours: No

Contribution to Project:

Completed MA thesis in 2008 on hydrochemistry of a wetland in Green Lakes Valley.

Name: Lee, Jeana

Worked for more than 160 Hours: Yes

Contribution to Project:

New graduate student with Suzanne Anderson (Geography), who will work on weathering and water chemistry across the Boulder CZO sites.

Name: Culp, David

Worked for more than 160 Hours: No

Contribution to Project:

Graduate student with Anne Sheehan (Geology), helping with seismic surveying.

Name: Cullis, James

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student in Civil, Environmental and Architectural Engineering with Diane McKnight, working on *Didymosphenia geminata* in Boulder Creek, and hydraulic controls. Supported by CU Chancellor's Fellowship in 2008-9, partial project support in 2009.

Name: McLoughlin, Rachel

Worked for more than 160 Hours: No

Contribution to Project:

Graduate student in Environmental Sciences with Diane McKnight. Completed MA thesis on *Didymosphenia geminata* in spring 2009.

Name: Cooper, Leigh

Worked for more than 160 Hours: No

Contribution to Project:

Graduate student in Ecology & Evolutionary Biology working with Bill Lewis on effects of spruce beetle on aquatic ecology; partially supported by CZO.

Undergraduate Student

Name: Buraas, Eirik

Worked for more than 160 Hours: No

Contribution to Project:

Keck Geology Consortium 2008 participant from Williams College. Completed senior thesis on infiltration in Gordon Gulch. Working in field with Keck students in 2009.

Name: Gannaway, Evey

Worked for more than 160 Hours: No

Contribution to Project:

Keck Geology Consortium 2008 participant from Sewanee. Complete senior thesis on fractures in Green Lakes Valley bedrock.

Name: Nelson, Ken

Worked for more than 160 Hours: No

Contribution to Project:

Keck Geology Consortium 2008 participant from Macalester College. Completed senior thesis on soils of Betasso catchment.

Name: Rodriguez, Miguel

Worked for more than 160 Hours: No

Contribution to Project:

Keck Geology Consortium 2008 participant from Colgate College. Completed senior thesis on apatite.

Name: Pettit, Mollie

Worked for more than 160 Hours: No

Contribution to Project:

Undergraduate intern from Virginia Tech, working with the geophysics team under guidance of Anne Sheehan.

Name: Rock, Nate

Worked for more than 160 Hours: Yes

Contribution to Project:

Field assistant, working on water sampling, snow surveying, sample processing.

Name: Mass, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Field and lab assistant: water sampling, soil sampling, lab processing of soil, rock and water samples.

Name: Kelsay, Travis

Worked for more than 160 Hours: No

Contribution to Project:

Undergrad assistant to geophysics team, supported by Geology department mentorship and this project.

Name: McClave, Graham

Worked for more than 160 Hours: No

Contribution to Project:

Undergrad assistant to geophysics team, supported by Geology department mentorship and this project.

Name: Austin, Andrus

Worked for more than 160 Hours: No

Contribution to Project:

Michigan Tech undergraduate student, supported as an IRIS intern, helping geophysics team.

Name: Anarde, Katherine

Worked for more than 160 Hours: No

Contribution to Project:

Undergrad assistant to the geophysics team and working with Alex Blum, USGS, on XRD analyses.

Name: Bonilla, Emanuelle

Worked for more than 160 Hours: No

Contribution to Project:

RESESS undergraduate intern.

Name: Byrd, Steve

Worked for more than 160 Hours: Yes

Contribution to Project:

Ecology and Evolutionary Biology undergraduate working with Diane McKnight.

Name: Ianniello, Rick

Worked for more than 160 Hours: Yes

Contribution to Project:

Environmental Studies undergraduate student working with Diane McKnight.

Name: Crisp, Steven

Worked for more than 160 Hours: Yes

Contribution to Project:

Environmental engineering undergraduate student working with Diane McKnight.

Name: Dengler, Liz

Worked for more than 160 Hours: No

Contribution to Project:

Bates College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

Name: Riddle, Evan

Worked for more than 160 Hours: No

Contribution to Project:

North Carolina State University undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

Name: Trotta, James

Worked for more than 160 Hours: No

Contribution to Project:

Williams College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

Name: Gilbert, Rebecca

Worked for more than 160 Hours: No

Contribution to Project:

Williams College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

Name: Krall, Lindsey

Worked for more than 160 Hours: Yes

Contribution to Project:

University of Michigan undergraduate student working with Diane McKnight

Name: Rosenbaum, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

Undergraduate student (CU) working with Diane McKnight and James Cullis on Didymo.

Technician, Programmer

Name: Parrish, Eric

Worked for more than 160 Hours: Yes

Contribution to Project:

Assists with web development, graphics.

Name: Frederick, Zan

Worked for more than 160 Hours: Yes

Contribution to Project:

Oversees field operations for CZO.

Name: Waterman, Jim

Worked for more than 160 Hours: No

Contribution to Project:

Jim is the developer of the BASIN website, and will sustain it and grow it to include the Boulder Creek CZO.

Name: Yang, Chi

Worked for more than 160 Hours: Yes

Contribution to Project:

Data manager.

Other Participant

Research Experience for Undergraduates

Organizational Partners

United States Geological Survey

Alex Blum and Sheila Murphy, both USGS, are integral members of the project team. Their contributions are in soil/rock/water geochemical analysis, lab support, and outreach.

Technical University of Munich

Two researchers (Joerg Voelkel and Matthias Leopold) of TUM are a major part of the geophysics team for the project. They conduct geophysical survey field work this summer, and are bringing several students with them. They work closely with several members of the team, including Nel Caine, Anne Sheehan, and David Dethier.

Williams College

David Dethier from Williams College is bringing a group of undergraduate students for summer research in the CZO this summer, and his work ties in with efforts of the geophysics, geochemical and geomorphology teams.

LELAND JUNIOR STANFORD UNIVERSITY

Keith Loague of Stanford is producing hydrologic simulations using the Integrated Hydrologic Model (InHM). He is currently working on a hydrologic simulation of Green Lakes Valley.

Keck Geology Consortium

A Keck Geology Consortium project involving 3 undergraduate students will take place at the Boulder Creek CZO this summer.

Niwot Long Term Ecological Res. (LTER)

Boulder Creek CZO shares one field site- Green Lakes Valley- with the Niwot LTER. LTER personnel assist CZO personnel, and we are sharing some lab work. The CZO will augment instrumentation in the Niwot LTER- notably the met station in Green Lakes Valley.

Other Collaborators or Contacts

U.S. Forest Service- one of our field sites is on National Forest.

Boulder County Open Space- one of our field sites is on Boulder County Open Space land.

City of Boulder- one of our field sites is on City of Boulder land.

Dr. Iggy Litaor, Tel-Hai Academic College, Israel, in 2008 re-sampled soil pit sites he originally sampled in the 1980s in Green Lakes Valley with CZO and Niwot LTER personnel.

Prof. Dennis Harry, Colorado State University, associate of HMF-Geophysics, collaborated with our geophysics team in 2008.

Dr. Andy Manning, USGS, is working with us on mountain hydrology and coring rock.

William J. (Bill) Stephenson at the USGS in Golden has provided us with advice and loaned us equipment for the shallow seismic work

IRIS Passcal has provided seismic equipment for the passive source tree seismology project as well as the active seismic work (reflection and refraction, surface waves). They are also providing some analysis software.

NEON is moving forward on establishing a test bed site at Gordon Gulch, one of our focus catchments.

Dr. William Manley, INSTAAR GIS laboratory, is working with us to develop a database of historical orthorectified high resolution imagery of our focus subcatchments.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

Year 2: 1 Sept 2008-31 August 2009

Graduate students Kevin Befus and Susan Riggins attended the SoilCritZone workshop in Chania, Crete in September 2008, and were able to make contacts with international researchers on Critical Zone processes. Graduate student Rory Cowie attended the 2009 Isotope Hydrology & Bio-geochemistry Workshop at Oregon State University in June 2009.

All 4 Keck undergraduate students who worked in Boulder Creek in summer 2008 completed senior theses (described in Activities). Buraas plans to attend graduate school after a year off to be assistant Coach of Alpine Skiing at Williams College. Gannaway will be a Fulbright Scholar at Technical University of Munich. Nelson will start Graduate school at Department of Geology, University of Georgia. Rodriguez is undecided about his plans.

