TSC TAHOE SCIENCE CONSORTIUM

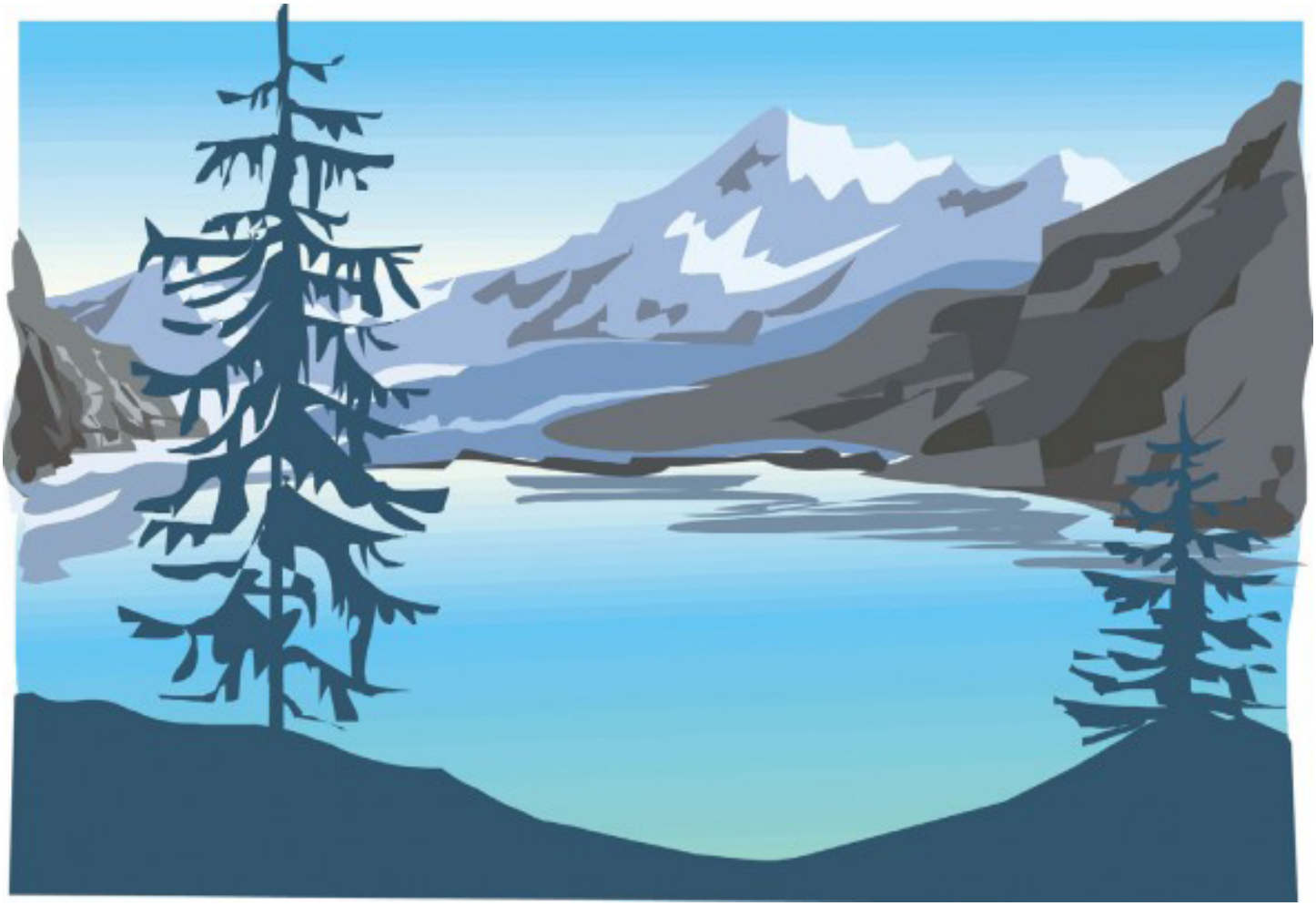
"Tahoe Science in a Changing Climate"

Tahoe Science Conference

September 21 - 23, 2015

Joe Crowley Student Union
University of Nevada, Reno

Hosted by the Tahoe Science Consortium,
University of Nevada, Reno and the Desert Research Institute



DRI Desert Research Institute

University of Nevada, Reno

USGS science for a changing world

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

UCDAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

TSC TAHOE SCIENCE CONSORTIUM
ADDRESSING SCIENCE NEEDS IN THE LAKE TAHOE BASIN

291 Country Club Drive
Incline Village, NV 89451

Tel (775) 881-7566
Fax (775) 832-1673
www.tahoescience.org

September 21, 2015

Dear TSC Conference Participants,

Over the last decade, researchers from the Tahoe Science Consortium - University of Nevada, Reno, Desert Research Institute, University of California, Davis, U.S. Forest Service, and U.S. Geological Survey – and many other organizations have worked tirelessly to provide the scientific foundation needed to restore and protect the Lake Tahoe Basin. Together, we have added to our understanding of the underlying processes responsible for the degradation of Tahoe's nearshore, changes in aquatic and terrestrial biodiversity, transport and deposition of airborne pollutants, ecosystem response and recovery following catastrophic wildfires, risks and impacts of naturally occurring extreme events, stream and meadow ecological functions, and the impacts of climate change. This reservoir of knowledge has helped natural resource managers, land-use planners, first responders, and the general public to understand, protect and restore Lake Tahoe's natural beauty.

Preserving Lake Tahoe for future generations will continue to require transdisciplinary efforts. We will continue to draw upon the expertise of our institutions and partner organizations, in fields from limnology to forest ecology, soil science to photography, atmospheric science to paleoclimatology, environmental policy to seismology, hydrology to resource economics, and many more. Management of Lake Tahoe, our national treasure, remains challenged by the impacts of legacy development, climatic change, invasive species, droughts, wildfires, and other factors. Your institutions and researchers are to be commended for the diverse and in-depth research that continues to be undertaken to preserve Lake Tahoe. In addition to engaging in research, the scientific community has also served as subject matter expert advisors to federal, state and local agencies, educated the next generation of environmental scientists, and shared their knowledge with communities around the world.

Science has underpinned major environmental and land-use planning decisions made by federal, state and local agencies, and stimulated the adoption of ecologically sustainable development practices. Much of the research conducted in the Lake Tahoe Basin over the last decade was supported under the Lake Tahoe Restoration Act and funded through the Southern Nevada Public Lands Management Act (SNPLMA). Research projects supported by the SNPLMA Science Program, including Tahoe Science Consortium operations, will end in early 2016 when the Lake Tahoe SNLPMA Science Program sunsets. A strong, vibrant and resourceful scientific community will remain the linchpin of sustainable management of the Tahoe Basin in the future. Researchers from all disciplines are critical to ensuring that we continue to protect our national treasure for generations to come.

Thank your for your commitment to the science that keeps Lake Tahoe blue, beautiful, and safe!

Sincerely,

Maureen I. McCarthy, PhD
Executive Director

DRI Desert Research Institute
University of Nevada, Reno
USGS science for a changing world
UCDAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

Photograph by Shelbi Whitehead

Tahoe Science Conference Planning Committee

Christine Albano
University of California, Davis

Andrzej Bytnerowicz
U.S. Forest Service, Pacific Southwest Research Station

Kim Caringer
Tahoe Regional Planning Agency / Environmental Improvement Program

Michael Dettinger
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Adrian Harpold
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Alan Heyvaert
Desert Research Institute

Scott Hinton
University of Nevada, Reno

Todd Hopkins
Great Basin Landscape Conservation Cooperative

Alan Gertler
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Ramon Naranjo
U.S. Geological Survey

Randall Osterhuber
Central Sierra Snow Lab

Shane Romsos
Spatial Informatics Group

David Saah
University of San Francisco

Penny Stewart
California Tahoe Conservancy

2015 Tahoe Science Conference Sponsors

The success of the conference would not be possible without the support of our generous sponsors.
Thank you for your support and dedication to our continuing work in the Lake Tahoe Basin.

University of Nevada, Reno

DRI Desert Research Institute

Great Basin LCC
LANDSCAPE CONSERVATION COOPERATIVE

Nevada Water Resources Association

Conference program design by Christina Clack, University of Nevada, Reno
Logistical support from Christina Clack, Kelsey Fitzgerald, Kelsey Poole, and Tina Triplett and Katie Keating, NWRA


Photograph by Shelbi Whitehead

Conference Schedule - Monday, September 21

9:00 a.m. – 12:00 p.m.

WORKSHOP: *(Great Room - 4th floor)*

Real-world Applications of Remote Sensing, Data Visualization and GIS - a Workshop on Data, Platforms, and Analysis Techniques for Natural Resource Management Professionals

Session Chairs: **Shane Romsos and Jarlath O'Neill-Dunne, Spatial Informatics Group**

Remote sensing, from satellite, aircraft and unmanned aircraft systems (drones), provides a wealth of information from which to monitor and assess features on the Earth's surface. However, use of remote sensing data can be challenging for most natural resource managers. The objective of the Real-world Applications of Remote Sensing, Data Visualization and GIS Workshop is to provide a forum for natural resources professionals looking to enhance their understanding of remote sensing data, data collection platforms and data analysis techniques. The workshop will include lecture formatted presentations of current research that utilizes remote sensing data and technologies, along with helpful information on accessing remote sensing data, using analysis software tools and an overview of different platforms used to collect remote sensing data.

Speakers:

Scott Conway, U.S. Forest Service, *Forest Management and the Evolution of Project Design in Dynamic Wildland Urban Interface Fire Environments*

Carol Ostergren, USGS, *Opportunities for lidar*

Charles Morton, DRI, *Cloud Computing of Remote Sensing and Climate Data for Hydrological and Ecological Monitoring*

Jarlath O'Neil Dunne, Spatial Informatics Group, *Application of remote sensing data to map aquatic resources and the stream environment zone in the Lake Tahoe Basin*

9:00 a.m. – 1:00 p.m.

Registration *(Theater Box Office - 3rd floor)*

Poster setup *(Ballroom A entrance - 4th floor)*

1:00 – 2:30 p.m.

Welcome and Remarks: *(Theater - 3rd floor)*

Maureen McCarthy, Executive Director, Tahoe Science Consortium
Mridul Gautam, Vice President for Research and Innovation, University of Nevada, Reno
Alan Gertler, Vice President for Research and Chief Science Officer, Desert Research Institute

Plenary Panel:

Joanne Marchetta, Executive Director, Tahoe Regional Planning Authority
Jeff Marsolais, Forest Supervisor, U.S. Forest Service, Lake Tahoe Basin Management Unit
Jim Lawrence, Deputy Director, Nevada Department of Conservation and Natural Resources
Patrick Wright, Executive Director, California Tahoe Conservancy
Patty Kouyoumdjian, Executive Director, Lahontan Regional Water Quality Control Board

2:30 – 3:30 p.m.

Keynote Speaker: *(Theater - 3rd floor)*

Dr. Elizabeth J. Austin, WeatherExtreme Ltd.

Weather is Everywhere: From Specialty Forecasting to Solving Cases Using Forensic Meterology

3:30 – 4:00 p.m.

Refreshment Break *(Theater - Entrance)*

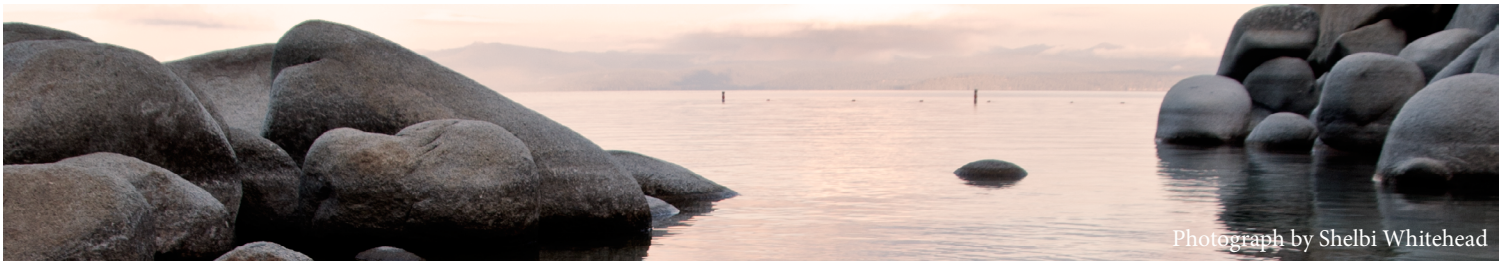
4:00 – 5:00 p.m.

Poster "Ignite" Oral Presentations *(Theater - 3rd floor)*

5:30 – 7:30 p.m.

Poster Session and Reception *(Ballrooms B and C - 4th floor)*

Cash bar. Refreshments and hors d'oeuvres provided.



Poster Session Presentations

Monday, September 21, 5:30 - 7:30 p.m., Ballrooms B and C - 4th floor

Complete abstracts for the poster presentations can be found online at: http://tahoescience.org/events/conferences/

Alexander, Michael	The influence of stormwater, lake level management, and boat waves on Lake Tahoe's nearshore transparency
Alvarez, Nancy	Continuous Turbidity Monitoring in LTIMP streams in Lake Tahoe
Coats, Bob	Is Lake Tahoe Terminal?
Dobre, Mariana	Development of a WEPP online watershed interface to predict effects of watershed management on runoff, and sediment and phosphorus delivery in the Lake Tahoe Basin
Drexler, Judith	Montane peatlands (fens) as gauges for drought and climate change in California
Fenn, Mark	Nitrogenous air pollutants and atmospheric nitrogen deposition in the Lake Tahoe Basin
Ferrell, Gail	What is the Future of the Sensitive Plant, the Tahoe Star Draba?
Ferrell, Gail	Winter Travel Management on Six forests including the Lake Tahoe Basin Management Unit
Fitzgerald, Brian	Rosewood Creek Restoration, Area A
Hu, Wuyang	An Incentive Compatible Water Conservation System
Huntington, Justin	Evaporation Estimates for Lake Tahoe: Review, Challenges, and Future Opportunities
Hwang, Hyun-Min	Sources of fine suspended particles (< 20 μm) in stormwater runoff from the Lake Tahoe Basin
Levitan, Charles	Comparison of Role and Effects of 'Animal Engineers,' beavers and elephants, in broadly different ecosystems
Markwith, Scott	On the Fens: Monitoring the Effects of Livestock Use in Northern Sierra Nevada Fens
Miller, Erin	Western Pearlshell Mussel (*Margaritifera falcata*) Pilot Relocation Monitoring
Molzan, Joshua	Optical Properties of Aerosols from Smoldering Laboratory Combustion of Wildland Fuels
Swim, Shannon	Long-Term Fuels Accumulations Following Mechanized Thinning and Prescribed Fire: Implications for the Lake Tahoe Basin
Tausch, Robin	Cold Desert Vegetation Response over 35,000 Years of Climate Change
Vanderpool, Aaron	Tracking the water cycle with real world data around Incline Creek watershed
Wigart, Russell	Responsible Winter Management Strategies and its Effect on Water Quality and Permit Compliance at Lake Tahoe
Ya-Chun Tai, Anna	Annual and Seasonal Fluxes of Particulate Matter from Atmospheric Deposition to Lake Tahoe: Assessment from a Long-Term Passive Monitoring Program

Conference Schedule - Tuesday, September 22

9:00 a.m. – 12:00 p.m.

