

Tahoe Science Center Tour Cheat Sheet

Welcome

- Welcome to the UC Davis Tahoe Science Center
- Introduction (name, tour info)
- Bathrooms needed? Visitor needs met?
- Where are you from?
- How much time do you have available?

Map (*Theme: Sense of Place*)

- Where are you staying? (point to location on the map)
- Where have you been? (find locations on the map)
- Where are we now? (point to Tahoe Science Center on the map)
- How Tahoe was formed (faults, earthquakes, volcanic activity, glaciers)
- Features – 3 faults, deepest point, landslide debris, glacially carved valleys/moraines, tributaries, Tahoe Keys, Angora fire
- Watershed outline (definition of a watershed)

Hands-On Interactive Exhibits

- Interactive activities (clarity, water pressure, light refraction, rocks, and erosion)
- Tahoe's plastic problem

Boat (*Theme: Sense of Place/Understanding Lake Tahoe*)

- Loss of clarity
- Pollutants are fine sediment (turn lake brown) and nutrients nitrogen and phosphorus (cause algae to grow and turn lake green)
- Research UC Davis does on the Research Vessel Le Conte (Secchi Disk, Van Dorn Sampler, Plankton Net, Research Buoys)

Research Photo Wall (*Theme: Science and Research*)

- Different types of research UC Davis does on Lake Tahoe
- Answers on corkboard in Docent Room and in the docent manual on pages 61-63

Lab (*Theme: Understanding, Discovering, and What Can Be Done?*)

- Food web (non-native introductions, decline of Lahontan Cutthroat Trout and Daphnia, and human impact)-
- Invasive species impacts (human impact)
- Aquariums (various ages of Lahontan Cutthroat Trout, native and nonnative species)

3D Theater

- Movies available:
 - “Lake Tahoe in Depth” (15 minutes)
 - “Mapping Change” (10 minutes)
 - “Following a Drop of Water” (2 minutes)
 - “Let’s Go Jump in the Lake” (9 minutes)
- 3D glasses required

Sandbox

- Shaping watersheds
- Making it rain (hold hand flat with outspread fingers)
- Build Lake Tahoe
- Insert 3D printed model of Lake Tahoe to fill lake (overflow, drought conditions result in different shape of lake, tsunami modeling)
- Learning how to read a topographic map (contour lines and contour intervals)
- Developed by UC Davis and now there are more than 720 Augmented Reality Sandbox exhibits around the world (visit <https://arsandbox.ucdavis.edu> for more information)

Other

- Kids’ corner with crayons and various take-home activity books
- Donation Buoy (the Tahoe Science Center is a non-profit organization that relies on donations to keep programs running)
- Lake Tahoe in Depth Touchscreen Exhibit (2 touchscreen monitors near women’s bathroom)
- Animal Tracks and “Who Left this Here?”
- Trees of Tahoe
- Green Building Exhibit (next to stairs)
- Forest Health and Fire Poster
- Take Care Flip Panel
- Take Care Pledge Wall
- Brochures, stickers, flyers by the front desk

Introduction to Tahoe Science Center Exhibits

The UC Davis Tahoe Environmental Research Center (TERC) worked with exhibit design consultants and a locally formed Education Steering Committee (ESC) to review the main themes and messages and determine ways to communicate these through interpretive exhibits. The following overarching themes and exhibit topics resulted.

Overarching Themes

1. A Sense of Place-----Welcome to This Place Called Lake Tahoe
2. Issues at Lake Tahoe-----Learning and Understanding
3. Science and Research-----Discovery
4. What Needs to Be Done-----Management and Engagement

Exhibit Topics by Theme

1. A Sense of Place = Welcome to This Place Called Lake Tahoe

- Why is Lake Tahoe special? Lake Tahoe is amazingly blue, very clear, extraordinarily deep, long residence time, and very old.
- The Lake Tahoe watershed was formed by faulting, volcanic activity, and glacial action. The area continues to be seismically active.
- What is a watershed? What is an airshed?
- Ecological history of lake.

2. Issues at Lake Tahoe = Learning and Understanding

- What are the main causes for concern at Lake Tahoe? How is Lake Tahoe changing?
- 3 main issues are clarity, climate change, and aquatic invasive species
- Lake Tahoe is losing water clarity.
- Erosion is a natural process; however, urbanization has caused the rate of erosion to speed up.
- The process of “eutrophication” (or the enrichment of a lake) is accelerating at Lake Tahoe.

3. Science and Research = Discovery

- Limnology is the study of lakes and inland waters.
- Lake systems are dynamic, driven by the sun, wind and weather patterns. (Physical Limnology)
- Lake Tahoe’s food web has been greatly altered. (Biological Limnology)
- Science and research have helped to protect Lake Tahoe. How is science helping us understand?
- Various environmental goals can sometimes come into conflict with each other.
- Global and long-term climate change impacts.
- Natural hazards – earthquakes, wildfires, tsunami potential, landslides, etc.

4. What Needs to Be Done = Management and Engagement

- Humans are part of the problem... and can be part of the solution.
- What can you do to help protect Lake Tahoe and other lakes, streams, and watershed systems?