Matt Miller spent four months working on a post-doc at CU between the CZO and Niwot LTER. In January 2009, he started a post-doc with Beth Boyers at Penn State, where he will continue to be involved in CZO work through the Shale Hills CZO.

Hydrological Sciences Student Research Symposium

Four CZO graduate students presented research or research plans in this student run symposium on campus. The venue provides a supportive

but professional setting for presenting research. Three of these students went from this symposium to the NABS Annual Meeting and gave their presentations again.

Becca Barnes

NSF Earth Sciences Post-doctoral fellow Barnes joined the Boulder team in Fall 2008. She has been learning about how to reformat a project rapidly (her original plan was unfeasible), and the Boulder CZO has benefited from having her turn to the infrastructure and community we offer.

Undergraduate students

Four undergraduate students will work with David Dethier and other CZO scientists this summer through the Keck Geology Consortium and CZO support. Liz Dengler (Bates), Evan Riddle (North Carolina State University), and James Trotta (Williams College) are the Keck Geology Consortium undergraduate students who will join Rebecca Gilbert (Williams College) to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on their summer field research.

CU undergraduates Nate Rock, Sarah Mass, Travis Kelsay, Graham McClave, Austin Andrus, Katherine Anarde, Steve Byrd, Rick Ianniello, and Steven Crisp are working with various teams in summer 2009, learning geophysical surveying, X-ray diffraction, water sampling, Dissolved organic carbon analysis, soil sampling, and instrumentation.

Graduate students Befus, Cowie, Gabor, Eilers and Kandel along with 9 other graduate students took a graduate level course on Earth's Critical Zone in Fall 2008, taught by S.P. Anderson. The course covered the development of the idea of the Critical Zone, geologic context, hillslope processes, hydrology, weathering, microbial ecology, geophysical observation techniques, biogeochemical cycles, and the role of vegetation in a combination lecture and seminar format. The most interesting parts of the course (from the instructor's perspective) was when the students did presentations to teach each other. See attached syllabus.

Earth's Critical Zone Syllabus

Geog 5100-005, Fall 2008

Instructor: Suzanne P. Anderson (tel: 2-7071, suzanne.anderson@colorado.edu)

Office hours by appointment on main campus or east campus

Class meeting time and place: 9-12 Fridays, Guggenheim 201E

Objectives

The Critical Zone is the near-surface region of Earth that supports life. This region was highlighted in a National Research Council report in 2001 as deserving focused research attention using interdisciplinary tools. This course is intended to introduce you to the CZ, and outline research frontiers on CZ topics. The material we will cover draws on numerous disciplines from geophysics to microbiology, from geology to hydrology. We'll find that we must span timescales from seconds to millions of years, and spatial scales from nanometers to kilometers. The goal is to help you see new connections, and perhaps see your own discipline within a new light.

Class structure

We will have a weekly three-hour block of time in which to explore processes that shape and control function of the Critical Zone. Class time will be a mixture of lecture, discussion of readings, and student presentations. Although the specifics may vary each week, the aim is to begin with an approximately 45 minute lecture, take a 10 minute break, spend 15-20 minutes on student presentations, and the remaining class time discussing papers assigned for the week. Ideally we discuss journal articles the week following the introduction of the topic, so topics may be staggered throughout the semester. I have several guest lecturers scheduled throughout the semester to introduce topics they specialize in.

Evaluation

Two major assignments for the semester are:

- 1) Class presentation on an aspect of CZ development or function. These will be scheduled throughout the semester, so sign up for a timeslot that works with your schedule.
- 2) Term paper and presentation on topic of choice. Term paper topic must be approved by October 17.

To promote interdisciplinary scholarship, one of these projects should be on a topic that is largely new to you, and the other may be on a topic closely allied with your current interests.

In addition, students are expected to read material for each class and to engage in discussion. I will give mini-reporting assignments to some students each week.

Grades: 40% participation, including mini-assignments; 20% in-class presentation; 40% term paper

Reading materials will be posted on the class website on CULearn. The reading list is still evolving, so please refer to the website for the most up-to-date version. These papers are your introduction to topics, your invitation to dig deeper.

Lecture and reading schedule:

- Aug 29 What is the CZ? History of the concept, and anatomy of the CZ
NRC (2001); Brantley et al. (2007); Wilding and Lin (2006); Paola et al. (2006)
- Sept 5 Subsurface structure: geophysical imaging (Anne Sheehan)
Burger et al. (2006), chapter 1; Schrott and Sass (2008); Anderson et al. (2002); late addition of local interest: Leopold et al. (2008)
- Sept 12 Betasso field trip: hands on weathered and unweathered rocks and soils
Dethier and Lazarus (2006); Isherwood and Street (1976); Dominguez-Villar et al. (2008)
- Sept 19 Deep time perspective: How tectonics affects landscapes, and geologic history of the Front Range (Bob Anderson)
Bishop (2007); Dickinson et al. (1988); Anderson et al. (2006)
- Sept 26 Erosion and landscape evolution- slope processes and regolith production
Gilbert (1909); Minasny et al. (2008); Roering et al. (2002); Wilkinson and Humphreys (2005)
- Oct 3 Erosion and landscape evolution- modeling (Greg Tucker)
Istanbulluoglu et al. (2005); Whipple (2004); Tucker and Hancock (in prep)
- Oct 10 Weathering front advance?the more physical processes
Molnar et al. (2007); Fletcher et al. (2006); Matsuoka and Murton (2008)
- Oct 17 Weathering front advance?the more chemical processes (Alex Blum)
Eggler et al. (1969); White et al. (2001); Blum and Hellmann (in review)
- Oct 24 Hydrology- processes (Mark Williams)
Dunne (1983); Manning and Caine (2007); Liu et al. (2004); Williams et al. (2006)
- Oct 31 Hydrology- models
Ebel et al. (2007a, 2007b)?the first one is background, focus on 2nd; Kirchner (2003); Kirchner et al. (2001)
- Nov 7 Biogeochemical cycles
Hedin et al. (2003); Chorover et al. (2007); Derry and Chadwick (2007)
- Nov 14 Organic carbon, nutrient spirals, and biogeochemical hotspots (Diane McKnight)
Cory & McKnight (2005); Cory et al. (2007)
- Nov 21 Roots and fungi
Gabet et al. (2003); McCulley et al. (2004); Danjon et al. (2008)
- Nov 28- Thanksgiving holiday
- Dec 5 Microbial ecology (Noah Fierer)
Landeweert et al (2001); Leake et al. (2004); Newman and Banfield (2002)
- Dec 12 Final student presentations
- Dec 13 9:00 am: More final student presentations

Outreach Activities:

Year 2: 1 Sept 2008-31 August 2009

-A mock stakeholder workshop was conducted with about 40 undergraduate students from ENV5 (Environmental Studies) and CEAE (Civil, Environmental and Architectural Engineering). The students were asked to represent a number of stakeholder groups including City of Boulder, Boulder Open Space, Boulder Flycasters, Trout Unlimited, the Colorado Department of Wildlife. Each group was asked to present key issues with regards to the potential impact of didymo and their recommendations for action. The workshop discussion was facilitated by James Cullis.

-Six undergraduate student groups, representing about 20 students, prepared reports on various impacts of *D. geminata* ranging from hydrologic factors affecting distribution to the composition of sediment trapped in the mats. Advice and guidance was provided by Aimee Mc Laughlin.

-Fluorescence Workshops were hosted at INSTAAR in November 2008 and on the 8th and 9th June 2009, each with about 12 participants. The November workshop was specifically designed for CZO participants, and instigated cross-CZO comparison of DOC.

-CU press release on Didymosphenia research was picked up by the Boulder Daily Camera, and published on May 13, 2009 (see Findings section for a copy). This information is also featured in a ?Science Spotlight? on the INSTAAR home page, see http://instaar.colorado.edu/research/science_spotlights.html#rsi.

-Suzanne Anderson has a Critical Zone unit in her freshman level course (required for Geography majors and fills a science requirement for other students) called Landscapes and Water.

-Suzanne Anderson gave presentations about the Critical Zone to:
 CSDMS Terrestrial Working Group meeting
 Colorado State University geosciences department
 University of Puget Sound chemistry department (Retirement symposium)

-Flyers and posters were developed for the Fall AGU meeting.