SESSION ONE: *(Theater)*

Air Quality in the Tahoe Basin and Sierra Nevada: Implications for People and Ecosystems

Session Chairs: **Andrezj Bytnerowicz, U.S. Forest Service - PSW and Alan Gertler, Desert Research Institute**

The session will discuss: spatial and temporal trends of air pollution distribution; pollution exposure regimes; long-range transport of pollutants; air pollution modeling in complex terrain; impacts of wildland fires on air quality; compliance with the National and California Ambient Air Quality Standards (NAAQS); atmospheric deposition and impacts on terrestrial ecosystems; suggestions for air quality control measures at the local scale of the Lake Tahoe Basin and regional scale of the Sierra Nevada Mountains. Focus of this session will be on the recent Tahoe Basin research findings in the context of the larger Sierra Nevada range.

Speakers:

Dan Jaffe, UW, *An Overview of Air Quality Issues in the Western U.S.*

Joel Burley, Saint Mary's College of California, *An Overview of Surface Ozone in the Lake Tahoe Basin*

Sandra Rayne, DRI, *The Impact of Meteorology on Ozone Levels in the Lake Tahoe Basin*

Haiganoush Preisler, U.S. Forest Service - PSW, *Understanding Spatial and Temporal Sources of Variation in Ambient Ozone Values in the Lake Tahoe Basin*

Barbara Zielinska, DRI, *Characterization of Ozone and Secondary Organic Aerosol Precursors in the Lake Tahoe Basin*

Andrzej Bytnerowicz, U.S. Forest Service - PSW, *Spatial and temporal changes of gaseous air pollutants on the Sierra Nevada and White Mountains topographic gradients*

Ricardo Cisneros, UC Merced, *Particulate matter air pollution in the Sierra Nevada in a presence and absence of wildland fires – air quality impacts caused by the Rim Fire.*

John Mejia, DRI, *A Modeling Study of Aug-Sept 2013 California Wildfire Smoke Plume Dispersion: Air quality effects over Lake Tahoe/Reno area.*

SESSION TWO: *(Ballroom A)*

Lessons in Paleoclimates from Sierra Nevada to the Great Basin

Session Chairs: **Scott Mensing, University of Nevada, Reno and Alan Heyvaert, Desert Research Institute**

Understanding historical climate trends, spatial patterns and variability can provide information on the range of potential changes that may occur in the future. This session presents studies from the Sierra Nevada and the Great Basin that examine conditions and responses to past climate regimes ranging over time scales from the Pleistocene to the recent Holocene.

Speakers:

Scott Mensing, UNR, *The Late Holocene Dry Period (~2500 to 1900 cal yr BP) in the Western United States*

Paula Noble, UNR, *Late Holocene (3.65 ka) Transition from Neopluvial Period to Increased Aridity in the Lake Tahoe - Pyramid Lake Watershed, CA*

Benjamin Hatchett, UNR, *Placing historical California and Nevada droughts into a paleo perspective*

Franco Biondi, UNR, *Space-Time Kriging of Precipitation Reconstructed at 12-km Grid Intervals from Tree-Ring Records*

12:00 p.m. Lunch on your own

1:00 – 3:00 p.m.

SESSION THREE: *(Theater)*

Extreme Tahoe—Droughts, Floods and other Natural Experiments

Session Chairs: **Mike Dettinger, U.S. Geological Survey and Christine Albano, UC Davis**

This session will address climatic forces that bring major droughts, storms and floods to the Tahoe basin and Sierra Nevada more generally, along with landscape and societal responses, historically and in the projected climates of the future. We will present recent research about the mechanisms of drought and storm, about meadow and forest responses to droughts, and about societal vulnerabilities in the region to epic winter storms. We will also present some new data systems and sources, specifically tuned to analysis, preparations, and planning for extreme weather and climate events in the Tahoe area.

Speakers:

Mike Dettinger, USGS, *Large Storms, Droughts, and the Tahoe Environment--Past and Future*

Chris Smallcomb, NOAA/NWS, *How Did It Come To This!? The Ongoing Exceptional Drought*

Chelsea Arnold, UC Merced, *Adaptability in the presence of extreme drought: investigating clues to mountain meadow resilience*

Judith Drexler, USGS, *Montane peatlands (fens) as gauges for drought and climate change in California*

Christine Albano, UC Davis, *ARkStorm@Tahoe: Addressing social and ecological resiliency to extreme winter storm events in the greater Lake Tahoe region*

Erica Fleishman, UC Davis, *Development, delivery, and application of data on climate extremes for the southwestern United States*

SESSION FOUR: *(Ballroom A)*

New Goals, New Science: The Future of Environmental Restoration in the Lake Tahoe Basin

Session Chairs: **Penny Stewart, California Tahoe Conservancy and Kim Caringer, TRPA**

Over the last twenty years of the Environmental Improvement Program, a tremendous amount of work has been done to restore and protect the natural environment. As we move into the future, new priorities and concepts in environmental improvement are beginning to emerge. This interactive session will include a panel of both scientists and managers that will touch on how science has informed management thus far and what new science managers may need going forward. How will new concepts and trends such as the valuation of ecosystem services, the changing economic landscape, and the new direction of the Regional Plan affect our science and management needs?

Dan Segan, Conservation Planner, Wildlife Conservation Society

John Hester, COO, Tahoe Regional Planning Agency

Kristen Podolak, Ecologist, The Nature Conservancy

Conference Schedule - Tuesday, September 22, continued

3:00 – 3:30 p.m.

Refreshment Break

(Theater and Ballroom A)

3:30 – 5:30 p.m.

SESSION FIVE: *(Theater)*

Monitoring for Extremes

Session Chairs: **Graham Kent, University of Nevada, Reno and Dale Cox, U.S. Geological Survey**

Americans are more at risk from natural hazards now than at any other time in our Nation's history. In the United States each year, natural hazards are the cause of hundreds of deaths and cost tens of billions of dollars in disaster aid, disruption of commerce, and destruction of homes, critical infrastructure and the environment. The stresses of climate change are projected to exacerbate these threats. To improve resilience, actions must be guided by the best information about hazards, risk, and the cost-effectiveness of monitoring and mitigation technologies. The session will focus on four efforts to provide such information.

Speakers:

Graham Kent, UNR, *A-21st-century-approach to firefighting in the Tahoe Basin and Central Nevada: How microwave-based seismic networks can change fire suppression from reactive to proactive*

Dale Cox, USGS, *Extreme Climate Scenarios for the American Southwest (SAFRR Initiative)*

William Elliot, USDA - RMRS, *Evaluating Fire Risk in the Tahoe Basin for Projected Future Climates*

SESSION SIX: *(Ballroom A)*

Forest Ecology and the Role of Fire

Session Chairs: **Pat Manley and Shana Gross, U.S. Forest Service - PSW, and Todd Hopkins, Great Basin Landscape Conservation Cooperative**

This session will report on new research findings, management applications, and future challenges in managing forest ecosystems in the Lake Tahoe basin for long-term resilience. The session is organized into two segments: 1) how fire has shaped forests and how to shape forests to be resilient to future change and disturbance; and 2) how to manage forests to maintain native species and communities and the vital role that biodiversity plays in forest resilience.

Speakers:

Patrick Wright, California Tahoe Conservancy, *Introduction: restoration, resilience, and fire in the Lake Tahoe basin*

Brandon Collins, UC Berkeley and US Forest Service - PSW, *Historical data yields insights into controls on forest structure in pine-mixed conifer forests*

Leland Tarnay, U.S. Forest Service - PSW, *Can larger-scale mechanical treatments lessen smoke impacts from wildfire in the Blackwood Canyon watershed of the Lake Tahoe Basin?*

Peter Weisberg, UNR, *Carbon Dynamics in Future Forests*

Matt Busse, U.S. Forest Service - PSW, *Soil quality and fire – what have we learned?*

Jessica Wright, U.S. Forest Service - PSW, *Using Provenance Test Data to Inform Ecological Restoration in the Tahoe Basin*

John Pascal-Berrill, Humboldt State University, *Aspen Restoration in a Changing Climate*

Becky Estes, U.S. Forest Service - Region 5, *Landscape design –How historic fire, current forest conditions, and future forest resilience shapes forest management*

Pat Manley, U.S. Forest Service - PSW, *Biodiversity Past, Present and Future in the Lake Tahoe Basin*

Angela White, U.S. Forest Service - PSW, *Biological diversity modeling, measurement, and assessment*

Gina Tarbill, U.S. Forest Service - ORISE, *No seven-year itch: black-backed woodpeckers still nesting in the Angora Fire*

Rahel Sollmann, U.S. Forest Service - PSW, *Small mammal community conservation and fire*

Keith Slauson, U.S. Forest Service - PSW, *Habitat Fragmentation and Winter Ski Recreation Activities Affect Movement and Seasonal Habitat Use by Pacific Martens in the Lake Tahoe Region of California*

Jonathan Long, U.S. Forest Service - PSW, *Ecological tradeoffs among fuel treatment strategies in mixed-conifer forests*

Svetlana Yegorova, California State Parks, *Twenty years of change in the understory characteristics of prescribed burned and passively managed forests on the West shore of Lake Tahoe*

Det Vogler, U.S. Forest Service - PSW, *White Pine Blister Rust, Host Disease Resistance, Climate, and Prognoses for Sustainability and Survival*

Conference Schedule - Wednesday, September 23

9:00 a.m. – 12:00 p.m.

SESSION SEVEN: *(Theater)*

A Tahoe Without Snow? Predicting and Adapting to Less Snow in the Tahoe Basin

Session Chairs: **Adrian Harpold, University of Nevada, Reno and Randall Osterhuber, Central Sierra Snow Lab**

Snow is an important resource for the Lake Tahoe Basin. It supports streamflow and groundwater, is critical to forest health, and provides significant economic benefit through recreation. However, meteorological drought and regional warming threaten the area with earlier and smaller snow melts. This session will explore both the snowpack observations and the consequences of changing precipitation and snowmelt patterns. In particular, we are interested in better understanding how water availability for people and ecosystems has responded to the recent drought and identify ways to build resiliency into these systems under expected changes in snowpack regimes over the 21st century.

Speakers:

Seshadri Rajagopal, DRI, *Using Observations, Models and Remote Sensing to Understand Winter Precipitation Dynamics in the Tahoe Basin*

Lorrie Flint, USGS, *Implications of snowpack decline on environmental resources in the Tahoe region*

Alan Flint, USGS, *Hydrologic response to climate change at a fine scale in the Tahoe region: Tools for adapting to climatic extremes*

Benjamin Trustman, DRI, *Characterizing Spatial Variability of Snow Water Equivalent Using Pressure Sensors*

Jeff Anderson, USDA - NRCS, *2015: Lake Tahoe's Lowest Snow in Over a Century of Measurement*

SESSION EIGHT: *(Ballroom A)*

Protecting Lake Tahoe: Aquatic Ecosystem Science Informing Management Decisions

Session Chairs: **Ramon Naranjo, U.S. Geological Survey and Darcie Goodman-Collins, League to Save Lake Tahoe**

Lake Tahoe is renowned for its pristine cobalt waters and impressive clarity. Protecting this outstanding national resource has been the focus of federal, state and local entities for over half a century. To effectively manage natural and anthropogenic influences, it is imperative that there is a current understanding of the interaction between chemical, physical and ecological processes. Management decisions must be adaptable and updated to include best available science and knowledge. In this session, we will hear some of the latest science on Tahoe's nearshore, water clarity, and nutrient and sediment conditions. We will then hear how agencies are incorporating new science into management decisions. There will be an opportunity for open discussion at the conclusion of the panel.

Speakers:

Ramon Naranjo, USGS - NWSC, *The importance of the hyporheic zone in nutrient transformations along the nearshore Lake Tahoe*

Angela Stevens, DRI, *Evaluation of Nearshore Water Clarity Conditions at Lake Tahoe*

Joseph Domagalski, USGS, CWSC, *Trends in Nitrogen and Phosphorus Concentrations and Fluxes in Six Streams Entering Lake Tahoe, California: Effectiveness of Best Management Practices*

Michael Alexander, U.S. Forest Service, *The influence of stormwater, lake level management, and boat waves on Lake Tahoe's nearshore transparency*

Bob Coats, Hydroikos Ltd., *Improving Estimates of Suspended and Dissolved Streamflow Discharges to Lake Tahoe*

12:00 p.m.

Closing Remarks

(Theater)

1:00 - 3:00 p.m.

Unmanned Aircraft Systems for Geospatial Mapping Workshop

(Ballroom A)

Unmanned Aircraft Systems (UAS) are a hot topic. In this workshop we will look beyond the hobbyist drones to mapping-grade systems that are capable of producing timely, accurate, GIS-ready 2D and 3D products. Participants will gain an understanding of end-to-end UAS operations from flight planning to data processing to analysis. Highlights from recent UAS operations in the Tahoe Basin will be shown. Attendees will have the opportunity execute a simulated UAS mission.

2:30 - 3:30 p.m.

Tahoe Environmental Research Center Tour

291 Country Club Dr.

Incline Village, NV 89451

Optional: Must register online or at registration desk

KEYNOTE SPEAKER

Dr. Elizabeth J. Austin, WeatherExtreme, Ltd.

Weather is Everywhere: From Specialty Forecasting to Solving Cases Using Forensic Meteorology

Weather—it is inescapable. The weather affects how we feel and what we do, and can even threaten our lives! From specialty forecasting projects to forensic meteorology, Dr. Austin will introduce you to some lesser-known, but rapidly growing areas of weather and climate. Murders, plane crashes and attempted bombings are just a few of the over 1,500 cases that Dr. Austin has been involved in over the years. Though it is a niche, as you will see, forensic meteorology plays a very important role in solving many of these cases.