Exhibit Interpretive Outline

The 100% Final Design Report (The Sibbett Group, June 2006) provides the interpretive outline for exhibits and exhibit elements of the Tahoe Science Center originally funded by the Thomas J. Long Foundation. This document is available for review at your request. The main outcomes are presented in the following table:

Ref. #	Exhibit Title	Topic	Outcomes & Messages
1.00	Donor Recognition & Information	Welcome to the Tahoe Science Center	<p>Receive an introduction and orientation to the UC Davis Tahoe Science Center. Learn about what to do and where to go in the building.</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Be welcomed to the Tahoe Science Center. • Become oriented to the building. • View the individuals and organizations that supported the Tahoe Science Center and the Tahoe Environmental research Center (TERC).

2.00	Welcome to the Tahoe Science Center	Welcome to the Tahoe Science Center	<p>Become familiar with the Tahoe Science Center and its relationship to TERC.</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Understand that they are entering the Tahoe Science Center. • Realize that the Education Center provides information about past discoveries, current research and conservation efforts to protect the clarity and natural resources of Lake Tahoe. • Discover that the Lake Tahoe Basin is a watershed (Tahoe Watershed Map Graphic).
3.00	The RV John LeConte / A Sense of Place	Lake Tahoe, Its Origin and Unique Characteristics	<p>Become familiar with Lake Tahoe's origin and its unique characteristics</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Become immersed in the research efforts at Lake Tahoe (Immersion Environment). • Be introduced to the field of limnology and that, limnologists at Lake Tahoe study how the lake works (A/V Program). • Understand that there is cause for concern from environmental changes that impact Lake Tahoe (A/V Program). • Realize that Lake Tahoe is losing water clarity (A/V Program). • Appreciate that Lake Tahoe is amazingly blue and extraordinarily deep (Photomural). • Discover that the Lake Tahoe Basin is a watershed (Graphic).

4.00	The Laboratory / Understanding Lake Tahoe	Lake Tahoe, its Environmental Threats	<p>Become familiar with Lake Tahoe's environmental threats and how the lake works.</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Become immersed in the research efforts at Lake Tahoe (Immersion Environment). • Understand that there is cause for concern from environmental changes that impact Lake Tahoe (A/V Program). • Discover that erosion is a natural process, but that urbanization has caused the rate of erosion to speed up at Lake Tahoe (A/V Program). • Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe (A/V Program). • Realize that Lake Tahoe's food web has been greatly altered (Interactive).
5.00	Research Photo Wall	Lake Tahoe, Its Ecological Protection	<p>Become familiar with the research efforts to protect the lake.</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Appreciate that science and research have helped to protect Lake Tahoe (Research Photo Wall). • Appreciate the number of scientific fields contributing to research at Lake Tahoe
6.00	Tahoe's Plastic Problem	UC Davis microplastic research and plastic pollution	<p>Become familiar with the plastic problem in Lake Tahoe.</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Learn the harm of single-use plastics • Plastics do not go away • The Resin Identification Codes (RIC) only show what type of plastic, not if it's recyclable or not • We must "turn off the tap" of plastic to stop plastic pollution

7.00	<p>Take Care Flip Panels</p> <p>Take Care Pledge Wall</p>	<p>Lake Tahoe, Its Protection</p>	<p>Become familiar with human efforts to protect Lake Tahoe</p> <p>Visitors will:</p> <ul style="list-style-type: none"> • Realize that humans are part of the problem and can be part of the solution. • Learn about what they can do to help protect Lake Tahoe and the watershed they live in. • Declare how they will help to preserve Lake Tahoe (Interactive Pledge and Voting).
8.00	3D Visualization Lab	<p>Lake Tahoe in Depth (3D movie)</p>	<p>Visitors will:</p> <ul style="list-style-type: none"> • Understand that Lake Tahoe was formed by faulting and volcanic activity. • Understand that lakes are dynamic systems driven by the sun, wind and weather patterns. • Be introduced to the ecological history of Lake Tahoe. • Understand that there are many environmental issues facing Lake Tahoe.
		<p>Let's Go Jump in the Lake (3D movie)</p>	<p>Visitors will:</p> <ul style="list-style-type: none"> • Understand seasonal effects on Lake Tahoe and its ecosystem. • Learn about Lake Tahoe's aquatic food web. • Be introduced to how climate change is altering the lake system.
		<p>Mapping Change in the Sierra Nevada Forests (3D movie)</p>	<p>Visitors will:</p> <ul style="list-style-type: none"> • Be introduced to historic and current mapping of the Sierra Nevada forests. • Understand how and why the forests have changed over recent years. • Learn about how climate change has and will affect the forests surrounding Lake Tahoe.
		<p>Follow Drop of Water (3D movie)</p>	<p>Visitors will:</p> <ul style="list-style-type: none"> • Understand what a watershed is. • Learn about how water travels through a watershed. • Learn about human impacts on a watershed.

Welcome Tour Groups and Individuals

Hello and Welcome

- My name is...
- We are glad you came today to visit the UC Davis Tahoe Science Center.