Journal Publications

Anderson, S.P., Blum, A.E., Dethier, D.P., Murphy, S.F., Williams, M.W., McKnight, D., Fierer, N., Tucker, G., Wobus, C., Anderson, R.S., Caine, N., Loague, K., Leopold, M., Voelkel, J., and Sheehan, A., "Developing Methods to Test the Influence of Critical Zone Development on Watershed Hydrology and Biogeochemistry", *Eos Trans. AGU, Fall Meeting Supplement*, p. Abstract, vol. 88, (2007). Published,

Riggins, SG, Anderson, SP, and Blum, AE, "Transformations across the bedrock/saprolite-regolith boundary", *Geochim. Cosmochim. Acta Suppl.*, p. , vol. , (2008). Accepted,

Anderson, SP, Anderson, RS, and Riggins, SG, "Fractures and the weathering front", *Geochim. Cosmochim. Acta Suppl.*, p. , vol. , (2008). Accepted,

Anderson, S.P., Bales, R.C., and Duffy, C.J., "Building a network to advance interdisciplinary study of Earth surface processes", *Mineralogical Magazine*, p. , vol. , (2008). Accepted,

Ward, D. W., Anderson, R. S., Briner, J. P., and Guido, Z.S., "Signatures of glacial erosion and retreat in the Front Range landscape: cosmogenic and numerical modeling constraints", *Journal of Geophysical Research- Earth Surface*, p. , vol. , (2008). Submitted,

Wobus, C., G. E. Tucker and R. S. Anderson, "Cenozoic incision of the North American High Plains: Topographic re-analysis and the possible role of climate change", *Geological Society of America Abstracts with Program*, p. , vol. , (2008). Submitted,

Dethier, David P., and Bove, Dana J, "Slow weathering of granitic rocks and the low-relief landscape of the Boulder Creek catchment, Colorado", *Geological Society of America Abstracts with Programs*, p. 108, vol. 39, (2007). Published,

Leopold, Matthias, Dethier, David, Voelkel, Joerg and Raab, Thomas, "Combining sediment analysis and seismic refraction to describe the structure, thickness and distribution of periglacial slope deposits at Niwot Ridge, Rocky Mountains Front Range, Colorado, USA", *Annals of Geomorphology*, p. 77, vol. 52, Sup, (2008). Published, 10.1127/0372-8854/2008/0052S2-0077

Leopold, Matthias, Dethier, David, Voelkel, Joerg, Raab, Thomas, Corson-Rickert, Tyler and Caine, Nel, "Using geophysical methods to study the shallow subsurface of a sensitive alpine environment, Niwot Ridge, Colorado Front Range, USA", *Arctic, Antarctic, and Alpine Research*, p. 519, vol. 40, (2008). Published, 10.1657/1523-0430(06-124)[LEOPOLD]2.0.CO;2

R.T. Jones, M.S. Robeson, N. Fierer, "Moving beyond 'species' richness: phylogenetic comparisons of fungal and bacterial communities in soil", *ISME Journal*, p. , vol. , (2008). Submitted,

C.L. Lauber, M.S. Strickland, M.A. Bradford, N. Fierer, "The influence of soil properties on the structure of bacterial and fungal communities across land-use types", *Soil Biology & Biochemistry*, p. , vol. , (2008). Accepted,

Anderson, S.P., von Blanckenburg, F., and White, A.F., "Physical and chemical controls on the critical zone", *Elements*, p. 315, vol. 3, (2007). Published,

- Huber, J., Voelkel, J. and Leopold, M., "Periglacial slope deposits and saprolites controlling water discharge ? results from a three years measurement on a test site in the Bavarian Forest, Germany", Geophysical Research Abstracts, p. EGU2008-A, vol. 10, (2008). Published,
- Leopold, M., Voelkel, M., Dethier, D. & Raab, T., "Combining geophysical methods and drillings to study the shallow subsurface of a sensitive alpine environment, Niwot Ridge, Colorado Front Range, USA.", Geophysical Research Abstracts, p. EGU2008-A, vol. 10, (2008). Published,
- Leopold, M., Dethier, D. & Voelkel, J., "Near surface geophysics and sediment analysis to precise the outburst of glacial Lake Devlin, Front Range Colorado, USA", Eos Trans. AGU, Fall Meeting Supplement, p. Abstract, vol. 88, (2007). Published,
- Lutterschmid, E., Placht, S., Huber, J., Roeder, J., Huerkamp, K., Leopold, M., and Voelkel, J., "Classification of subsurface sediments to assess the importance of slope deposits and saprolites within the critical zone (Bavarian Forest, Germany)", Geophysical Research Abstracts, p. EGU2008-A, vol. 10, (2008). Published,
- Voelkel, J., Raab, T. and Leopold, M., "Stratigraphy, material characteristics and dating of periglacial slope deposits as a crucial element of the critical zone", Geophysical Research Abstract, p. EGU2008-A, vol. 10, (2008). Published,
- Voelkel, J. Huber, K. Huerkamp and E. Lutterschmid, "Regolith and Saprolite as crucial elements within the Critical Zone", Geophysical Research Abstracts, p. EGU2008-A, vol. 10, (2008). Published,
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Books or Other One-time Publications

- Hill, Ken, "Hydrologic and hydrochemical response to 25 years of climate change, Green Lakes Valley, Colorado", (2008). Thesis, Published
Bibliography: M.A. Thesis, University of Colorado at Boulder
- Nielson, Ashley, "The hydrology and hydrochemistry of an alpine wetland, Green Lakes Valley, Colorado", (2008). Thesis, Published
Bibliography: M.A. Thesis, University of Colorado at Boulder
- Miller, Matthew, "Interactions between hydrology, dissolved organic matter, and algal populations in the headwaters of Boulder Creek", (2008). Thesis, Published
Bibliography: Ph.D. dissertation, University of Colorado at Boulder.
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Bibliography: Undergraduate senior thesis, Williams College, 102 pp.
- McLauhlin, Aimee, "The impact of the growth of *Didymosphenia geminata* on macro-invertebrates in Boulder Creek", (2009). Thesis, To be submitted July, 2009.
Bibliography: MA thesis in Environmental Science, University of Colorado.
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Thesis, Published

Bibliography: MA thesis, Environmental Science, University of Colorado

Ianniello, Richard S, "Effects of Simulated Flood Disturbance on *Didymosphenia geminata*", (2009). Thesis, Published

Bibliography: University of Colorado, Senior honors thesis in Environmental Science

Bonilla, F. E. A., A. Sheehan, and G. Tucker, "Terrestrial Laser Scanning Study of Gully Erosion at West Bijou Creek, Arapahoe County, Colorado: An Investigation on Field Acquisition and Data Processing", (2009). Abstract, Published

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Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-2508.

Wobus, C.W., Tucker, G.E., and Anderson, R.S., "Cenozoic incision of the North American High Plains: topographic re-analysis and the possible role of climate change.", (2008). Abstract, Published

Bibliography: Geological Society of America, Abstracts with Programs

DM McKnight, MP Miller, SC Chapra, and MW Williams, "A model of degradation and production of three pools of dissolved organic matter in an alpine lake", (2009). Abstract, Published

Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-13374

M. Williams, K Hill, N Caine, and J Janke, "Climate impacts on the hydrology of high elevation catchments, Colorado Front Range", (2009). abstract, Published

Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-6387

M. Williams and D. McKnight, "Scientific Outreach for K-6 Students: The LTER Schoolyard Children's Book Series", (2009). Abstract, Published

Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-14047

Web/Internet Site

URL(s):

<http://czo.colorado.edu/>

Description:

Other Specific Products

Contributions

Contributions within Discipline:

The Boulder Creek Critical Zone Observatory takes an interdisciplinary approach to understanding the structure and function of the region at the Earth's surface (known as the critical zone) where air, water, rock, and life interact. Our observatory spans three distinctive erosion regimes in which the rate and history of removal of material from the 'reactor' of the critical zone varies. We posit that these differences in erosion will be manifested in differences in the depth and development of the weathered rock profile. Simply posing the conceptual model of weathered profile development in terms of interplay between erosion and weathering front advance constitutes an advance of the science.

The project has brought together team scientists from geomorphology, geophysics, biology, geography, and engineering to think in a unified way about the critical zone.

Contributions to Other Disciplines:

The Boulder Creek CZO has provided support to others working on instrument development (COSMOS soil moisture) and cyberinfrastructure (Purdue DataNet). To date, our support has not come to fruition.

Contributions to Human Resource Development:

We are providing the research context for a group of undergraduate students for the Keck Geology Consortium in summer 2008 and summer 2009. A group of 4 undergraduates from across the country will learn about the critical zone and will undertake senior research projects rooted in the Boulder Creek CZO.