Elizabeth Austin is the President of WeatherExtreme, Ltd., a research and consulting firm. She has also held affliate research professor positions at the Desert Research Institute, the University of Nevada, Reno and Sierra Nevada College. Dr. Austin received her Ph.D. in Atmospheric Physics from the University of Nevada, Reno.

SESSION ABSTRACTS

Real-world Applications of Remote Sensing, Data Visualization and GIS - a Workshop on Data, Platforms, and Analysis Techniques for Natural Resource Management Professionals

FOREST MANAGEMENT AND THE EVOLUTION OF PROJECT DESIGN IN DYNAMIC WILDLAND URBAN INTERFACE FIRE ENVIRONMENTS

Scott Conway, U.S. Forest Service

The Truckee Ranger District on the Tahoe National Forest, in the heart of the Sierra Nevada Mountains, has a rich history of human activities. Native American influences, comstock-era logging, fire suppression, development, and recreation have all shaped the natural environment into what it is today. Like much of our national forests in California, forest conditions that have developed are generally much more homogenous and less resistant to disturbance from fire, insect, and disease than they might have been without the myriad of human influences. However, in order to improve the resiliency of our forests to stand-replacing disturbances like high severity fire, while managing for sensitive wildlife species habitat and integrated anthropomorphic values; it is imperative that land management evolves from analysis with traditional datasets and modeling programs that generalize forest conditions over large stands of trees, to utilizing high-resolution remotely sensed data that supports multi-scale analyses. Recent advances in remote sensing, such as fusing hyperspectral and multispectral datasets with LiDAR point clouds in seamless workflows, allows land managers better access to spatially-explicit forest information and can inform site-specific prescriptions to align the trajectory of the stand towards a more desired condition. The ecological and socio-political complexity associated with Sierra Nevadan forests warrants the ability to convert these massive datasets into useful information that provides a micro- and macroscopic view of the landscape. This presentation will focus on how the Truckee Ranger District specifically applied analytics and associated fused data sets to extract, analyze, and display current conditions and proposed treatment effects.

USGS--OPPORTUNITIES FOR LIDAR

Carol Ostergren, U.S. Geological Survey National Geospatial Program

On July 17, 2015, the US Geological Survey issued the FY15/FY16 Broad Agency Announcement (BAA) for 3D Elevation Program (3DEP). The BAA and associated meetings held across the country provide guidance on how to understand local requirements, how to make your own requirements known to others, and how to partner with the USGS and other Federal agencies to acquire high-quality 3D Elevation data. This year's BAA process included a series of public workshops designed to increase awareness and enable stakeholders to prepare in advance for this BAA opportunity. This talk will provide the details as lidar requirements pertain to California and Nevada.

CLOUD COMPUTING OF REMOTE SENSING AND CLIMATE DATA FOR HYDROLOGICAL AND ECOLOGICAL MONITORING

Charles Morton[1], Justin Huntington[1], Katherine Hegewisch[2], Britta Daudert[1], Donovan VanSant[2], Dan McEvoy[1], John Abatzoglou[2]
1) Desert Research Institute, Reno, NV, 2) University of Idaho, Moscow, ID

Climate and weather impacts all sectors of society at regional to local scales. Massive volumes of climate, meteorology, and remote sensing data are collected and developed each day. However, the usefulness of these data for researchers, decision makers, and the general public is limited because of the difficulty of downloading, managing, and processing of the data. In this work, we demonstrate GIS and remote sensing applications in the Lake Tahoe Basin and surrounding Great Basin utilizing the Google Earth Engine massively parallel cloud computing system. We also highlight the development and utility of Climate Engine, a web application that utilizes Google Earth Engine to allow users to visualize and download regional climate, meteorological, and remote sensing products for custom time scales and regions of interest.

APPLICATION OF REMOTE SENSING DATA TO MAP AQUATIC RESOURCES AND THE STREAM ENVIRONMENT ZONE IN THE LAKE TAHOE BASIN

Jarlath O'Neil-Dune, Sean MacFaden, Shane Romsos and David Saah, Spatial Informatics Group

As an element of a SNPLMA funded project, A Review of Stream Environment Zone Definitions, Field Delineation Criteria and Indicators, Classification Systems, and Mapping – Collaborative Recommendations for Stream Environment Zone Program Updates (Roby et al. 2015), we used LIDAR and Worldview-2 (collected in August 2010) to map aquatic resources and the stream environment zone throughout the Lake Tahoe Basin. Aquatic resources/features were divided into three general groups for the purposes of mapping: 1) open water polygonal features, 2) stream centerlines, and 3) wetlands. We used the final aquatic resources map in combination with an analysis of spectral criteria (Visible Brightness, Normalized Difference Vegetation Index) and spatial context with other existing GIS datasets (including thematic layers for riparian vegetation, fens, and seeps\springs from the U.S. Forest Service, soils from the U.S. Natural Resources Conservation Service (SSURGO), and 100-year flood zones (FEMA)) to develop a Basin-wide SEZ map. All pertinent layers for the SEZ map were compiled into a single, seamless map using eCognition (Trimble). A detailed description of methods used to produce maps will be presented. These maps substantially improved the on-the-ground representation aquatic features and sensitive lands in the Tahoe Basin, and can be used for planning and monitoring purposes.

Air Quality in the Tahoe Basin and Sierra Nevada: Implications for People and Ecosystems

AN OVERVIEW OF AIR QUALITY ISSUES IN THE WESTERN U.S.

Dan Jaffe, University of Washington

The Western US is perceived to have relatively pristine air, but at present the west is facing a number of significant air quality issues, including:
1. Urban Ozone: While ozone is being reduced in California, tougher standards are likely on their way and these may be very challenging to meet.
2. Background Ozone: High elevation areas in the west receive significant concentrations of ozone due to background/free tropospheric air. This will make it very hard for these regions to meet a tougher ozone standard. Does EPA have a way to account for this?
3. PM and ozone from wildfires: Wildfires are likely increasing in the west due to climate change. Our understanding of the PM emissions and O3 formation from wildfires is very limited.
4. Emissions from oil and gas production: Oil and gas activities may contribute significantly to global methane. Oil and gas activities are also responsible for significant wintertime ozone formation in some areas of the west.
5. Emissions from new coal and gas export activities: Exporting coal and oil from west coast ports may exacerbate PM concentrations due to diesel and coal dust emissions.
In this presentation, I will summarize our knowledge on the issues above, with a particular emphasis on key scientific questions and the interactions between science and policy in the Western US.

AN OVERVIEW OF SURFACE OZONE IN THE LAKE TAHOE BASIN

Joel D. Burley[1], Andrzej Bytnerowicz[2], Barbara Zielinska[3], Susan Schilling[2]
1) Chemistry Department, Saint Mary's College of California, 2) USDA Forest Service, Pacific Southwest Research Station, 3) Desert Research Institute, Reno, NV

Surface ozone concentrations were measured in and around the Lake Tahoe Basin using both active monitors (12 sites in 2010) and passive samplers (31 sites in 2002; 34 sites in 2010). The results indicate average summertime diurnal maxima of approximately 50-55 ppb during the well-mixed hours of 10:00 to 17:00 PST, with minimal site-to-site variability at these times. During the late evening and pre-dawn hours, however, large differences between different sites are observed. The site-to-site differences correlate most strongly with elevation, topography, and surface vegetation, and to a lesser extent with local emissions of nitric oxide (NO), which can efficiently titrate ozone during the night. High elevation locations with steeply sloped topography and drier ground cover experience elevated O3 concentrations throughout the night because they maintain good access to downward mixing of ozone-rich air from aloft with minimal losses due to dry deposition. Low elevation sites with flat topography and wetter surface vegetation experience low O3 concentrations in the pre-dawn hours because of greatly reduced downward mixing coupled with enhanced O3 removal via efficient dry deposition. In terms of overall exposure to surface-level ozone, most of the Tahoe Basin sites experience average ozone concentrations that are significantly higher than costal locations like San Francisco or Eureka, but lower than western-slope Sierra Nevada NPS sites like Yosemite or Sequoia – Kings Canyon NP or high elevation sites in the White Mountains. Comparisons between the Tahoe Basin sites and nearby upwind locations (Folsom, Placerville) indicate that the higher elevation Tahoe sites with good nocturnal exposure to ozone-rich air from aloft frequently experience higher average ozone than Sacramento and its downwind (i.e., eastern and northeastern) suburbs.

THE IMPACT OF METEOROLOGY ON OZONE LEVELS IN THE LAKE TAHOE BASIN

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The Lake Tahoe Basin is located on the California-Nevada border and occasionally experiences elevated levels of ozone exceeding the 70 ppb California Air Resources Board (CARB) ambient air quality standard (8-hour average). Previous studies indicate that both the local generation of ozone in the Basin and long-range transport from out-of-Basin sources are important in contributing to ozone exceedances, but little is known about the impact of meteorology on the distribution of ozone source regions. In order to develop a better understanding of the factors affecting ozone levels and sources in the Lake Tahoe Basin, this study combines observational data from a 2010 and 2012 summer field campaigns, HYSPLIT back trajectories, and WRF model output to examine the meteorological influences of ozone transport in the topographically complex Lake Tahoe Basin. Overall this study concludes that transport from the west is less significant than transport from the south and east, and that transport only influences ozone values at higher elevations. Within the Basin itself (at lower elevations), local factors including mixing depth, rising or sinking air, and lake/land breeze circulations are more significant in influencing ozone values. Thus, based on this study, we suggest that development and implementation of effective ozone control strategies in the Lake Tahoe Basin should be focused on in-basin sources as well as contributions from the east and entrainment from aloft.

UNDERSTANDING SPATIAL AND TEMPORAL SOURCES OF VARIATION IN AMBIENT OZONE VALUES IN THE LAKE TAHOE BASIN

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In 2010 a large air quality study was conducted in the Lake Tahoe Basin. The aim of the study was to understand the distribution of ozone (O3) in the region in order to evaluate the potential effects of this pollutant on human and ecosystem health. The concern of the present work within the larger study was the modeling and understanding of sources of diurnal, seasonal and spatial variations in the hourly ozone values. Empirical data were collected with active 2B Technologies ozone monitors at 10 sites distributed around the Tahoe Basin. Additional data were obtained on hourly weather patterns and terrain features (elevation, distant to major road, position relative to lake). The data were used to develop a statistical model to study the questions at hand. Some of the interesting results were that almost all the monitoring sites seemed to have higher O3 values on weekend nights with wind coming from the south to southwest. While all sites had similar O3 concentrations in the range of 55-60 ppb during the daytime, at night the low elevation sites showed much lower concentrations than sites at higher elevations. As site elevations increased, the nighttime O3 concentrations also increased.

CHARACTERIZATION OF OZONE AND SECONDARY ORGANIC AEROSOL PRECURSORS IN THE LAKE TAHOE BASIN

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During the period of July 21 - 26, 2012, we conducted a field study in the Lake Tahoe Basin designed to characterize the precursors and pathways of ozone and secondary organic aerosol (SOA) formation. Four sites were selected: two were located at high elevations (one each on the western and eastern sides of the Basin) and two near the Lake level. Ozone and NO/NO2 concentrations were continuously measured. With a resolution of several hours over a 6-day sampling period, canister samples were collected for detailed speciation of volatile organic compounds (VOC), 2,4-dinitrophenylhydrazine (DNPH) impregnated Sep-Pak cartridges for analysis of carbonyl compounds, PM2.5 Teflon and quartz filter samples for determination of mass, organic and elemental carbon (OC/EC) concentrations and speciation of organic compounds. All four sites showed maximum ozone concentrations in the range of 60 ppb, with the lower sites showing a pronounced diurnal pattern (maximum concentrations during the daytime hours, with minimum values at night and in the early morning), and the upper sites showing much less variability over the 24-hour period. The concentrations of ozone precursors, VOC and NOx at all sites were low, in the range of a few ppb. The concentrations of measured precursors of SOA (biogenic hydrocarbons, isoprene and α-pinene, and anthropogenic aromatic hydrocarbons) were also low. However, SOA tracers, 2-methyltetrols and cis-pinionic acid concentrations were significant ranging from 0.3% - 3% (2-methyltetrols) and 0.1% - 0.7% (cis-pinonic acid) of total organic mass. Our experimental results indicate higher relative significance of the regional transport versus local emissions for ozone and SOA formation.

SPATIAL AND TEMPORAL CHANGES OF GASEOUS AIR POLLUTANTS ON THE SIERRA NEVADA AND WHITE MOUNTAINS TOPOGRAPHIC GRADIENTS

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Concentrations of ammonia (NH3), nitric oxide (NO), nitrogen dioxide (NO2), nitric acid (HNO3), sulfur dioxide (SO2), and ozone (O3) were monitored as 14-day averages by passive samplers during the summer seasons of 2012 and 2013. Measurements in the Sierra Nevada Mountains were performed at nine sites (elevation range 511 to 3,490 masl) along a west-east transect between Prather near Fresno and North Lake near Bishop, while those in the White Mountains were conducted at five sites (elevation range 1,237 to 4,342 masl) along a south-north transect. Similar concentration ranges and elevational trends were observed for the pollutant seasonal averages along both transects, but with significant site-to-site variability. Concentrations of NH3, NO2 and HNO3 decreased with elevation in both 2012 and 2013, while those of NO and O3 increased with elevation during both years. Elevational trends of SO2 concentrations, however, were different in 2012 (decrease with elevation) and 2013 (increase with elevation). Ranges of seasonal average pollutant concentrations were: NH3 (1.2 - 8.0 ug m-3); NO (1.9 – 4.0 ppb); NO2 (0.6 – 3.0 ppb); HNO3 (1.0 – 3.0 ug m-3); SO2 (0.2 – 1.1 ug m-3), and O3 (36 – 60 ppb). Impacts of meteorology, long-range atmospheric transport and effects of wildland fire emissions on spatial and temporal changes of the monitored air pollutants will be discussed. Our results represent the first empirical data on concentrations of these air pollutants throughout various ecological zones (forest, subalpine and alpine) of the Sierra Nevada and White Mountains of California. Although measured pollutant concentrations were generally below their phytotoxic levels, elevated NH3 and HNO3 could increase atmospheric nitrogen deposition and cause undesirable ecological impacts at some locations.

PARTICULATE MATTER AIR POLLUTION IN THE SIERRA NEVADA IN A PRESENCE AND ABSENCE OF WILDLAND FIRES – AIR QUALITY IMPACTS CAUSED BY THE RIM FIRE

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With droughts currently persisting in the west and southwestern United States, wildland fires have become much more common. Out of the 15 largest fires in United States history, half of them have happened since the year 2000. Particulate matter of less than 2.5 microns (PM2.5) in diameter is emitted from wildfires and adversely affects health of the exposed humans. Prior to 2006, there has been little real time PM2.5 monitoring in the Sierra Nevada. Here we are presenting an analysis of the 2013 Rim Fire, the third largest fire in California's history that burned 104,131 ha (257,314 acres). This case study quantifies the increase of PM2.5 concentrations across multiple locations surrounding the Rim Fire. The highest mean PM2.5 concentrations were observed at locations closest to the fire in the Central Sierra Nevada, followed by Northern Sierra locations and the state of Nevada sites. At fire camp, the closest location to the Rim Fire, the 24 hour mean PM2.5 concentration was 121 gm-3 with a range of 24.3-450g m-3. The 24 hour mean PM2.5 concentration at Tuolumne City, the second most impacted site, was 69 gm-3 with a range of 5.3-223.7gm-3. In South Lake Tahoe, the 24 hour mean concentration was 20.6 gm-3 with a range of 3.6-80.6gm-3. In Reno, the 24 hour mean PM2.5 concentration measured was 13.7 gm-3 with a range of 0.3-89.5 gm-3. Spatial and seasonal patterns of PM2.5 in the Sierra Nevada along with other case studies will also be discussed in a context of particulate air pollution in the presence or absence of forest fires.

A MODELING STUDY OF AUG-SEPT 2013 CALIFORNIA WILDFIRE SMOKE PLUME DISPERSION: AIR QUALITY EFFECTS OVER LAKE TAHOE/RENO AREA

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A modeling framework to diagnose and predict the impact on the Lake Tahoe/Reno air quality due to wildfires during the Aug-Sept 2013 California fire outbreak (including the Yosemite Rim fire) is presented. We used simulated meteorology based on 4 km grid size WRF simulations to drive two regional air-quality modeling systems: (i) a Eulerian system based on wildfire emissions inventories produced by SmartFire-BlueSky, the SMOKE Emission Processor, and the Community Multi-Scale Air Quality (SMOKE-CMAQ) model; and (ii) a Langrangian system based on SmartFire-BlueSky, remotely sensed aerosols measurements from CALIPSO, and DRI's Lagrangian particle tracking systems. Preliminary simulation experiments show good confidence in the meteorology component of the systems. Additionally, results suggest there is good confidence in the timing and moderate confidence in the concentration of particulate matter generated from remote wildfires affecting the area. In general, our modeling experiment shows that both the Eulerian and the Langrangian systems can provide complementary and added-value information for diagnostic and prognostic wildfire related emissions affecting air quality in the Lake Tahoe/Reno area.

Lessons in Paleoclimates from Sierra Nevada to the Great Basin

THE LATE HOLOCENE DRY PERIOD (~2500 TO 1900 CAL YR BP) IN THE WESTERN UNITED STATES

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Recent studies have refined the temporal and spatial reconstruction of Great Basin Holocene climate. In particular, a suspected period of drought between ~2500 and 1900 cal yr BP, which we term the Late Holocene Dry Period, is supported by new palynological and sedimentary evidence. Comparison of multiple records extending from the eastern Sierra Nevada across the central Great Basin to the Great Salt Lake support the interpretation that this dry period was regional. Beginning and ending dates vary among sites, but all sites record multiple centuries of dry climate between 2500 and 1900 cal yr BP making this the longest persistent dry period within the late Holocene. In contrast, Great Basin sites north of 40° to 42° N latitude show either no clear evidence of drought, or wetter than average climate during this period. This dipole precipitation pattern is consistent with large-scale ENSO climate patterns and provides a temporal and spatial climatic hypothesis for testing paleoclimate models and for comparing with archaeological data.

LATE HOLOCENE (3.65 KA) TRANSITION FROM NEOPLUVIAL PERIOD TO INCREASED ARIDITY IN THE LAKE TAHOE - PYRAMID LAKE WATERSHED, CA

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We present evidence for a millennial-scale interval of high winter precipitation (neopluvial) in the Lake Tahoe-Pyramid Lake watershed that reached its peak ~3.7 kcal yr BP. Cores recovered from Fallen Leaf Lake, southern Tahoe Basin were dated using AMS14C on plant macrofossils, and analyzed using scanning XRF, C and N elemental and stable isotope measurements, and diatoms as paleoclimate proxies. In Fallen Leaf Lake, the end of the neopluvial is dated at 3.65 ± 0.09 kcal yr BP, and is the largest post-glacial signal in the cores. The neopluvial interval is interpreted to be a period of increased snowpack in the upper watershed, supported by depleted δ 13Corg (-27.5‰) values, negative baseline shifts in TOC and TN, lower C:N, and high % Aulacoseira subarctica, a winter-early spring diatom. Collectively, these proxies indicate cooler temperatures, enhanced mixing, and/or shortened summer stratification resulting in increased algal productivity and/or suppressed terrestrial runoff. The neopluvial ends abruptly at 3.65 ka, with a change from mottled darker opaline clay to a homogeneous olive clay with decreased A. subarctica and opal, and followed by a 50% reduction in accumulation rates. After this transition δ 13Corg becomes enriched by 2‰ and TOC, TN, and C:N all show the start of positive trends that continue through the Holocene. In Pyramid Lake, and also in the Walker, Mono, and Owens lake basins, the neopluvial represents the highest late Holocene shorelines. These data indicate that the neopluvial and subsequent aridification intervals were at least regional in scale.

PLACING HISTORICAL CALIFORNIA AND NEVADA DROUGHTS INTO A PALEO PERSPECTIVE

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Closed basin lake systems offer ideal natural laboratories for model-proxy evaluations of how the regional water balance may be altered by climatic change. We use an existing coupled water balance and lake-evaporation model of the Walker Lake Basin and a 1600-year reconstruction of Walker Lake shoreline elevations to provide a paleo perspective on historical droughts. We find that: 1) The three major historical droughts observed in the California-western Nevada region (the 1930s, 1987-1992, and 2012-2015) are comparable in magnitude to the severe droughts of the Medieval Climate Anomaly but not in duration; 2) The atmospheric circulation anomalies associated with these events include poleward deflections of storm tracks and reduced moisture transport into the region; 3) To produce the Medieval lowstands of Walker Lake, precipitation and circulation anomalies similar to historical droughts must persist for a minimum of 50 years. These insights show how severe historical and ongoing droughts in this region are within the range of natural variability of precipitation. However, positive temperature anomalies extending beyond the range of natural variability have exacerbated the 2012-2015 drought, making it more extreme in magnitude than Medieval droughts. These results can help to improve future water resource planning for the Sierra Nevada region, where ongoing and future changes in climate leading to increased water scarcity will have negative impacts on socioeconomic and ecological systems.

SPACE-TIME KRIGING OF PRECIPITATION RECONSTRUCTED AT 12-KM GRID INTERVALS FROM TREE-RING RECORDS

Franco Biondi, University of Nevada, Reno, NV

Understanding and preparing for future hydroclimatic variability greatly benefits from long (i.e., multi-century) records at seasonal to annual time steps that have been gridded at km-scale spatial intervals over a geographic region. Kriging is a geostatistical technique commonly used for optimal interpolation of environmental data, and space-time geostatistical models can improve kriging estimates when long temporal sequences of observations exist at relatively few points on the landscape. Here I present how a network of 22 tree-ring chronologies from single-leaf pinyon (Pinus monophylla) in the central Great Basin of North America was used to extend hydroclimatic records both temporally and spatially. First, the Line of Organic Correlation (LOC) method was used to reconstruct October-May total precipitation anomalies at each tree-ring site, as these ecotonal environments at the lower forest border are typically moisture limited. Individual site reconstructions were then combined using a hierarchical model of spatio-temporal kriging that produced annual anomaly maps on a 12x12 km grid during the period in common among all chronologies (1650-1976). Hydro-climatic episodes were numerically identified and modeled using their duration, magnitude, and peak. Spatial patterns were more variable during wet years than during dry years, and the evolution of drought episodes over space and time could be visualized and quantified. The most remarkable episode in the entire reconstruction was the early 1900s pluvial, followed by the late 1800s drought. The 1930s 'Dust Bowl' drought was among the top ten hydroclimatic episodes in the past few centuries. These results directly address the needs of water and natural resource managers with respect to planning for 'worst case' scenarios of drought duration and magnitude at the watershed level.

Extreme Tahoe—Droughts, Floods and other Natural Experiments

LARGE STORMS, DROUGHTS, AND THE TAHOE ENVIRONMENT--PAST AND FUTURE

Michael Dettinger, U.S. Geological Survey, Carson City, NV

Significant 21st Century warming is projected for the Tahoe basin along with still-uncertain changes in overall precipitation and increased storm intensities. Severe storms already play important roles in variations of the water budgets of basin and Lake, sediment and nutrient loadings to the Lake, and Lake clarity. For example, the total amount (18%) of sediments transported by the Upper Truckee on days with loads > 150 tons/day is much larger than flows (4%) on those days and far out of proportion with the number (0.5%) of such days. Two-thirds of those loading days have involved the arrival of large, warm, atmospheric-river storms. Thus projected intensifications of storms should be matters of great concern, with the potential to adversely affect basin landscapes and the Lake.

Notably, precipitation at Lake Tahoe—and California--varies more from year to year than anywhere else in the US. Two-thirds of this variability comes from fluctuations in the wettest 5% of wet days, so that large-storm contributions explain about twice as much precipitation variance as do contributions from all other storms combined. In climate-change projections, eight of 10 climate models yield increases in precipitation from largest storms, and in models where increases are large, total precipitation also increases. All ten models project declines in contributions from smaller storms, and models that dry overall reflect that decline. Projected changes in interannual precipitation variance also reflect changes in large-storm variance. Thus Tahoe's largest storms dictate its cycles of wet and dry, historically and in climate-change projections.

HOW DID IT COME TO THIS!? THE ONGOING EXCEPTIONAL DROUGHT

Chris Smallcomb, NOAA/National Weather Service, Reno, NV

Water restrictions, #droughtshaming, rivers running low, ski resorts closing early, mass tree die-offs, increased wildfire risk. We've all seen the impacts of the ongoing exceptional drought around Reno and Tahoe. This presentation will look back and put into context the precipitation deficits and temperature anomalies that make this drought different, and the weather patterns which caused them. We'll also look into the unusually active summer thunderstorm patterns of the past few years. While producing widespread flash flooding and keeping vegetation somewhat greener than normal, these storms have done little to help the drought. The presentation will conclude with a look forward at the uncertain prospects of a strong El Niño relieving the drought in the Sierra this coming winter.

ADAPTABILITY IN THE PRESENCE OF EXTREME DROUGHT: INVESTIGATING CLUES TO MOUNTAIN MEADOW RESILIENCE

Chelsea L. Arnold, Teamrat A. Ghezzehei, Asmeret Asefaw Berhe, University of California, Merced

High elevation meadows are stable features of the mountain landscape in the Sierra Nevada, however recent research has shown how sensitive they are to shifts in seasonality. The balance between the accumulation of carbon (from meadow plant productivity) and loss of carbon (from decomposition of plant residues) hinges on key seasonal milestones including onset of continuous snowpack in winter and the onset of spring. We investigate the past few years to examine the impact of continuous drought on subalpine meadow carbon storage and hydrology and show how mountain climate, and geologic relics from past volcanic eruptions are key to subalpine meadow resilience.

MONTANE PEATLANDS (FENS) AS GAUGES FOR DROUGHT AND CLIMATE CHANGE IN CALIFORNIA

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Fens are montane peatlands, which store carbon and rely on steady groundwater discharge to persist in the landscape. Here we present two studies on fen sustainability. In the first, we studied five fens in the Sierra Nevada and two in the southern Cascade Range over 50-80 years using aerial photography and climate analysis. Over the study period, the Sierra fens decreased by 10-15% in area, but little change occurred in the Cascade fens. The climate analysis showed that Sierra fens are highly vulnerable to long-term increases in minimum air temperature and decreases in snowpack. Such changes resulted in decreases in groundwater discharge, which ultimately led to contraction of fen boundaries over time. In the second, we studied Landsat-derived normalized difference water index images (NDWI) for a subset of the same fens. NDWI is used to evaluate the liquid water content of vegetation and soil, with the common range being between -0.1 (lowest) to 0.4 (highest). We analyzed NDWI images acquired during July 1-August 30th from 1984-2015 for two Sierra fens and one Cascades fen. NDWI values were all negative from 2013-2015, indicating that the fens are responding to the current severe drought in California. In the Sierra fens, NDWI drought values were the lowest on record (as low as -0.1845), whereas in the Cascades fen, the NDWI drought values were among the ten lowest values (between 0 and -0.1400). These studies suggest that groundwater systems in the Sierra are more responsive to hydrologic changes, especially water shortage, than the groundwater systems of the Cascades. Initiation of studies along a fen network could provide rare insights into the impact of drought and climate change in California.

ARKSTORM@TAHOE: ADDRESSING SOCIAL AND ECOLOGICAL RESILIENCY TO EXTREME WINTER STORM EVENTS IN THE GREATER LAKE TAHOE REGION

Christine M. Albano, Michael D. Dettinger, Maureen M. McCarthy, Dale A. Cox

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Atmospheric rivers (ARs) are strongly linked to extreme winter precipitation events in the western U.S., accounting for ~80% of extreme floods in the Sierra Nevada and surrounding lowlands. In an effort to better explore and mitigate potential impacts of these events to natural resources and communities in montane and adjacent environments, we applied the USGS ARkStorm extreme winter storm scenario to the greater Lake Tahoe area. This ArkStorm@Tahoe scenario was presented at six stakeholder meetings, each with a different geographic and subject matter focus, and discussions were facilitated to identify social and ecological vulnerabilities, science and information needs, and proactive measures that might minimize impacts from this type of event. Information collected in these meetings was used to develop a tabletop emergency response exercise and set of recommendations for increasing resilience to extreme winter storm events.

Over 300 individuals participated in ARkStorm@Tahoe stakeholder meetings and the emergency response exercise. Interruption of transportation, communications, and lack of power and backup fuel supplies were identified as the most likely and primary points of failure across multiple sectors and geographies, as these interruptions have cascading effects on natural and human environments by impeding emergency response efforts. Natural resource impacts of greatest concern include flooding, impacts to water quality, spread and establishment of invasive species, and interactions with other disturbance types (e.g., fire, landslides). Science needs include improved monitoring and models to facilitate better prediction and response, real-time and forecast inundation mapping to understand flood risks, and vulnerability assessments related to geomorphic hazards and water quality impacts. Results from this effort highlight several opportunities for increasing the resilience of communities and the environment to extreme winter storm events.