PI Suzanne Anderson teaches about the critical zone in her large, freshman level physical geography class titled Landscapes and Water. The majority of these students are non-science majors for whom this course may be their sole training in college level science.

Contributions to Resources for Research and Education:

We are augmenting the meteorological instrumentation of the Niwot LTER Green Lakes Valley site, and adding soil instrumentation (moisture, temperature, hydraulic head, and soil water samplers) to this heavily studied valley.

We are developing two entirely new watershed field sites in Gordon Gulch and Betasso. This entails first developing an understanding with the landowners (USFS, County and City of Boulder). Each watershed will be instrumented with stream gauges, soil instrumentation, and meteorological instrumentation.

PI Anderson is expanding her water analysis lab to handle the regular field sampling and parts of the analyses for CZO samples. The lab now occupies more space at INSTAAR, and is being reorganized to act as a hub of field activity for the project. The lab is run by the CZO field and lab technician, Zan Frederick.

We are in the process of establishing a data management system for the research community.

Contributions Beyond Science and Engineering:**Conference Proceedings****Special Requirements****Special reporting requirements:****Data Access and Standardization:**

We are in the process of searching for a data manager for the Boulder Creek CZO. Our data collection systems are just becoming established in summer of 2008. For the present, our data is stored and available through the Niwot Ridge LTER.

Discussions have been ongoing with the Sierran CZO and the Susquehanna CZO about how they will establish their data management systems. Significant progress will come when we all have data managers on-board.

Annual Meetings:

The first annual CZO science meeting will be held in September 2008 at the Sierran CZO. We have requested supplemental funding that includes support for non-hosting CZO members to attend this meeting.

Steering Committee (SC):

A national Steering Committee has been established. Five distinguished scientists have accepted membership on the committee, and the first meeting of the group will take place at the first annual CZO science meeting in September 2008.

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Product

Contributions: To Any Beyond Science and Engineering

Any Conference

Project Activities

Boulder Creek Critical Zone Observatory

Goals and objectives

The Boulder Creek CZO is designed to study how weathering and erosion processes together form the critical zone and affect its structure. Three focus field sites are situated in crystalline bedrock regions within the Boulder Creek watershed, each representing different erosional rates and histories. The CZO will undertake activities to understand the differences across these sites in CZ architecture, erosion rates, and in hydrologic-geochemical-ecological function. This understanding will be built into models of landscape evolution, hydrology and geochemical processes. We also seek to build cross-disciplinary bridges in Critical Zone study, and to engage a broad community participation in working and thinking about the CZ in this way.

Year 2: 1 Sept 2008-31 August 2009

Graduate students

Four graduate students recruited in year 1 (Eilers, Befus, Gabor and Cowie) are deeply engaged in research on microbial ecology, seismic refraction, dissolved organic carbon and hydrology, respectively. (One 2008 recruit, Kandel, left school. We have recruited 2 additional graduate students, who begin in Fall 2009. Jeana Lee starts in summer 2009, and hence is included in this report. The other, Abby Langston, will start in Fall 2009. In addition, students already at CU are contributing to CZO research (Cullis, Culp, Cooper, McLoughlin, McLaughlin).

Hydrological and meteorological monitoring in focus sites

Meteorological towers are now operating at two of three focus sites (Green Lakes Valley and Betasso). The Betasso tower is entirely new, while the Green Lakes Valley one is an LTER installation that we have augmented. We plan to have the Betasso tower data telemetered and streaming onto the web this summer. A third tower will be constructed at the old B-1 site (Mountain Climate Program), pending USFS approval. Instruments are in hand. Stream gauges are operating in all of our focus sites, with two gauges running in Gordon Gulch. Snow surveys were conducted in Green Lakes Valley and Gordon Gulch in late spring. R. Cowie and M. Williams established two snow stake lines in Gordon Gulch and monitored over winter. Two time-lapse cameras were established in GLV and GG to monitor snow cover, and in GLV to observe lake ice cover. Two vertical strings of temperature sensors (4 depths) were installed in GG on different aspect slopes. TidBit thermal dataloggers have been deployed at near surface depths in GLV and Betasso. Soil moisture and temperature sensors were installed in 5 soil pits in GLV in late summer 2008, and are being connected to dataloggers in early summer 2009. Similar sensors are being installed in GG in June 2009, and will be placed in Betasso in July or August 2009. Soil water samplers will be installed in summer 2009. Weekly runoff sampling continues at all focus sites. Additional sampling sites on Boulder Creek were established for the summer.

Soil and Rock Sampling

In Green Lakes Valley R.S. Anderson and M. Duhnforth collected samples of glaciated bedrock for documentation of the deglaciation history of the valley following the LGM

(see Ward et al., 2009). As well, moraine samples will aid in constraining the timing of the LGM. A dozen ^{10}Be samples have been in the queue at the PRIME lab in Purdue since March 2009.

In early summer 2009, R.S. Anderson and M. Duhnforth gained access to a soil pit dug by the NEON team on Table Mountain north of Boulder. This is one of several major smooth pediment surfaces that bound the mountain front, and records a time at which a local stream system (likely Lefthand Creek) debouched coarse sediment from the mountain front. As the surface is ~100 m above the modern stream, dating this surface would document mean rates of lowering of the stream valley, analogous to that in Boulder Creek immediately to the south. We collected a suite of eight ^{10}Be samples from the pit, which we will assess for both in situ produced ^{10}Be and meteoric (garden variety) inventories. These should independently constrain the age of the surface and hence place one more constraint on the incision of the high plains adjacent to the mountain front. This in turn controls the baselevel history of our Boulder Creek system. The samples are presently being processed to generate targets for sending to the PRIME lab.

A.E. Blum and S.P. Anderson sampled soil profiles in Betasso, and plan to sample soils in all three subcatchments in summer 2009. Analyses of mineralogy (quantitative XRD) are underway, and elemental analysis will follow. New graduate student J. Lee will work to sample soils along catenas in all three subcatchments this summer. A team of Blum, Anderson, Tucker and Lee will explore bedrock weathering profiles in roadcuts over the summer.

Bedrock coring

Obtained permission for drilling on Boulder County Open Space, and will proceed with bidding and drilling of two deep cores at Betasso in summer 2009. These will be finished as wells for monitoring the regional water table. We will undertake downhole geophysics to help ground truth the geophysical surveys.

Microbial ecology

K. Eilers and N. Fierer are planning to collect soil samples from Gordon Gulch in late June-early July 2009 to examine microbial distribution patterns at a watershed scale. The surface soil sampling grid will be anchored with about 10 soil pits, which will be sampled and analyzed by A. Blum, S.P. Anderson and J. Lee for mineralogy, and R Gabor for DOC. Vegetation surveys will be conducted by R. Cowie. An REU student will be engaged in this study.

Eilers and Fierer have been designing and setting up a microbial mineral weathering experiment that will run in winter 2009-10.

Didymosphenia geminata

The McKnight group is:

-collecting water and periphyton samples at nine study sites in Boulder Creek to investigate the hydrologic factors affecting the growth of the nuisance diatom

Didymosphenia geminata.

- processing periphyton and macro-invertebrate samples from summer 2008 to investigate interactions between macro-invertebrates and *D. geminata*.
- developing 1D and 2D hydraulic models of study sites to investigate the impact of key hydraulic parameters such as depth, velocity, shear stress and bed disturbance on variations in the growth and removal of *D. geminata*
- Analyzing samples from Boulder Creek to determine the impact of Barker Reservoir and other potential point sources for DOC

Geophysical surveying

Leopold and Volkel spent several weeks in the field in the late summer 2008 and 1.5 weeks in early May 2009. Their main efforts were electric resistivity tomography (ERT) in the field (~ 2 km of lines) testing different array types and collecting final data. In summer 2009 they want to combine geophysical data with field observations from Betasso (mapping bedrock outcrops) to develop a first 3D-image of the CZ at Betasso. Anne Sheehan and Kevin Befus will add seismic data to complete the image. They plan fieldwork in August 2009 to collect data in Green Lakes and Gordon Gulch (ERT and GPR).