DEVELOPMENT, DELIVERY, AND APPLICATION OF DATA ON CLIMATE EXTREMES FOR THE SOUTHWESTERN UNITED STATES

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We are improving the scientific capacity to estimate climate extremes, evaluate responses of natural resources to these extremes, and enhance a platform for derivation of and access to customized climate information for the full extent or any subset of the southwestern United States. Extreme climate can have substantial effects on species, ecological and evolutionary processes, and the health of visitors to public lands. Our work has three complementary areas of emphasis. First, we are screening global climate models on the basis of their realism in representing natural regional patterns and extremes of temperature and precipitation, including those driven by El Niño and La Niña. We are assessing how well each model represents different climate elements. We also are delivering point and gridded observations and downscaled model projections, all at daily and 6 km resolution, on past and future climate extremes. Additionally, we are using the downscaled outputs to drive a hydrologic model and derive multiple probabilistic measures of water availability, flood, and drought. Second, we are extending the capacity of the Southwest Climate and Environmental Information Collaborative (SCENIC; wrcc.dri.edu/csc/scenic), a product developed by the Western Regional Climate Center, to provide access to diverse observed and simulated data on regional weather and climate, particularly on extremes. Third, we are working with managers and with researchers who collaborate with decision-makers to use data on climate extremes to inform resource management. The focus of these partnerships ranges from sudden oak death to estuarine productivity to microclimatic patterns in the Sierra Nevada.

A-21ST-CENTURY-APPROACH TO FIREFIGHTING IN THE TAHOE BASIN AND CENTRAL NEVADA: HOW MICROWAVE-BASED SEISMIC NETWORKS CAN CHANGE FIRE SUPPRESSION FROM REACTIVE TO PROACTIVE

Kent, G., Smith, K., Slater, D., Plank, G., Williams, M., McCarthy, M. and Rojas, R. (UNR); Vernon, F., Hidley, G., and Driscoll, N. (UCSD)

The Nevada Seismological Laboratory (NSL) at UNR has recently embarked on a bold technical initiative, installing a high-speed (up to 190 Mb/sec) mountaintop-based Internet Protocol (IP) microwave network, enabling a myriad of sensor systems for Multi-Hazard Early Warning detection and response. In the Tahoe Basin, this system is known as AlertTahoe; a similar network has been deployed in north-central Nevada as part of a 5-year-long grant with BLM. The UNR network mirrors the successful HPWREN multi-hazard network run through UCSD; the UNR "Alert" program (Access to Leverage Emergency information in Real Time) has expanded on the original concept by providing a framework for early fire detection and discovery. Both systems do not rely on open-access public Internet services such as those provided by cellular service providers. Instead, they utilize private wireless communication networks to collect data 24/7 in real-time from multiple sensors throughout the system. Utilizing this restricted-access private communication platform enhances system reliability, capability, capacity and versatility for staff and its community of certified users. Both UNR and UCSD fire camera systems are presently being confederated under a common framework (AlertWildfire) to provide end users (e.g., BLM, USFS, CalFire) a unified interface.

Earthquake response has been both organizations' primary mission for decades; high-speed IP microwave fundamentally changes the playing field allowing for rapid early detection of wildfires, earthquakes and other natural disasters, greatly improving local and regional disaster response/recovery. For example, networked cameras can be optimally placed for wildfire detection and are significantly less vulnerable due infrastructure hardening and the ability to avoid extreme demands by the public on cellular and other public networks during a crisis. These systems also provide a backup for emergency responders to use when public access communications become overwhelmed or fail during an event. The crowd-sourced fire cameras can be viewed year round through AlertTahoe and AlertSoCal websites with on-demand time-lapse, an integrated real time lightning map, and other useful features.

Successes in the Tahoe basin and central Nevada have been many in the first year of deployment. Nearly two-dozen fires have benefited through early Intel, with about ½ dozen fires discovered first with this camera system. Examples include the "dry" lightning storm on June 27th, 2015 in the Tahoe basin, where 4 fires where tracked, two were first seen through the Axis HD cameras. Fires during this incident were held to <1 acre. The Cold Creek Fire east of Fallon, NV was discovered late in the afternoon during August 14th, 2015, while the region was experiencing severe red flag conditions; early discovery limited the damage from this fire, with a total of 4,000 acres burned, although given the extreme conditions, it could have been much worse.

EXTREME CLIMATE SCENARIOS FOR THE AMERICAN SOUTHWEST (SAFRR INITIATIVE)

Michael D. Dettinger (USGS), Maureen I. McCarthy (UNR), Christina Albano (SWCSC), Dale Cox (USGS SAFRR)

The USGS SAFRR program will develop science-based scenarios of meteorological and hydrological extreme events across the American Southwest Region, specifically targeting the natural hazards, secondary hazards, ecological impacts, physical damages, and social and economic disruptions throughout the region, as a basis for stakeholder preparations for future hazards.

SAFRR will leverage its past scenario developments (e.g., ARkStorm) and two stakeholder-centric projects - Water for the Seasons, funded by National Science Foundation (NSF) and U.S. Department of Agriculture (USDA), and Native Waters on Arid Lands, funded by USDA – that are developing scenarios to assess likely impacts of climate change on water resources in snow-fed arid river basins in Northwest Nevada and on tribal lands across the Great Basin and Southwest, respectively. SAFRR's scenarios and associated impact models will provide ecosystem and natural resource managers, emergency managers, and infrastructure owner/operators, more generally, with a common basis for assessing the most pressing climatic impacts. Leveraging these projects offers a crucial head start ensuring that the SAFRR scenarios will be stakeholder-relevant and actionable.

EVALUATING FIRE RISK IN THE TAHOE BASIN FOR PROJECTED FUTURE CLIMATES

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The Blackwood Creek watershed, a tributary of Lake Tahoe in California, was assessed for potential changes in climate and fire risk under 21st century climates projected by the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (5AR). While total precipitation varied by decade, the portion of precipitation falling as snow decreased by as much as 26%, and projected air temperatures increased by as much as 3.4°C by 2090. Total soil water (TSW) predictions by the Water Erosion Prediction Project (WEPP) model indicated that fire ignition in the Sierra Nevada region from 1984-2013 coincided with simulated minimum TSW. Risk categories based on simulated TSW changed under projected future climate, with an increase in the number of high risk days defined by TSW less than 40 mm. Simulated TSW in the Blackwood Creek watershed at the time of nearby historic fires also indicated that the Keetch-Byram Drought Index (KBDI) was correlated to TSW ($R2 = 0.59$) when KBDI was less than 500. These findings suggest that the hydrologic modeling within the WEPP model may be a useful tool for predicting fire risks under future climates.

CAN LARGER-SCALE MECHANICAL TREATMENTS LESSEN SMOKE IMPACTS FROM WILDFIRE IN THE BLACKWOOD CANYON WATERSHED OF THE LAKE TAHOE BASIN?

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The Lake Tahoe Basin (LTB) is a relatively unique high elevation (1900 m) watershed in the Sierra Nevada, dominated by a large lake (812 km2) and fringed by a smaller area (498 km2) of forested land. A large fraction of this land lies in the Wildland Urban Interface (WUI), where risks to life and property are high when large-scale wildfires like the 2007 Angora fire manifest under extreme fire danger conditions. When outdoor events and activities have to be canceled due to the large quantity of daily smoke from these large-scale wildfires, public health and tourism are also threatened. This work examines how, and whether, mechanical treatments can slow down and/or reduce emissions from wildfires enough to reduce smoke impacts in the event of an incursion into the Tahoe Basin. Our modeling scenario simulated a hypothetical wildfire modeled to burn into the LTB over Barker Pass and through the Blackwood and Ward Canyons, under conditions similar to those that occurred during the 2014 King fire. Under this scenario, we find that there is relatively little change in the severity of smoke impacts from wildfires in areas pre-treated with mechanical-only strategies, largely due to the relatively small proportion of the watershed receiving treatments, and the resulting small changes in emissions. We explore the parameters for further modeling prescribed fire treatments to reduce severity and duration of smoke impacts.

CARBON DYNAMICS IN FUTURE FORESTS

Peter Weisberg, E. Louise Loudermilk, Robert M. Scheller, Alec M. Kretchun, Matthew D. Hurteau, Jian Yang, Alison Stanton, Thomas E. Dilts, Carl Skinner

Projecting future forest dynamics in a managed landscape requires knowledge of long-term forest succession as well as past and future disturbances, such as wildfires, bark beetle outbreaks, timber harvesting, and forest thinning. Wildfire and insect outbreaks are linked with changes in climate and require special attention when addressing long-term forest management goals. Our objective was to evaluate the emergent responses of multiple interacting processes: climate change, bark beetle outbreaks, wildfire activity, and fuels management on forest productivity, tree species interactions, and ecosystem carbon dynamics, within the regional landscape of the Lake Tahoe Basin, CA, and NV. We simulated forest change using the LANDIS-II model (www.landis-ii.org) and validated our productivity estimates with scaled Aboveground Net Primary Productivity data from tree-core data.

Results from our simulations indicated that the Comstock logging era in the 1880s caused legacy effects, wherein forest growth continues for multiple centuries regardless of climate or future disturbance regime. We also found that although intensive fuels management may be imperative for creating a more fire resilient landscape in the future, the effectiveness of fuel treatments may be limited by the projected increases in climate-driven disturbances. For instance, climate change is projected to increase drought conditions that will exacerbate wildfire activity and bark beetle outbreaks. This may make it difficult to maintain fuel levels and reduce tree stress at the landscape level. Furthermore, we found that response of individual tree species to each disturbance type may counterbalance the effects of climate change on landscape level carbon. For example, post-disturbance recruitment in forest gaps of nearby fire tolerant tree species or those not targeted by host-specific insects will, to an extent, restore live carbon lost from disturbance. However, direct climate effects on tree species (such as changes in forest growth and establishment) were less important for determining overall forest growth and carbon storage potential than the more immediate impacts from bark beetles and wildfires. We found little to no overlap of insect outbreaks and wildfires, likely due to the concentration of wildfire ignitions nearby human settlement and infrastructure and high densities of insect tree hosts throughout the basin. Future forest management has the potential to increase forest resilience to future wildfires, particularly if treatments are targeted in high-ignition areas, but this effectiveness may become reduced in future climate-fire scenarios with increased fire frequency and a dramatic expansion of high fire risk conditions across space and time. This study highlights the importance of understanding legacy effects of past land-use and future climate-driven disturbances that will alter the way we manage our forested landscapes in the LTB.

SOIL QUALITY AND FIRE – WHAT HAVE WE LEARNED?

Matt Busse, USDA Forest Service, Pacific Southwest Research Station

Soils are beautiful. They sustain our terrestrial ecosystems, help fuel plant growth, and govern key ecosystem services such as the storage and provision of clean water, degradation of toxic compounds, and regulation of greenhouse gases. Although visually dull and commonplace to many (dirt), soils are an outrageously complex media of pliable physical properties, chemical reactions, and nearly unsurpassed biological diversity that can be temporarily or, in extreme cases, permanently altered by fire. Excess soil nutrient release to stream water is a particular concern in the Lake Tahoe Basin, as high nitrogen and phosphorus concentrations have been detected in surface water following wildfire. Additional questions about pile burning within riparian zones have been raised due to the anticipated effects of severe burning on soil and water quality. In both cases, published findings indicate that Lake Tahoe Basin soils effectively buffer or limit off-site nutrient release following wildfire or pile burning. Fire effects on soil quality have also been well studied across a diversity of soils and forest vegetation types throughout the western United States. The majority of studies show a benign effect of prescribed fire on soil chemical, physical, and biological functions except on vulnerable sites with either low nutrient capital (infertile soils) or high erosion potential. The use of mixed-severity burning is a consideration on such sites to protect soil quality (prevent excess soil or nutrient loss) while meeting fuel reduction targets. Although the effect of wildfire on soil quality can be acute, especially regarding soil erosion, nutrient loss, and reduced water infiltration, the lessons learned are difficult to summarize because of the variety of site conditions (plant community type, vegetation recovery rate, slope, soil type, climate) both within and among fires. For this reason, the importance of local expertise in understanding the consequences of fire on soil quality cannot be understated.

USING PROVENANCE TEST DATA TO INFORM ECOLOGICAL RESTORATION IN THE TAHOE BASIN

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When ecological restoration projects involve reforestation, for example after a fire, the choice of what seeds to use for the project is critical. Traditionally, seed transfer in California (and hence the Tahoe Basin) is guided using the California Seed Zone map. This map was created in the 1960s, long before any discussions of climate change. This suggests the question of how effective is this map given today's changing climate? As part of our SNPMLA-funded project, we have been analyzing data from historic provenance tests to address this question. Provenance tests are plantings of trees from a wide range of collecting locations. These trees, all from different climates, are planted into a common garden setting, and compared for survival and growth. Here we present the results of our analyses of this data, comparing growth and survival in 4 planting sites of sugar pine, and 3 in ponderosa/Jeffrey pine across California and Oregon. In sugar pine, using a linear model that takes into account the spatial relationships between collecting sites, we found that the climate where the seeds were collected can be associated with performance in the planting sites, and that performance varied across growth stages of the trees, as well as planting sites. In ponderosa/Jeffrey pine, we analyzed the spring phenology of the trees to determine if different sources of trees have spring bud burst at different times, despite 30 years of growing in the same environment.

ASPEN RESTORATION IN A CHANGING CLIMATE

John-Pascal Berrill and Christa M. Dagley, Humboldt State University

Throughout the Lake Tahoe Basin, ecosystem values and services provided by healthy aspen stands are being lost as these stands undergo natural succession to mixed conifer.

The conifers regenerate successfully beneath aspen, grow taller than aspen, and become more crowded than aspen can endure. The diverse understory plant communities associated with aspen disappear with increasing conifer presence, in part due to the heavy shade cast by conifers but also due to changes below ground. Cutting numerous smaller conifers relieves some of the crowding but any remaining large conifers and their offspring quickly re-occupy growing space made available by cutting. Heavier cutting would prolong treatment longevity but generates too much down wood for piling and burning in remote areas. Proposed solutions include more frequent lighter cutting and associated pile burning of conifers, and leaving some larger cull conifers standing dead. In tandem with restoration and maintenance of existing aspen stands, we have initiated a genetic conservation and climate adaptation program for aspen to support assisted migration of aspen into newly disturbed areas near existing stands or to distant sites where the future climate is more amenable.

LANDSCAPE DESIGN –HOW HISTORIC FIRE, CURRENT FOREST CONDITIONS, AND FUTURE FOREST RESILIENCE SHAPES FOREST MANAGEMENT

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Landscapes in the Sierra Nevada have been impacted by large fires over the past few years. These fires are characterized by a high percentage of area where more than 90 percent of the vegetation was consumed with often large contiguous high severity patches. As the climate changes, the size and severity of fires are predicted to increase and shifts in current species assemblages are likely. This has prompted a need to focus management at the landscape scale and highlight the importance of future fire resilience. However, the post-fire management of burned areas has been given much less attention than other efforts in the Sierra Nevada. In these post-fire landscapes, particularly with regards to long term establishment of resilient forests, management is limited by two major issues: our capacity to predict how affected ecosystems will react to fire and the definition of management objectives for the burned area. In a recent fire, innovative spatial data, predictive models, and landscape strategies were used to guide restoration plans within the fire perimeter. These tools can also be used to plan for resilience in pre-disturbed forested landscapes. For example, historic vegetation maps and future bioclimatic envelope models were utilized to identify potential shifts in species composition. Additionally, new predictive models identified natural regeneration hotspots allowing management to exclude areas where desirable regeneration was likely to occur. The development of management guidelines, drawing on similar concepts, is necessary to assure that objectives are trending these forests to a more resilient condition.

BIODIVERSITY PAST, PRESENT AND FUTURE IN THE LAKE TAHOE BASIN

Patricia N. Manley, US Forest Service, Pacific Southwest Research Station, Placerville, CA

There has been a long-standing commitment within the Lake Tahoe basin to conserve the wild nature of this place, and biodiversity is the underpinning of its wildness. The integrated science plan for Lake Tahoe developed in 2000 identified a number of key information needs related to the role and value of biodiversity, the short- and long-term effects of various disturbances on biodiversity, and the development of meaningful measures and targets for biodiversity in the basin. Broadly, the highest priority questions were those regarding the amount and distribution of habitat needed, the target composition and structure of plant and animal communities, the path to restoring forest resilience, and the potential impacts to old-forest associated species that depend on higher canopy cover and complex forest structure. Specific priority information needs included: 1) develop and test new approaches to silviculture that reduced the risk of fire while maintaining habitat; 2) more comprehensive data on the status, reference conditions, restoration effectiveness, and the development of performance measures for special communities including aspen; 3) greater understanding of the mechanisms driving the impacts of urban development and recreation and how to mitigate or raise thresholds for biodiversity; 4) ascertain disturbance thresholds for recreation for sensitive wildlife species such as marten and northern goshawk; 5) reliable models of potential responses of species to projected climate change scenarios; and 6) the ability to effectively measure, monitor, and interpret status and change in performance measures for habitat conditions and biodiversity. Some of these questions have been addressed, and additional questions have been posed since 2000. What have we learned that can catapult our learning and scientific foundation ahead of the demand to inform and support conservation and restoration?

BIOLOGICAL DIVERSITY MODELING, MEASUREMENT, AND ASSESSMENT

Angela White, USDA Forest Service, Pacific Southwest Research Station

Managers frequently use single species, or subsets of species, to make monitoring and evaluation of conservation efforts more manageable and efficient. Selection of a species or species-group should be based on their ability to serve as an indicator of ecosystem integrity and because their response to changes in the system can be generalized to a broader set of species. Using a multi-species hierarchical model we explore applications of the focal species concept – species that represent ecological conditions, which in turn support biological diversity – to bird occupancy data collected in the Lake Tahoe Basin. We further test whether focal species selected would help us manage for ecological resilience by evaluating whether habitat associations were consistent across a 10-year sampling interval. Our results indicate that few species were strongly associated with local elements of forest structure, although we did find that over the 10 year timeframe there was consistency in response for most species that were strongly associated with specific habitat conditions. Co-occurrence patterns of species were not entirely consistent with species habitat associations, indicating that additional information on biodiversity and ecosystem resilience can be gleaned by tracking changes in composition and strength of co-occurrence within an among suites of focal species.

NO SEVEN-YEAR ITCH: BLACK-BACKED WOODPECKERS STILL NESTING IN THE ANGORA FIRE

Gina Tarbill, USDA Forest Service, The Oak Ridge Institute for Science and Education

Changes in climate are predicted to lead to warmer temperatures and less precipitation in the Sierra Nevada, potentially increasing risk of large, high severity fire. Fire creates habitat for many species by producing snags and increasing shrub cover, both of which provide nesting, denning and foraging opportunities for many wildlife species. Several species of woodpeckers readily use burned forests and act as ecosystem engineers by creating cavities that are used by several species of birds and small mammals. One of these species, the black-backed woodpecker, is considered an indicator of burned, snag-rich forests and may depend upon fire-created habitat. Research from other regions indicates that this ephemeral habitat is only occupied by black-backed woodpeckers for 3-5 years post-fire and that nesting densities of these woodpeckers decrease significantly in salvage logged areas; however there is little research in the Sierra Nevada. The Angora fire burned in 2007 was salvage logged in 2012, offering the unique opportunity to study how time since fire, logging, and wildlife retention prescriptions affect nest density and selection black-backed woodpeckers. We nest searched before and after logging and found that black-backed woodpeckers still nested at relatively high densities in the seventh year after fire. Although woodpeckers avoided areas that had been logged, they did use snags adjacent to logged areas, suggesting that as long as areas with dense snag stands were available, black-backed woodpeckers would utilize them. This indicates that burned forests of the Sierra Nevada are unique in providing long-term habitat for black-backed woodpeckers, perhaps due to the high diversity of trees which die and decay at different rates, continuously supplying habitat for nesting black-backed woodpeckers and their prey, wood-boring beetles.

SMALL MAMMAL COMMUNITY CONSERVATION AND FIRE

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Our understanding of how small mammals use forested habitat relies heavily on studies in systems not naturally prone to frequent disturbances. Small mammals that evolved in frequent-fire forests, however, may be less restricted to specific habitat conditions due to the instability of these resources in time and space. We investigate how canopy cover and the volume of coarse woody debris (CWD) impact abundance of eight small mammal species across 23 sites in the Tahoe basin. Canopy cover and CWD had strong positive associations with abundance of deer mice, and influenced populations of several other species negatively. Despite these habitat associations, the small mammal community showed spatial and temporal variation in dominant species suggesting that species were flexible in their use of habitat. This dominance of generalist species has frequently been interpreted as a result of anthropogenic homogenization of forests. We propose the alternative hypothesis that the small mammal community of the Tahoe basin is generalist-dominated due to the historical frequent-fire regime. While further research is needed to disentangle these two hypotheses, the latter would imply that fire needs to be reintroduced into the system to maintain its small mammal community.

HABITAT FRAGMENTATION AND WINTER SKI RECREATION ACTIVITIES AFFECT MOVEMENT AND SEASONAL HABITAT USE BY PACIFIC MARTENS IN THE LAKE TAHOE REGION OF CALIFORNIA

Keith M. Slauson, William Zielinski, USDA Forest Service, Pacific Southwest Research Station

We investigated the effects of fragmentation from ski area development and winter recreation activities on movement, occupancy, and density of Pacific martens (Martes caurina) in the Lake Tahoe region of California and Nevada by comparing 3 ski and 3 control study areas. We surveyed martens using hair snares and live traps during spring-summer and winter seasons from 2009-2011. Martens selectively moved between remnant forest patches with the shortest crossing distances in open, non-forested ski runs in both seasons, with females selecting shorter crossings than males. During spring-summer, occupancy rates were similar between habitat within or outside of ski operations areas. However, in winter occupancy was reduced from 88% outside to 52% inside ski area operations boundaries and reduced detection probabilities indicated reduced frequency of use of habitat in operations areas in winter. Marten density did not differ between ski areas and controls during spring, but during winter female density declined at ski areas by 63% and was < 50% of female density at controls in winter. This suggests females seasonally avoid habitat in ski areas by shifting their habitat use to areas outside ski operations boundaries. Ski recreation may not be incompatible with marten habitat use, but habitat fragmentation from ski areas affects marten movement and recreation activities affect winter habitat use. Integrating the importance of habitat connectivity, maintaining networks of short ski runs crossings linking habitat in and out of ski areas, into ski area management will be important for maintaining or improving marten persistence at developed ski areas.

ECOLOGICAL TRADEOFFS AMONG FUEL TREATMENT STRATEGIES IN MIXED-CONIFER FORESTS

Jonathan Long, Jens T. Stevens, Brandon M. Collins, Angela White, Lee Tarnay, Susan Prichard, Malcolm North, Roger Ottmar
USDA Forest Service Pacific Southwest Research Station, University of California Davis, USDA Forest Service Pacific Northwest Research Station

We integrated commonly used modeling tools and Tahoe-specific datasets to evaluate tradeoffs among forest management strategies within the Ward and Blackwood watersheds of Lake Tahoe in terms of reducing fire hazard, maintaining diversity of native bird species, and moderating smoke impacts (considered in a separate presentation). We simulated three strategies that varied in treatment placement and prescription: (1) fuel reduction in the Wildland Urban Interface (WUI) zone (2) high fire hazard areas throughout the watershed, and (3) areas of greatest departure from reference tree densities. We restricted the area treated in each strategy to 13% of the total watershed based on the area planned for treatment in a 2006 fuels management strategy for the watershed. Simulated treatment effects, specifically reductions in canopy cover, had minimal effects of the avian community. However, the departure-based treatment did provide a slight benefit in terms of increased wildlife diversity when compared to the other treatment strategies. These modeling results showing a relatively muted effect on wildlife are consistent with recent field studies. Simulations of a hypothesized wildfire starting at the top of the Blackwood watershed found that expected fire behavior was moderate even under 97th percentile weather conditions without any additional treatments since 2005. Each treatment strategy decreased the area likely to burn at high severity, with the fire hazard reduction strategy resulting in the largest decrease (44%), followed by the WUI strategy (33%), and the density-restoration strategy (11%). The results suggest that there are opportunities to judiciously treat the forests in ways that could mitigate the undesirable impacts of a more extreme wildfire, restore forest structure, and also facilitate greater use of managed fire.

TWENTY YEARS OF CHANGE IN THE UNDERSTORY CHARACTERISTICS OF PRESCRIBED BURNED AND PASSIVELY MANAGED FORESTS ON THE WEST SHORE OF LAKE TAHOE

Svetlana Yegorova, Daniel Shaw, Rich Adams, California State Parks

California State Parks established a prescribed burning program in 1984 with the goal to re-introduce fire as a natural process and reduce fuel loading in the parks in the Lake Tahoe basin. Overstory and understory characteristics were monitored for twenty years in 15 treated (first entry prescribed fire) and 12 control (untreated) plots. Understory species richness varied and steadily increased in both treatment and control plots. There was no statistical difference in species richness between treatment and control plots by year twenty. Although species richness was similar, understory species composition, as measured by species frequency, differed in treatment and control plots. Ceanothus cordulatus and Arctostaphylos patula, whose germination is known to be stimulated by fire, were the most frequently found species in treated plots. Kelloggia galioides and Quercus vaccinifolia, a late-successional species in the absence of fire, were the most frequent species in control plots. Treatment and control plots had species uniquely associated with them, suggesting that both types of management provided distinct habitat types for understory species and contributed to the overall species richness of the study area. High variability of species richness within treated and control plot groups suggests that other ecological processes are influencing the outcome of management on the understory, and that variability in the understory is to be expected when measuring management outcomes. Twenty years of observations suggest that in Sierran mixed-conifer forests characterized by a century of fire suppression, both prescribed burning and passive management may be needed to maintain the full suite of species in the understory.

WHITE PINE BLISTER RUST, HOST DISEASE RESISTANCE, CLIMATE, AND PROGNOSES FOR SUSTAINABILITY AND SURVIVAL OF SUGAR PINE, WESTERN WHITE PINE, AND WHITEBARK PINE IN THE LAKE TAHOE BASIN

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The five-needle pines native to the Tahoe Basin ¬ sugar, western white, and whitebark ¬ are distributed from lakeshore to the upper rim, with sugar pine at lower to mid-elevations, western white at mid to upper elevations, and whitebark at or near the summits. All are charismatic species that contribute to the scenic beauty that draws visitors to the Lake. All three are susceptible to the blister rust fungus, Cronartium ribicola. To complete its life cycle, the pathogen requires two hosts, a 5-needle pine and a member of the genus Ribes. The pathogen was first recorded at Tahoe in the 1950s and is now distributed nearly everywhere its hosts occur. We report on present infection frequencies for the three pine hosts, on the modes of resistance to or tolerance of the pathogen for each, and, for sugar and western white pine, frequencies of genes that confer simply-inherited, complete resistance. In whitebark pine, some individuals exhibit tolerance to the pathogen, which favors their survival despite infection. Effects of a wetter climate are likely to alter the fecundity, growth, and distributions of the three pine hosts, as well as those of the alternate host Ribes, potentially leading to more conducive conditions for infection than at present. Greater aridity, however, might tend to favor the plant hosts in the pathosystem, since the temperatures and humidity during Spring pine-to-Ribes infection, Summer Ribes-to-Ribes spread, and Fall Ribes-to-pine reinfection could well be less conducive than at present.

A Tahoe Without Snow? Predicting and Adapting to Less Snow in the Tahoe Basin

USING OBSERVATIONS, MODELS AND REMOTE SENSING TO UNDERSTAND WINTER PRECIPITATION DYNAMICS IN THE TAHOE BASIN

Seshadri Rajagopal[1], Rich Niswonger[2], Justin Huntington[1], Charles Morton[1]
1) Desert Research Institute, 2) U.S. Geological Survey

Precipitation in the winter, which predominantly falls as snow in the headwaters, is a significant driver of hydrology in the Tahoe Basin and impacts ecology, water resources decisions on the Truckee River from Lake Tahoe to Pyramid Lake. Hence, understanding the dynamics of observed winter precipitation in the headwaters is critical to knowing the water availability in the basin for multiple competing uses. Observations of precipitation are limited to nine stations in the Tahoe Basin which were used in developing a watershed hydrology model that is physically based and used to simulate basin wide snow accumulation and melt. One of the model outputs has been validated against remotely sensed snow cover area and the results compare well. Both observations and model output are used as tools to understand the historical observed winter precipitation dynamics in the Tahoe Basin. Research questions, such as 1) What proportion of the winter storms is due to atmospheric rivers and how much snow do these storms contribute to the seasonal snowpack?, 2) Why is there a lack of snow in the winter in recent years? 3) Can we use the lake stage to infer winter precipitation amount in the basin? will be answered in this presentation.