Sheehan and Befus analyzed seismic refraction data collected summer 2008 in Betasso and Green Lakes Valley subcatchments. Collected electrical resistivity data at Gordon Gulch. Planned 2009 field season, now underway. A crew of undergraduate assistants has been hired, trained, and they are actively working on the data collection and analysis. They collaborated with Matthias Leopold on collection of electrical resistivity data in Betasso May 2009. P and S wave refraction data collected at Betasso June 2009 along lines shown in figure below. Gordon Gulch seismic surveys will be done in July 2009, and Green Lakes Valley in August 2009. Analysis using SeisImager/2D software. Literature review and discussion with experts about shallow surface wave analysis, and S wave refraction. Began surface wave data collection and analysis. Map of seismic refraction lines completed at Betasso, summer 2009.



Modeling

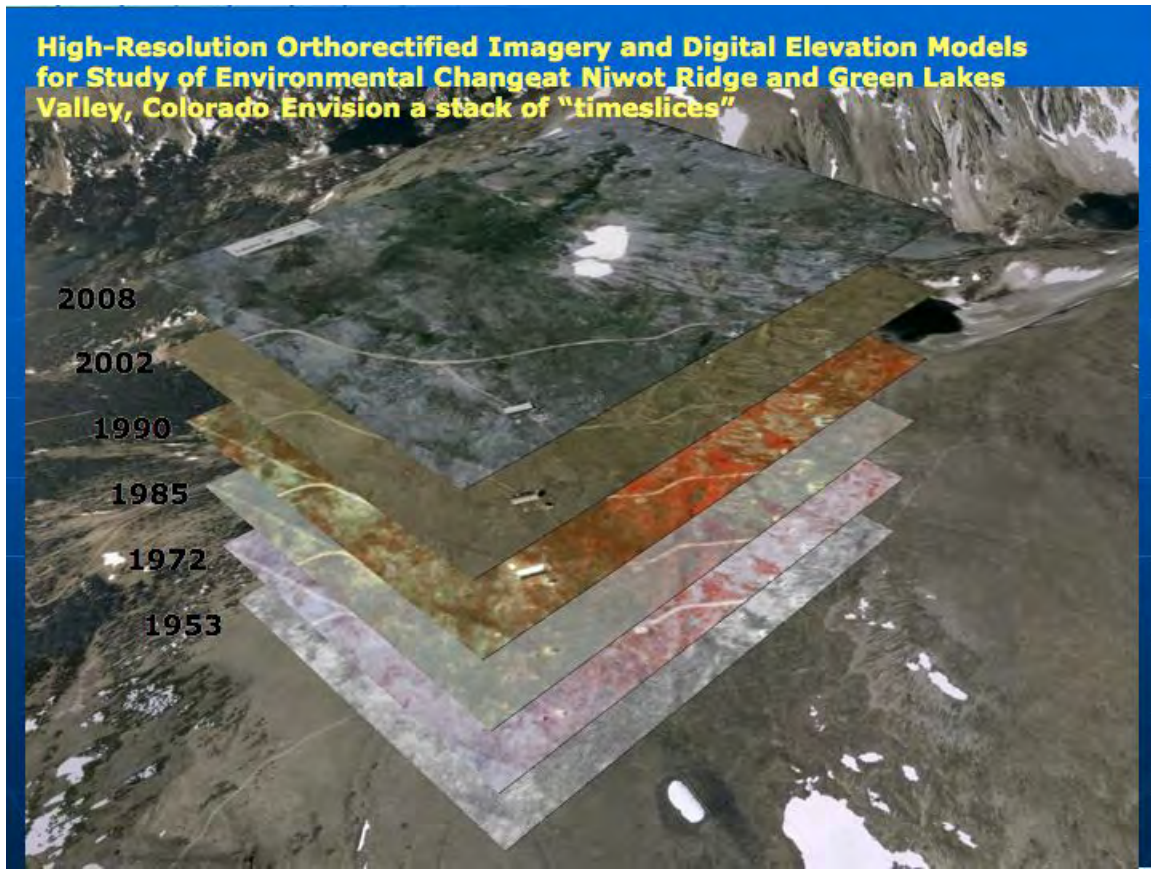
We are continuing to develop long-term landscape evolution simulations using both a 1D river-profile model and a 2D whole-landscape model (the Channel-Hillslope Integrated Landscape Development [CHILD] model). These simulations are targeted toward several related questions: (1) Are there diagnostic differences in river-profile morphology and erosion/sedimentation patterns between scenarios that involve tectonic forcing (e.g., regional tilting) versus various forms of climatic forcing (e.g., changes in amount/pattern of water discharge, changes in sediment delivery)? (2) Given our current understanding of drainage basin dynamics, what type of post-orogenic geomorphic development is predicted for a Front-Range-type uplift and its adjacent sedimentary basin? (3) Are there computational scenarios that can account for the observed mountain-range topography and pattern of fluvial deposits and unconformities in the adjacent piedmont?

We have developed a prototype particle-based model of regolith development and hillslope erosion/transport. The model is intended to provide a template for formulating and testing mechanistic hypotheses for critical-zone formation and evolution, and for comparison with field data.

High-resolution imagery

INSTAAR's Quaternary GIS lab, run by Bill Manley, is acquiring and orthorectifying high resolution images of our focus subcatchments. Orthophoto mosaics date back to 1953 (and earlier imagery is available), many with resolutions up to 30 cm. This resolution is sufficient to observe spatial changes in vegetation, surface water, and mass disturbances of the surface (debris flows, landslides, etc). The Niwot Ridge imagery (Green Lakes Valley is the adjacent basin and is included in the coverage) was released in June 2009, a project that was done in collaboration with the Niwot LTER. Work will begin on Gordon Gulch and Betasso when we decide on the best course for acquiring the DEM needed for the orthorectification. See <http://instaar.colorado.edu/QGISL/> for the June 2009 release.

This data release consists of orthorectified digital photography – as well as Digital Elevation Models (DEM's) and other map layers – for the Niwot Ridge Long-Term Ecological Research (LTER) Site and the Green Lakes Valley portion of the Boulder Creek Critical Zone Observatory (CZO). The high-resolution imagery and data will be useful for a variety of environmental research, including time-series analysis of climate-related changes in vegetation, hydrology, geomorphology, etc. The datasets should also be useful for visualization, mapping, modeling, and other objectives tied to science planning, land management, research, education, and outreach.

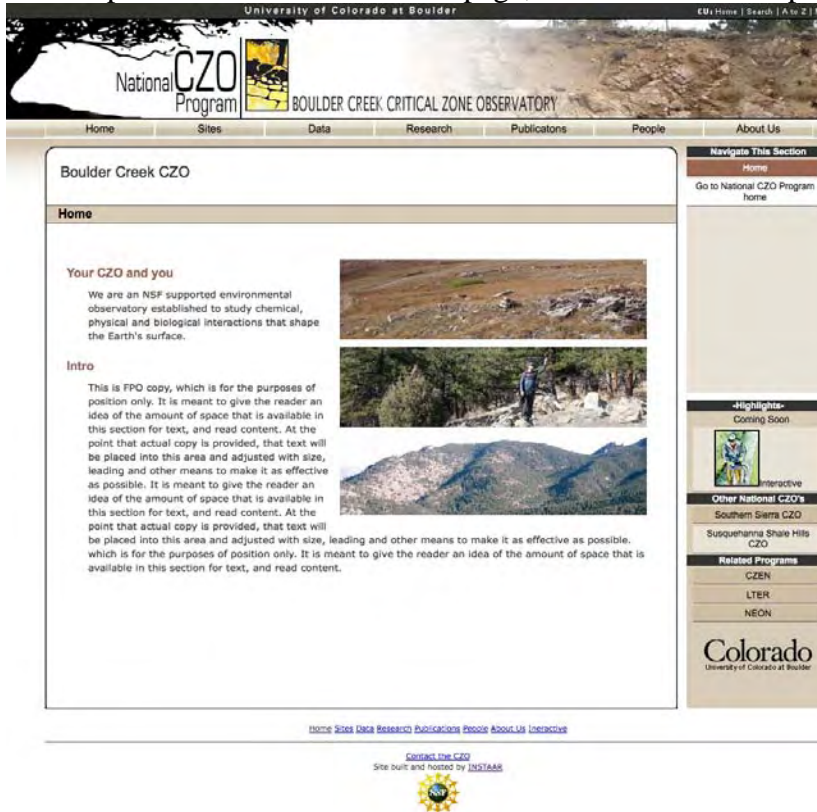


The ten "timeslices" of orthophoto mosaics have a resolution of 0.3 m to 1.0 m and encompass the past five decades. Previously orthorectified imagery was obtained from various sources for years 2008, 2006, 2005, 2004, 2002, and 1999. Imagery was also orthorectified from historic aerial photography for years 1990, 1985, 1972, and 1953. Each high-resolution image has the qualities of a photograph and the functionality of a map layer for use in Geographic Information Systems (GIS) or remote sensing software. Digital scans of the historic photography were fully orthorectified in Leica Photogrammetry Suite (LPS) at INSTAAR, University of Colorado, using air-photo camera models, a 2 m DEM, information from calibration reports, and image-to-image control points linked to the 2008 reference imagery. Horizontal errors (RMSE) average 1.6 m, relative to the 2008 mosaic. The images are provided in georeferenced .tif (GeoTIFF) format, accompanied by pyramid files (.rrd) generated by ArcGIS. The orthophoto mosaics carry a resolution and accuracy as good or better than satellite imagery; they provide a time series for detailed analysis of environmental change through time.