IMPLICATIONS OF SNOWPACK DECLINE ON ENVIRONMENTAL RESOURCES IN THE TAHOE REGION

Lorrie Flint, Alan Flint, U.S. Geological Survey

Reductions in snowpack in the Tahoe region have implications for water supply, forest health, environmental flows and landscape stress, including wildfire risk. A warming climate results in not only a diminished snowpack but earlier timing of springtime snowmelt, which changes the timing of available annual water supply and lengthens the dry season. Changes in total precipitation have been negligible over the region, however with increases in air temperature of 1 to 1.5C over the last 40 years have resulted in more rain and less snow. The lowest snowpack on record occurred in 2015. Future projections all point to warming and further declines in snow. One of the biggest implications of a decreased snowpack is the change from spring runoff to winter runoff and a longer dry season. The estimated accumulation of deficit over the water year (climatic water deficit = potential minus actual evapotranspiration) has risen nearly 20% over the last 3 decades. This deficit causes additional stresses to the landscape, forest die-off, increases in wildfire risk and erodability, as well as losses in replenishment and storage of water supply. Whether recharge increases or decreases with losses of snowpack is primarily a function of the permeability of the underlying geologic materials. Basins underlain with glacial till, for example have shown increases in recharge with resulting sustenance of summer baseflows, whereas baseflows originating from basins underlain by granite have shown reduced recharge and decreases in baseflows.

HYDROLOGIC RESPONSE TO CLIMATE CHANGE AT A FINE SCALE IN THE TAHOE REGION: TOOLS FOR ADAPTING TO CLIMATIC EXTREMES

Alan Flint, Lorrie Flint, U.S. Geological Survey

Impacts to water supply and the environment as a result of changing climate are being felt in a broad range of sectors, from water supply management and wildfire to fisheries and conservation. Ongoing drought conditions in California are highlighting the value of adaptation and preparedness with regard to climatic extremes. We have developed a California statewide product that translates changes in climate to hydrologic response (recharge, runoff, snow processes, landscape demand) on a monthly time step and at a fine spatial scale that is calibrated to the historical record (with monthly updates), and simulated for 18 future climate scenarios. We will present a series of case studies focused on the Tahoe region to illustrate the utility of this product to provide regional information to aid the planning and develop adaptation alternatives with regard to extreme conditions such as drought and floods that are ongoing and projected to increase. Case studies will include examples of projected changes in water supply, changes in landscape demand and vegetation stress, including their potential effects on wildfire risk, tree recruitment, and tree mortality throughout the Sierra Nevada and the Tahoe region. The data sets are available on-line (http://ca.water.usgs.gov/projects/reg_hydro/).

CHARACTERIZING SPATIAL VARIABILITY OF SNOW WATER EQUIVALENT USING PRESSURE SENSORS

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Measurement of snow water equivalent (SWE) with pressure sensors in the Snake Range, Nevada shows both spatial and temporal variability in small catchment areas. Two sets of co-located sensors attached to a climate station in a 3300m elevation subalpine woodland were compared across sun-exposed and shaded conditions. Results show that there is similar response to accumulation and ablation, but total SWE is different between the sets of sensors located less than 10 meters apart. Further variability in SWE exists between the sensors that were within 2 meters of each other. Continuous electronic monitoring of snow depth at the sensors was used to estimate snow density. After initial accumulation, density is shown to shift over time with an inverse relationship to changes in snow depth. Manual snow cores taken at the study site also showed the same depth-to-density relationship, as the snow depth fluctuated within the micro-topography of the site. Spatial variability is not only present in the sensors located <2m apart, but also in samples taken at ≈0.2-1m intervals thru the sensors. The manual snow cores were also used to define a correlation length and create a sampling strategy to estimate SWE in comparable settings. Statistical resampling suggests that ten samples taken at a minimum of 0.8 meter intervals are needed to estimate mean SWE.

2015: LAKE TAHOE'S LOWEST SNOW IN OVER A CENTURY OF MEASUREMENT

Jeff Anderson, USDA Natural Resources Conservation Service, Reno, NV

The Natural Resources Conservation Service (NRCS), with help from its partners, is responsible for monitoring the snowpack within the Lake Tahoe Basin and forecasting the spring rise of Lake Tahoe's water surface elevation. The efforts of the NRCS continues the legacy of Dr. James E. Church who pioneered snow measurement techniques in the early 1900s. Dr. Church installed a number of snow courses within the Lake Tahoe Basin and some of these continue to be measured today resulting in over a century of data. This is the longest snow water dataset in the western United States. In the late 1970s and early 1980s the NRCS began installing automated SNOTEL weather stations to collect daily snow water content values using snow pillows. Based on snow course and SNOTEL measurements made April 1, 2015 the winter of 2015 set a new low for seasonal snow water accumulation in the Lake Tahoe basin.

Protecting Lake Tahoe: Aquatic Ecosystem Science Informing Management Decisions

THE IMPORTANCE OF THE HYPORHEIC ZONE IN NUTRIENT TRANSFORMATIONS ALONG THE NEARSHORE LAKE TAHOE

Ramon Naranjo, Richard Niswonger, David Smith, U.S. Geological Survey, Nevada Water Science Center

A significant amount of resources have been allocated towards evaluating the nutrients associated with surface water runoff from natural and urbanized watersheds in the Lake Tahoe Basin. Nutrients (nitrogen and phosphorus) are of importance to nearshore biomass production as increased in nutrient loads contribute to increases in primary productivity. However, limited data has been collected from subsurface areas near the lake to associate the contributions of nutrients from groundwater or hyporheic zones. The purpose of this study were to characterize subsurface flow and nutrient concentrations to understand the role of the hyporheic zones in barrier beach and stream environments along the nearshore. A synoptic evaluation of flow and nutrient concentrations in the hyporheic zone of two distinct systems was carried out in September 2012 and in 2013. Continuous monitoring of subsurface temperatures was collected along a barrier beach at Marlette Creek near chimney beach and beneath the streambed at Incline creek to characterize the flow paths and rates. Multi-depth sampling of nitrogen and phosphorus were taken to estimate the spatial variability beneath the water table (Marlette)

and the streambed (Incline). This investigation highlights the importance of combining the understanding of subsurface flow and wave action on nutrient transport along the shoreline. The results of this study allow us to develop nutrient conceptual models for the hyporheic zones of barrier beaches and streams at the shoreline of Lake Tahoe to improve monitoring and assessment of nutrient loads. Ongoing efforts towards understanding nutrient-algal relationships along the nearshore of Ward Creek will be also be presented.

EVALUATION OF NEARSHORE WATER CLARITY CONDITIONS AT LAKE TAHOE

Angela Stevens[1], Brian Fitzgerald[1], Alan Heyvaert[1], Ken McGwire[1], Sudeep Chandra[2], Rick Susfalk[1]
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Although the waters of Lake Tahoe are some of the clearest in the world, the clarity of the lake has been decreasing over time. Long-term monitoring of water clarity has been conducted in the pelagic zone of Lake Tahoe, but water clarity in the nearshore or littoral zone has not been studied as extensively. The nearshore is important for lake clarity as it is the zone where most clarity reducing sediments, nutrients and materials enter the lake. Both the landscape and land use varies substantially around the nearshore of Lake Tahoe, from nearly pristine subalpine forest to heavily urbanized and developed areas. This research aims to analyze available nearshore water clarity data, examine factors that may contribute to spatial variation in nearshore water clarity, evaluate nearshore water clarity on a seasonal basis, and identify potential targets for management. Turbidity and transmissivity data were collected in 2008, 2009, 2012, 2014, and 2015 using a specially equipped research vessel built for year-around use in Lake Tahoe's shallow nearshore zone. These water clarity conditions were averaged over multiple runs for the period of record and across a 1-kilometer scale to better indicate long-term trends for the entirety of Lake Tahoe's nearshore.

TRENDS IN NITROGEN AND PHOSPHORUS CONCENTRATIONS AND FLUXES IN SIX STREAMS ENTERING LAKE TAHOE, CALIFORNIA: EFFECTIVENESS OF BEST MANAGEMENT PRACTICES

Joseph Domagalski, U.S. Geological Survey, California Water Science Center, Juliet Hutchins, California State University, Sacramento

Lake Tahoe, a popular national resource for recreational and scenic attractions is impaired due to the input of excess fine sediment and nutrients from rivers and streams, resulting in a reduction in lake clarity. In order to reduce nutrient and sediment loading, best management practices (BMPs) have been implemented throughout the watershed. A trend analysis of water quality and discharge collected during the late 1980's through 2008 was completed to understand the effectiveness of the BMPs. The analysis confirms that nutrient loading is influenced strongly by season, especially spring runoff from snowmelt. The highest total nitrogen concentrations and loads occurred in the late 1980's and early 1990's, typically during high flows, followed by significant decreases in concentration or load in most streams in later years. Some observed increases in nitrogen during base flow may be attributable to increasing concentrations in the groundwater that discharges to the streams.

In contrast, total phosphorus has a less noticeable reduction, and in some cases appear stable or with slight increases, and therefore, largely uninfluenced by BMP implementations. The six streams are located around the lake, suggesting some regional improvements in stream quality compared to the conditions found the early 1990's. However, most of the streams in this study showed some increases in phosphorus concentrations after 2000. A possibility for this is that the existing BMPs require modification, or an increase in anthropogenic activities has surpassed the ability of the BMPs to prevent nutrients from entering the streams during high stream flows.

THE INFLUENCE OF STORMWATER, LAKE LEVEL MANAGEMENT, AND BOAT WAVES ON LAKE TAHOE'S NEARSHORE TRANSPARENCY

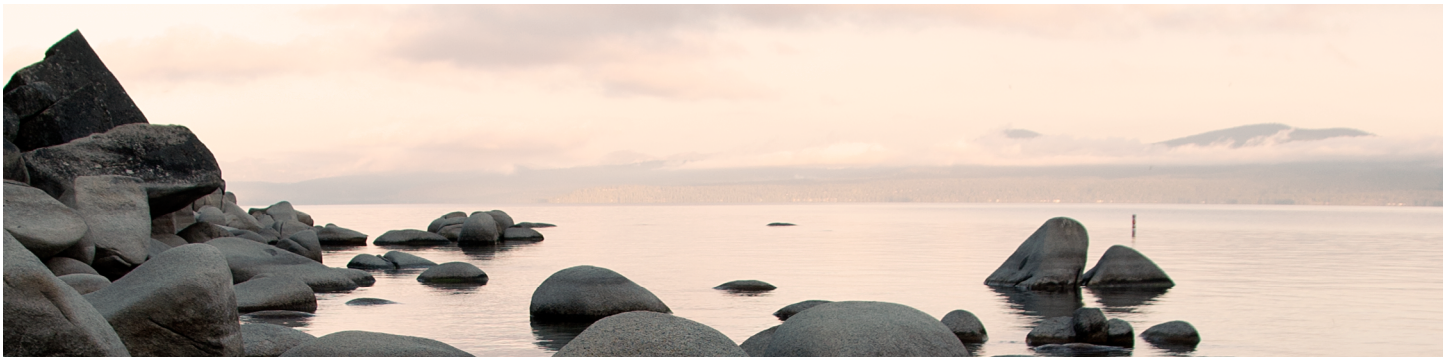
Michael Alexander, U.S. Forest Service, Russell Wigart, El Dorado County

The geographic position and physical setting surrounding Lake Tahoe combined with its exceptional size, depth, and transparency promises long standing prominence with residents and visitors. Urbanization is threatening ecological values of the region and resulted in a decrease in offshore transparency. Nearshore processes are not as well understood as the offshore and there is limited in-lake science statistically differentiating between natural and anthropogenic nearshore turbidity plumes. We investigated the influence of stormwater, lake level management, and boat waves on Lake Tahoe's Southern nearshore transparency by measuring stormwater turbidity, lake bed sediment, and wave height. During one winter and three summer seasons we measured daily morning and evening lake turbidity and horizontal black disc transparency from piers in South Lake Tahoe. By reviewing rain, lake level, and summer boating intensity between 2012 and 2014 we found nearshore transparency was significantly degraded by stormwater during wet weather, boating during summer dry weather, and that the management of lake level dominated interannual variability in nearshore transparency. Improved nearshore transparency will be realized if urban infiltration facilities accommodate 25 mm rain events and if summer nearshore lake bed sediment is buffered from resuspension by boating. April 1, 2015 the winter of 2015 set a new low for seasonal snow water accumulation in the Lake Tahoe basin.

IMPROVING ESTIMATES OF SUSPENDED AND DISSOLVED STREAMFLOW DISCHARGES TO LAKE TAHOE

Robert Coats, Hydroikos Ltd., Jack Lewis, Retired, U.S. Forest Service, Pacific Southwest Research Station

Since 1980, the Lake Tahoe Interagency Monitoring Program (LTIMP) has measured discharge and sampled water quality at up to twenty stations in Tahoe basin streams. Measured constituents have included total and fine suspended sediment and various forms of nitrogen and phosphorus. To identify the best load calculation methods for estimating each constituent, we resampled synthetic data sets and part of the historic record. Synthetic data sets were generated using turbidity, discharge, and time of year as explanatory variables. In general regression methods were more accurate than interpolating methods for suspended sediment, fine sediment, and total phosphorus. Simple rating curve estimates of load were improved by including lagged discharge and/or day number as predictors. Improvement was the greatest when turbidity was available as a predictor. Interpolating methods were more accurate for total Kjeldahl nitrogen and dissolved constituents. The composite method, a hybrid of regression and interpolation, appears to improve upon interpolating methods and should improve upon regression when serial correlation is present in the residuals. Using the best models, we recalculated total annual loads for all constituents and stations over the period of record, removing known biases due to historic changes in sampling and laboratory methods to the extent possible. We regressed total loads against total annual and maximum daily discharge, and tested for time trends in the residuals. Significant long-term downward trends were identified in some constituent loads and streams.



Photograph by Shelbi Whitehead

General Conference Information

REGISTRATION

Registration will be available at the Joe Crowley Student Union, Theater Box Office (3rd floor) on:

Monday, September 21, 2015
9:00 a.m. – 12:00 p.m.

MEETING LOCATION

The conference venue is the Joe Crowley Student Union on the campus of the University of Nevada, Reno.

FACILITY AMENITIES AND INFORMATION

The Joe Crowley Student Union offers a number of retail and food options including: Starbucks, u-Swirl, Greatfull Gardens, Keva Juice, Einstein Bros Bagels, Panda Express, Port of Subs, Nevada Wolf Shop (bookstore) and mini-mart, and Cantina del Lobo.

Photograph by Jean Dixon

MEALS AND BREAKS

Light refreshment breaks are provided each day. Lunch is on your own. There are several eating establishments at the Joe Crowley Student Union and near the University campus. The reception on Monday evening will offer appetizers, refreshments and a no-host bar.