Collaboration/communication/education

-Website: czo.colorado.edu is being reformatted to have same look and feel as other CZOs. Boulder established the templates for these websites, and developed logos for the Boulder CZO and the National CZO program.

Mock-up of new Boulder CZO webpage, with national CZO program logo.



-An interactive web page (below) has been developed to demonstrate CZO field activities, and will be activated summer 2009. This diagram shows, in one image, the many different projects that CZO scientists are engaged in, and how these projects relate to the environment of the field sites and to each other. This web page was developed to stimulate interest and inform different audiences about the CZO. The interactive page shows the science from a human perspective; for example, the collection of geophysics data is collected is shown by a woman hammering a strike-plate, connected to a string of geophones. Clicking on any research activity takes the viewer to another webpage that contains detailed information about the goals of that research, graphs and diagrams about the data, preliminary findings, and contact information. The interactive webpage not only shows the activities of the researchers, but relays accurate environmental information about the site, including geology and soils, hydrology, trees, birds, and fish.

Mock-up of interactive web page

University of Colorado at Boulder

CU Home | Search | A to Z | Map

CZO
BOULDER CREEK CRITICAL ZONE OBSERVATORY

Pages

- CZO HOME
- Interactive Home
- This Section**
- Geomorphology
- Geophysics
- Meteorology
- Hydrology
- Stream Chemistry
- Soil & Weathering

test interactive

[Index](#) [Sites](#) [Pub](#) [Calendar](#) [Data](#) [People](#) [Opportunities](#) [Contact](#) [Interactive](#)

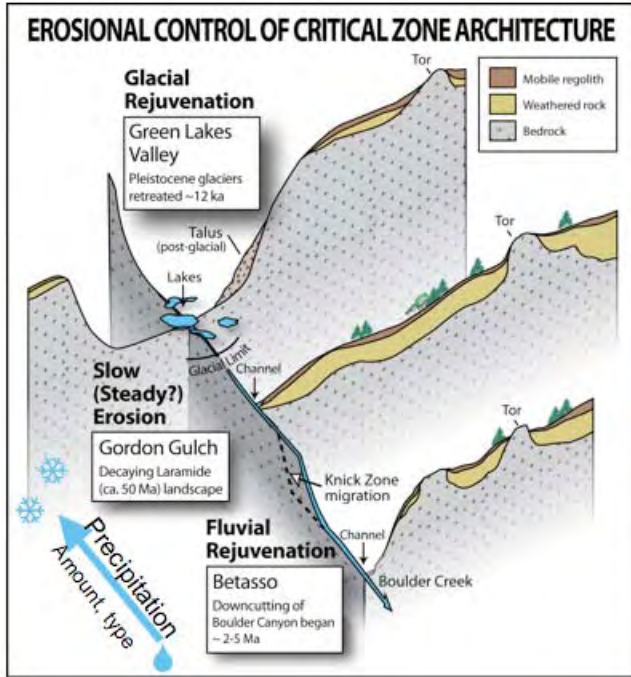
[Contact the CZO](#)

Copyright © 2008 University of Colorado
Site built and hosted by [INSTAAR](#)

Concept and scientific information by Sheila Murphy
Artwork and website design by Eric Parrish

-Produced flyer and poster on CZOs in collaboration with UC Merced and Penn State for AGU Fall meeting. A one page Boulder flyer was also produced (see below), and distributed in any appropriate setting (meetings, presentations, classes). Our flyer includes a schematic diagram of our conceptual model of the Critical Zone, developed in response to suggestions from the National CZO Steering Committee (see “Erosional Control of Critical Zone Architecture” in flyer below).

Boulder CZO flyer



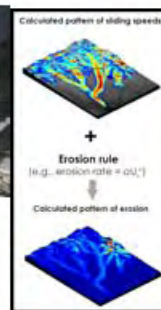
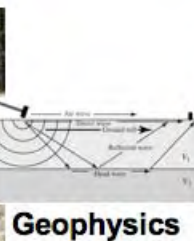
Boulder Creek CZO exploits three natural experiments in the Front Range of Colorado to study how erosion and weathering interact to produce differing critical zone architectures.

Science questions:
What is the legacy of long-term geologic history in the critical zone?

What governs the dynamics of key interfaces within critical zone architecture?

How do landscape position, slope aspect, microclimate and rock properties control the evolution of the critical zone?

What feedbacks govern the co-evolution of the CZ and its hydrologic and ecological function?



Want to be in?

See <http://czo.colorado.edu>. Contact: suzanne.anderson@colorado.edu



-Fall 2008 S.P. Anderson taught a graduate level course on Earth's Critical Zone, with 14 students enrolled from 5 departments.

-In August 2009, we will hold our second all-hands annual science meeting. The meeting is timed to occur when team members from Williams College and the Keck Geology Consortium undergraduate students are present. We plan to invite local researchers (mostly associated with the Niwot LTER) to join us to expand our connectivity.

-Established a national Steering Committee for all three CZOs. The Steering Committee members are: Gordon Grant, USFS; Carol Kendall, USGS; George Hornberger, Vanderbilt University; Lou Derry, Cornell University; David Furbish, Vanderbilt University.

-Mark Williams and Suzanne Anderson attended the First Annual National CZO Science Meeting, held at Shaver's Lake, California in September 2008.

-Hosted a Fluorescence Workshop for scientists involved in the CZO network. Workshop was held at INSTAAR in November (see attached report at end of this activities report). Another workshop was held on the 8th and 9th June 2009, and was attended by scientists from 5 other universities, one of which is involved in a potential new CZO project.

Proposals

Participant in European Union call FP7-ENV-2009-1: Large-scale integrated project titled "Climate and management effects on life cycles in soils of mountainous ecosystems: SOILIFE". Proposal number 243981. Coordinator: Marco Marchetti, University of Molise, Italy. Budget (CU part): €300,154. Four year project, with start date in early 2010. Submitted Jan 8, 2009.

NSF-EAR 0922307 Acquiring Airborne Lidar data to study hydrologic, geomorphologic, and geochemical processes at three Critical Zone Observatories (CZO). PI: Qinghua Guo, UC Merced. Co-PIs: SP Anderson, Roger Bales (UC Merced), Chris Duffy (Penn State). \$675,446 (budget for UC Merced). 6/1/09-5/31/12. Submitted January 16, 2009.

NSF-EAR 0930048 Acquisition and upgrade of instrumentation for research on transport and reactivity of dissolved and particulate organic materials in soils, sediments and the atmosphere. PI: Diane McKnight. Co-PIs: SP Anderson, Natalie Mladenov, Mark Williams. \$113,054. 6/1/09-5/31/10. Submitted Feb 23, 2009.

NSF 0932799 "IDR: Understanding the Hydrologic Factors Affecting the Growth of the Nuisance Diatom *Didymosphenia geminata* in Rivers" PI: Diane McKnight, Co-PI: John Pitlick. Submitted to CBET: Environmental Sustainability on 03/02/2009.

Wrote letters of support for the following proposals:

Peter Raymond (Yale) proposal to NSF-EAR instrumentation to develop an automated DIC/DOC/CO₂ instrument for field deployment

Henry Lin (Penn State) proposal to NSF-EAR Hydrological Sciences to study preferential flow in diverse settings.

William Bowman (CU Boulder) facilities proposal to NSF to expand lab and teaching space at the Mountain Research Station.

Jérôme Gaillardet (Institut de Physique du Globe de Paris) EU Framework 7 proposal.

Steven Banwart (University of Sheffield) EU Framework 7 proposal titled “Soil Transformations in European Catchments (Soil TrEC)”.

Presentations

Anderson, Suzanne, “Boulder Creek Critical Zone Observatory” for CSDMS Terrestrial Working Group meeting, February 2, 2009.

Anderson, Suzanne, “Boulder Creek Critical Zone Observatory: A new approach to understanding the Earth's surface” Colorado State University, Geosciences Dept. Seminar series, February 9, 2009

Anderson, Suzanne, presentation at University of Puget Sound, Retirement Symposium for Dr. Ken Rousslang, April 19, 2009. Title: “Interdisciplinary science of Earth’s Critical Zone: Where rocks meet water, air and life”

Befus, Kevin; Sheehan, Anne; Leopold, Matthias; Volkel, Jorg, Geophysical Investigation of the Boulder Creek Critical Zone Observatory, Soil Crit Zone 3 Workshop, Poster presentation, September 5-9, 2008, Technical University of Crete, Chania, Crete.

Bonilla, F. E. A., A. Sheehan, and G. Tucker, Terrestrial Laser Scanning Study of Gully Erosion at West Bijou Creek, Arapahoe County, Colorado: An Investigation on Field Acquisition and Data Processing, Eos Trans. AGU,89(53), Fall Meet. Suppl., Abstract G53B-0635.

Cowie, R., Williams, M., and Anderson, S. (2009) Application of distributed fiber-optic temperature sensing to study surface/groundwater interactions in a mountain catchment. Poster Presentation: CU Hydrological Sciences Student Research Symposium, April 2009.

Cullis JDS, Miller M and McKnight D (2009) The impact of bed disturbance on the growth of the nuisance diatom *Didymosphenia geminata* in Boulder Creek, CO – Oral Presentation: NABS Annual Meeting, Grand Rapids, Michigan, April 2009

Cullis JDS, Miller M and McKnight D (2009) The impact of bed disturbance on the growth of the nuisance diatom *Didymosphenia geminata* in Boulder Creek, CO – Oral Presentation: CU Hydrological Sciences Student Research Symposium, April 2009.

- Cullis JDS (2009) "Understanding the Hydrologic Factors Affecting the Growth of the Nuisance Diatom *Didymosphenia geminata* in Rivers: Preliminary Results from Boulder Creek, CO" Oral Presentation at the 33rd IAHR 2009 Congress - Water Engineering for a Sustainable Environment, Vancouver, August 2009.
- Ianniello, R.S. (2009) "Effects of simulated flood disturbances on *Didymosphenia geminata*" Oral Presentation: CU Hydrological Sciences Student Research Symposium, April 2009.
- LEOPOLD, M., VÖLKEL, J. & DETHIER, D. (2009): Imaging the Critical Zone Using Ground Penetrating Radar and Electric Resistivity. Initial Results from the Boulder Creek Critical Zone Observatory. Geophysical Research Abstracts, Vol. 11, EGU2009-9450.
- McLaughlin A and McKnight D M "The effect of nuisance diatom growth on benthic macroinvertebrate communities" Poster Presentation at NABS Annual Meeting, Grand Rapids, Michigan, April 2009
- McLaughlin A and McKnight D M "The effect of nuisance diatom growth on benthic macroinvertebrate communities" Oral Presentation: CU Hydrological Sciences Student Research Symposium, April 2009.
- Mc Loughlin, R A, Gabor, R, and McKnight, D. "Characterization of water chemistry in the presence of *Didymosphenia geminata* in Boulder Creek" Oral Presentation at NABS Annual Meeting, Grand Rapids, Michigan, April 2009
- Mc Loughlin, R A, Gabor, R, and McKnight, D. "Characterization of water chemistry in the presence of *Didymosphenia geminata* in Boulder Creek" Oral Presentation: CU Hydrological Sciences Student Research Symposium, April 2009.
- VOELKEL, J., HUBER, J., HUERKAMP, K. & LEOPOLD, M. (2009): Periglacial slope deposits and saprolites controlling water discharge – critical zone characteristics in the Otterbachtal (Bavarian Forest, Germany) and the Boulder Creek CZO (Colorado Front Range, U.S.A.). Geophysical Research Abstracts, Vol. 11, EGU2009-2508.
- Williams, Mark, oral presentation at European Geophysical Union annual meeting, "A model of degradation and production of three pools of dissolved organic matter in an alpine lake ", April 22 2009, Vienna Austria. Filled in for Diane McKnight, who was not able to attend.
- Williams, Mark, Invited talk, European Geophysical Union annual meeting, "Climate change impacts on the hydrology of high-elevation catchments", April 20 2009, Vienna Austria.
- Williams, Mark, Invited talk, European Geophysical Union annual meeting, "Scientific

Outreach for K-6 Students: The LTER Schoolyard Children's Book Series", April 24 2009, Vienna Austria.

Williams, Mark, Keynote address, "The future of snow and the future of skiing in the Rockies", 2009 Spring runoff conference and intermountain meteorology workshop: "Climate Change and the Intermountain West: Downscaling the Future, Logan Utah, 2 April 2009.

Williams, Mark, Keynote speaker, workshop on "Evaluating current and future climate change impacts on the distribution of mountain plants in the Rocky Mountains and in the Alps: assessing differential sensitivity and testing the high-elevation refuge hypothesis", Lausanne Switzerland, Oct 5-11, 2008.

Wobus, C.W., Tucker, G.E., and Anderson, R.S., Cenozoic incision of the North American High Plains: topographic re-analysis and the possible role of climate change. Paper presented at the Geological Society of America annual meeting, October 2008

Summary of CZO Fluorescence/PARAFAC Workshop – November 10th & 11th 2008

Diane McKnight, Matt Miller, and Beth Boyer hosted a fluorescence and PARAFAC workshop on Monday and Tuesday November 10-11. The workshop primarily served as training for students and scientists working on or interested in working on projects involving dissolved organic matter (DOM) analyses at one of the three critical zone observatory (CZO) sites. In addition, one of the objectives of the workshop was to discuss the implementation of a CZO cross-site DOM monitoring program which will be lead by Matt Miller and Beth Boyer. There were a total of 15 participants listed below.

On Monday morning there were presentations related to background information on fluorescence spectroscopy, the usefulness/limitations of fluorescence in characterizing DOM in natural waters, and how to collect reliable fluorescence scans. Additionally, Beth Boyer gave a presentation on proper sample collection and handling. On Monday afternoon participants spent time in the Limnology and DOM labs at INSTAAR learning the laboratory techniques associated with collecting 3-dimensional fluorescence scans. There were then presentations on Tuesday morning that described the theoretical and statistical approaches used to develop the parallel factor analysis (PARAFAC) model. Finally, the rest of the day was spent teaching the participants how to use Matlab to correct fluorescence scans and subsequently fit the corrected scans to the PARAFAC model.

Throughout the meeting participants discussed how to most effectively implement the cross-site DOM monitoring program. In addition, plans were developed to construct a database of such data that would be useful to both CZO scientists and the broader earth science community.

List of Participants:

CZO participants

Elizabeth Boyer – Penn State University
Danielle Andrews – Penn State University
Carolyn Hunsaker – USDA Forest Service, CA
Suzanne Anderson- University of Colorado
Rachel Mcloughlin –University of Colorado
Rachel Gabor – University of Colorado
Bailey Simone –University of Colorado
Becca Barnes – USGS-Boulder

Non-CZO participants

Craig Allan – University of North Carolina-Charlotte
Joseph Needoba – Oregon Health & Science University
Alina Handorean – University of Colorado Health Sciences Center
Emily Leshner – Colorado School of Mines
Durelle Scott – Virginia Tech
Josh Koch – University of Colorado
Sabre Duren – University of Colorado

Project findings

Boulder Creek Critical Zone Observatory

Year 2: 1 Sept 2008-31 August 2009

Theses

Two MA theses completed under the direction of Diane McKnight on *Didymosphenia geminata* in Boulder Creek. Rachel McLoughlin studied the impact of variations in dissolved organic matter on *Didymo* populations over the course of seasonal discharge variations. She found few significant relationships between the variables. Aimee McLaughlin studied the impact of *Didymo* populations on macro-invertebrates in four sites in Boulder Creek over summer 2008.

Undergraduate theses

Ianniello, Richard S “Effects of Simulated Flood Disturbance on *Didymosphenia geminata*” Senior Honors thesis in Environmental Science. University of Colorado, May 2009.