CAMPUS PARKING

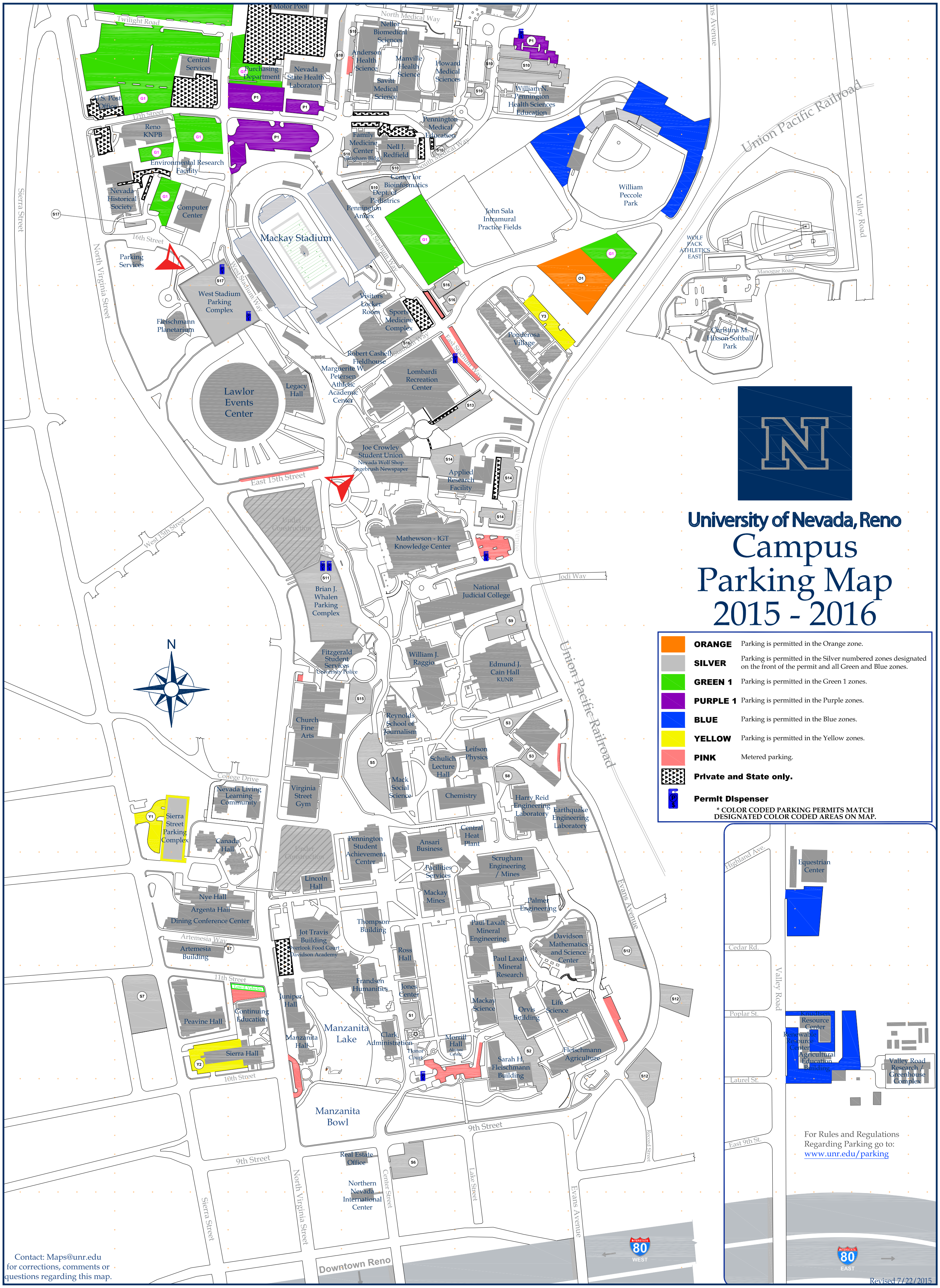
Complimentary event parking is available at the West Stadium Parking Garage on the east side of Virginia Street, just north of the Lawlor Events Center. Park on the top level and enter the provided event parking code (#9212315) at the kiosk by the elevators for a day use pass each day. It will dispense a parking pass to display on your dash. A campus map is provided on page 23.

LOCAL PUBLIC TRANSPORTATION

The Sierra Spirit is a bus that travels from downtown Reno to the University every 15 minutes from 7:00 a.m. to 7:00 p.m. every day of the week for $0.25 each way. Conference attendees can catch the northbound bus across Virginia Street on the east side of the Silver Legacy hotel. It is a yellow bus that is easily identified. Sierra Spirit is wheelchair accessible and offers free WiFi. A route map is included on page 25 of this program. RTC Ride is the local public transportation system. The main bus terminal is one block east of the Silver Legacy at 40 East 4th Street. To get to the University, take Route 7, which runs every 30 minutes, and get off at Lawlor Events Center. The Joe Crowley Student Union is near the Lawlor Events Center. The cost is $2 per ride. Exact change is required. RTC Ride is wheelchair accessible.

WIRELESS ACCESS

Wireless Internet access is available in the Joe Crowley Student Union. Please check at the registration desk for a guest user name and password.


University of Nevada, Reno
Campus Parking Map 2015 - 2016
ORANGE Parking is permitted in the Orange zone.
SILVER Parking is permitted in the Silver numbered zones designated on the front of the permit and all Green and Blue zones.
GREEN 1 Parking is permitted in the Green 1 zones.
PURPLE 1 Parking is permitted in the Purple zones.
BLUE Parking is permitted in the Blue zones.
YELLOW Parking is permitted in the Yellow zones.
PINK Metered parking.
Private and State only.
Permit Dispenser
* COLOR CODED PARKING PERMITS MATCH DESIGNATED COLOR CODED AREAS ON MAP.
For Rules and Regulations Regarding Parking go to: www.unr.edu/parking
Contact: Maps@unr.edu for corrections, comments or questions regarding this map.
Revised 7/22/2015
Motor Pool
Twilight Road
Central Services
Purchasing Department
Nevada State Health Laboratory
U.S. Post Office
17th Street
Reno KNPB
Environmental Research Facility
Nevada Historical Society
Computer Center
16th Street
Parking Services
West Stadium Parking Complex
Fleischmann Planetarium
Sierra Street
North Virginia Street
Nell J. Redfield Biomedical Sciences
Anderson Health Sciences
Manville Health Science
Howard Medical Sciences
Savitt Medical Science
North Medical Way
William N. Pennington Health Sciences Education
Pennington Medical Education
Family Medicine Center (Brigham Bldg)
Nell J. Redfield
South Medical Way
Center for Bioinformatics
Dept. of Pediatrics
Pennington Annex
Mackay Stadium
West Stadium Way
East Stadium Way
John Sala Intramural Practice Fields
William Peccole Park
Union Pacific Railroad
Valley Road
WOLF PACK ATHLETICS EAST
Manogue Road
Christina M. Hixson Softball Park
Ponderosa Village
Visitors Locker Room
Sports Medicine Complex
Robert Cashell Fieldhouse
Marguerite W. Petersen Athletic Academic Center
Lombardi Recreation Center
Lawlor Events Center
Legacy Hall
Joe Crowley Student Union
Nevada Wolf Shop
Sagebrush Newspaper
East 15th Street
West 15th Street
Applied Research Facility
Mathewson - IGT Knowledge Center
Brian J. Whalen Parking Complex
Jodi Way
National Judicial College
Fitzgerald Student Services
University Police
William J. Raggio
Edmund J. Cain Hall KUNR
Church Fine Arts
Reynolds School of Journalism
Leifson Physics
Schulich Lecture Hall
Mack Social Science
Chemistry
Harry Reid Engineering Laboratory
Earthquake Engineering Laboratory
College Drive
Nevada Living Learning Community
Virginia Street Gym
Sierra Street Parking Complex
Canada Hall
Pennington Student Achievement Center
Ansari Business
Central Heat Plant
Scrugham Engineering / Mines
Lincoln Hall
Facilities Services
Mackay Mines
Palmer Engineering
Nye Hall
Argenta Hall
Dining Conference Center
Artemesia Way
Artemesia Building
Thompson Building
Jot Travis Building
Overlook Food Court
Davidson Academy
Paul Laxalt Mineral Engineering
Davidson Mathematics and Science Center
Evans Avenue
Ross Hall
Paul Laxalt Mineral Research
11th Street
Frandsen Humanities
Jones Center
Juniper Hall
Continuing Education
Peavine Hall
Mackay Science
Orvis Building
Life Science
Manzanita Lake
Manzanita Hall
Clark Administration
Morrill Hall
Thoma Court
Sierra Hall
Fleischmann Agriculture
Sarah H. Fleischmann Building
10th Street
Manzanita Bowl
9th Street
Real Estate Office
Northern Nevada International Center
Center Street
Lake Street
Record Street
Downtown Reno
80 WEST
80 EAST
Highland Ave.
Equestrian Center
Cedar Rd.
Poplar St.
Laurel St.
East 9th St.
Resource Center
Renewable Resource Center
Agricultural Education Building
Valley Road Research / Greenhouse Complex
N
Under Construction

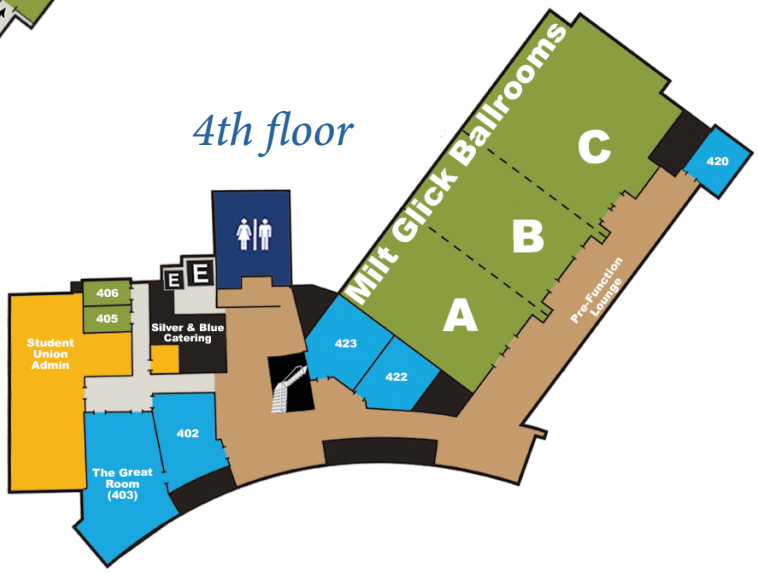
JOE CROWLEY STUDENT UNION FLOORPLANS

1st floor

2nd floor

3rd floor

4th floor



The **SIERRA SPIRIT** route will take you from Reno to the University of Nevada, Reno, all around downtown and back!

EVERY 15-20 MINUTES
Every Day
7:00 AM-7:00 PM

To learn more about the **SIERRA SPIRIT** route, call **348-RIDE** or visit **rtcwashoe.com**

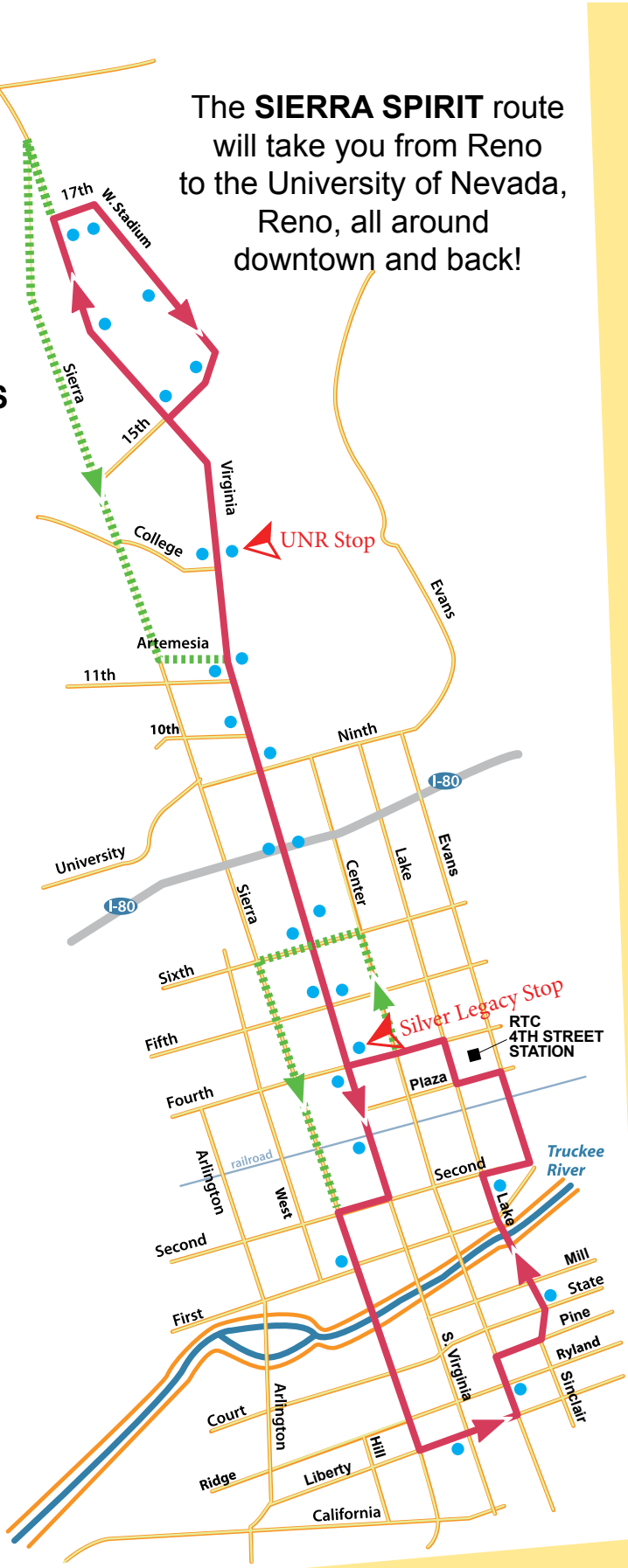
25¢ Regular fare
10¢ Reduced fare

Sierra Spirit Catch it here! Bus Stop

SIERRA SPIRIT bus stop locations

LEGEND

- SIERRA SPIRIT Route
- SIERRA SPIRIT Special Event Detour Routing (most events)
- SIERRA SPIRIT Route bus stop locations



NOTES

Photograph by Shelbi Whitehead