Burass, E., 2009, Getting water into the ground and to the channel, Gordon Gulch, Colorado. Williams College senior honors thesis (Geosciences), supported by this project.

Sand-rich soils in upper Gordon Gulch have morphology typical of Holocene development and have high infiltration rates measured in the field using a double-ring infiltrometer. Roads, trails and other disturbed surfaces in the area are compact and have low infiltration rates. Simple hydrologic models suggest that rainfall intensity typical of a 100-year recurrence interval will generate surface runoff only from disturbed areas and possibly from areas near channels, depending on antecedent moisture.

Gannaway, E., 2009, Fracture control of glacial erosion within Green Lakes Valley, Front Range, Colorado, Suwanee University senior honors thesis supported through Keck Geology Consortium.

Evey Gannaway studied the distribution of fractures in an extensive area of bedrock scoured by latest Pleistocene glaciers near Green Lakes 3 and 4, in the Boulder Watershed. Fractures produced by tectonism (Molnar et al., 2007) and local stresses (Selby, 1980) play a central role in weathering, in preparing rock for erosion and in groundwater recharge and flow, but regolith masks fractures in most areas. By measuring fractures and their orientation on 30 traverses, Gannaway demonstrated that fracture spacing has a mean value between about 0.5 and 1.0 m (n= 786) and that spacing varies depending on rock type and location in the basin. Fracture spacing in the foliated biotite gneiss and metasediments mainly reflects the influence of rock fabric but there are also zones of more widely spaced fractures. In the massive Silver Plume Granite, fractures are closely spaced (0.00 to 0.50 m) within the topographic step between Green Lakes 3 and 4; fracture spacing is wider at the top of the step. Data from Gannaway’s reconnaissance study provide a sound basis for estimating the scale of blocks available for glacial quarrying and for rockfall, but do not suggest any simple control for local fracture density.

Nelson, K., 2009, Characterization and comparison of weathering profiles within Betasso catchment, Front Range, Colorado (Macalester College senior honors thesis in Geology, supported by Keck Geology Consortium)

Nelson's research involved characterizing soils developed in colluvial deposits and bedrock along a catena in Betasso gulch and laboratory measurements of soil properties. Calibrated ^{14}C ages from two sites in a buried soil show that colluvial deposition isolated the soil from exchange with the surface by between 8400 and 9000 yrs BP. Chemical and physical characteristics of the overlying Holocene soil, including clay concentration, mineralogy and CBD-extractable Fe suggest that the buried soil developed over a period of at least tens of thousands of years, probably under the influence of a different climate (Birkeland et al., 2003). Upslope from the colluvial deposits, saprolitic bedrock is exposed close to the surface. Field and some laboratory characteristics suggest that soils on the saprolite are old, perhaps developed during hundreds of thousands of years of weathering *in-situ* and slow downslope transport as mobile regolith. Kaolinite and smectite are the dominant clay minerals, formed by the weathering of feldspar and mica. Smectite concentrations generally decrease and kaolinite increase upwards in the weathering profile. Smectite is not present in any modern A horizons and was found in only one modern B horizon. Measured trends imply that smectite is unstable near the surface in the modern temperate/semi-arid climate (Brady, 1974; Moore and Reynolds, 1997). Quantifiable amounts of smectite in the Ab and Bb horizons at the colluvial site suggest that the late Pleistocene/early Holocene climate was wetter than that of today. Soil chemical characteristics, however, generally indicate that eolian deposition and physical weathering are more significant than chemical weathering in this relatively dry environment.

Rodrigues, M., 2009, Apatite in the soils of Betasso Preserve, Colorado (Colgate College senior honors thesis in Geology, supported by Keck Geology Consortium)

Rodriguez measured the concentration and effects of weathering on apatite, generally the primary source of ecosystem phosphorus (Penn, 2005), in the Betasso catchment. He also collected rock and sediment samples for phosphorus analysis, on a reconnaissance basis, at locations in the Gordon Gulch and Green Lakes catchments. Rodriguez separated and concentrated apatite and other heavy minerals using heavy liquid techniques and hand-picked the apatite grains. Bulk samples also were analyzed for total phosphorus using ICP-MS techniques. Rodriguez's results from Betasso show that apatite concentrations in soils and unweathered colluvial deposits range from 0.10 to 0.27 weight percent. Concentrations are lowest in a soil profile buried in early Holocene time, which may reflect changes in parent material or weathering (Banfield and Eggleton, 1989). SEM morphology of the apatites does not appear to show any depth-related trends, suggesting that if weathering is significant it must involve chemical dissolution of the apatite. Total phosphorus concentrations increase in the soil profile where apatite concentrations decrease. If chemical weathering controls this pattern, phosphorus may have been released from apatite and adsorbed by clays and $\text{FeO}(\text{OH})_x$ compounds.

Betasso regolith

The Betasso catchment, which has undergone significant baselevel lowering in the last 2-5 Ma, has pockets of deep colluvium (hillslope sediment) in its headwaters. These deposits are missing in the lower parts of the catchment, closest to the influence of Boulder Creek downcutting. The colluvial fill is currently being incised by gullies. One of these gullies exposes 4 m of colluvium, within which is a buried soil. A bulk

radiocarbon date on the buried A horizon, obtained by D. Dethier in his work with K. Nelson, returns an early Holocene date. There is an A horizon found at the top of this exposure as well. The geologic history then reveals periods of accumulation of hillslope sediment, punctuated with periods of low accumulation during which soils develop. This very preliminary finding is driving our geophysical surveying efforts, study of soils, and geomorphic modeling.

Didymosphenia geminata

The nuisance diatom *Didymosphenia geminata* has shown rapid growth in Boulder Creek since the 2002 drought. If unchecked, *Didymo* can cover a stream bed and prevent growth of other algae species that support insects and fish. A team led by Diane McKnight has shown that hydraulic controls can keep *Didymo* blooms in check. This work was published in 2009 in *Hydrobiologia* (Miller et al.). The team is continuing to monitor *Didymo* and water conditions, and to develop 2-dimensional flow and transport model to determine the bed disturbance and/or hydraulic conditions needed to control *Didymo*. See attached article published in the Boulder Daily Camera newspaper.



CU research could reduce 'rock snot' in Boulder Creek

Scientists say heavy flow can reduce the slippery algae

By Brittany Anas

Wednesday, May 13, 2009

BOULDER, Colo. — University of Colorado researchers have found a way to scale back the slippery algae -- known as "rock snot" -- that pesters tubers, fishers and native insects in Boulder Creek.

In 2002, a historic drought parched the state and its streams. A large snowpack the next year filled the reservoirs, pumping water back into streams like Boulder Creek. Along with it came a form of algae called *Didymosphenia geminata*, or informally "didymo" or rock snot.

CU Professor Diane McKnight says heavy creek flow, though, keeps the didymo in check, and controlled flow releases from reservoirs during summer could limit the impact of this nuisance species in streams in the Colorado Front Range. The high flow destabilizes rocks, which move in the streambed.

Flows below Barker Reservoir near Nederland that are above 200 cubic feet per second -- similar to those experienced last year once the reservoir started to spill in late June -- appear to be enough to control the rock-clinging didymo, according to CU research.

McKnight and her colleagues, working with the Niwot Ridge Long-Term Ecological Research Site and Boulder Creek Critical Zone Observatory projects, are unsure whether the explosion of didymo blooms happened because of the drought or if there were man-made changes.

The didymo research projects are funded by the National Science Foundation, and the team's research was published this month in *Hydrobiologia*, an international journal of aquatic sciences.

"If there's some, that's OK," she said. "But if it covers the stream bed with thick mats from side to side it becomes a problem. The didymo chokes out natural algae in the stream and destroys the habitat for insects on which the fish feed."

Larry Quilling, president of Boulder Flycasters, said the rock snot in Boulder Creek hasn't been too bad this spring, although he expects more blooms when the weather heats up. He said there are fewer didymo blooms in areas where there are canopies, blocking sunlight.

"Low flow certainly can have an impact on the blooms," he said.

CU's McKnight said James Cullis, a CU-Boulder doctoral candidate studying water resources engineering, will continue the research over the summer to develop a two-dimensional model to predict

how much water flow it would take to create movement in the stream bed at given points in the creek.

McKnight, a fellow at CU-Boulder's Institute of Arctic and Alpine Research, said the research can help slow didymo growth before it gets out of control, as it has in New Zealand, where it has taken over streams and rivers.

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