Gathering Information from Visitors

- Ask: Where are you from and what interests brought you to TERC?
- Ask: If visiting, where are you staying while at Lake Tahoe?
- Ask: How did you find out about us?
- Ask: How much time do you have today, and which tours are you interested in?

What to Expect

We offer three different tours:

- Tours of our Science Education Center.
- Tours of the North Tahoe Demonstration Garden.
- Green building tours of the Tahoe Center for Environmental Sciences.
- Each tour lasts between 30 and 60 minutes, but we can adjust the schedule to suit your interests.

Who are we?

- UC Davis Tahoe Science Center operated by the UC Davis Tahoe Environmental Research Center
 - Researchers in the lab on the third floor
 - Educators in the education center on the first floor
- The building itself is a collaboration with Sierra Nevada University, but the science center is designed, supported, funded, and operated by UC Davis.

Education Center Tour

- The Education Center tour lasts between 45 and 90 minutes (can also be shortened).
- Ask: How familiar are you with the Lake Tahoe area?
- Begin by introducing the lake at the watershed map. Ask: What is a watershed?
- Before moving to the boat, be sure to point out where we are located on the map as well as some other points of interest (this will help when at the 3D visualization lab).

- See Video Exhibit Talking Points and Discussion/Questions in the Docent Manual.

Demonstration Garden Tour:

- The full garden tour lasts 60 to 90 minutes (can also be shortened).
- Begin at the Trees of Tahoe exhibit. You can discuss the different types of trees commonly found in Tahoe before heading outside.
- Your starting point in the garden can vary. If you are following the cheat sheet guide, begin discussing the Trees of Tahoe on your way to the defensible space shed. From the shed, make your way through the garden towards the parking lot, stopping at the interpretive signs throughout the garden.
- Give visitors time to scan the interpretive signs and the surrounding environment. Use the signs to guide discussion and check for understanding.
- See the Garden Tour Cheat Sheet for talking points, and example discussion questions.
- Be sure to address as many of the talking points as time allows, but the order can be altered based on how you prefer to walk through the garden or what your visitors are inquiring about.

Green Building Tour (available upon request)

- The Green Building Center tour lasts between 45 and 60 minutes (can also be shortened).
- The building is “Green” – Ask: What does it mean to be a “green building”?
- This building received a Platinum award from the U.S. Green Building Council for “Leadership in Energy and Environmental Design” (LEED). This is the highest LEED award that a building can receive.
- Begin in front of the building by describing the site chosen for the building.
- See *Green Building Tour Talking Points* in the Docent Manual.

Before Visitors Leave

- Any questions?
- Please take the time to complete our **Visitor Exit Survey**
- Ways to be a part of the solution:
 - **Support the Tahoe Science Center through donations!** (Show them the donation buoy near the boat) Checks can be made out to “UC Regents”
 - QR Code to donation link
 - Carpool, bike, and use mass transportation
 - Leave no trace!

- For Residents, please share:
 - UC Davis TERC Newsletter
 - Top 10 Ways to Save Lake Tahoe (“Learn How You Can Help Save Lake Tahoe”)
 - What You Can Do to Keep Tahoe Blue
 - Best Management Practices (“Saving Lake Tahoe in Your Backyard”)
 - Defensive Space (“Get Defensive”)
 - Environmental Improvement Program (EIP)
- For Visitors, please share:
 - UC Davis TERC Newsletter
 - Top 10 Ways to Save Lake Tahoe (“Learn How You Can Help Save Lake Tahoe”)
 - What You Can Do to Keep Tahoe Blue
 - Tahoe Boat Inspections (“We’re All in This Boat Together”)
 - Trail maps
 - TART bus schedule
- All additional information materials are available next to the front desk.

Lake Tahoe Basin Watershed Map

Images from remotely sensed data can be used to investigate environmental changes. Work conducted at the UC Davis Tahoe Environmental Research Center uses this imagery to detect and differentiate vegetation, communities on land, temperature changes across the lake, and document subtle changes in the regional landscape over time.

This map is an artificially colored infrared IKONOS image. The IKONOS satellite sees objects as small as 3 feet! Taken in July 2002, we placed the image over a digital elevation model that represents the actual shape or topography of the ground. The bright green color has been artificially enhanced to highlight features of the watershed.



Talking Points

Creation of the Lake Tahoe Basin Watershed Map

- The map consists of two separate digital elevation models (or DEMs):
 - Topography of the watershed and surrounding areas from the USGS.
 - Bathymetry under the lake was obtained in 1998 using high-resolution multibeam-SONAR by the USGS.
- IKONOS satellite image draped over watershed is false color.

Water Movement in the Lake Tahoe Basin

- The colored area represents Lake Tahoe's watershed.
 - Ask if everyone understands the concept of a watershed (the area of land that drains to a common water body). This concept is very important and should be explained.
 - Any precipitation that falls within the colored area on the map will end up in Lake Tahoe, unless it evaporates or is taken up by plants first.
 - Examples of other well-defined (and much larger) watersheds include those of the Mississippi River-Missouri Drainage Basin, Great Lakes and St. Lawrence River Watershed, and California's Central Valley.
- One reason Lake Tahoe has remained so clear is the small size of its watershed in relation to the lake's size. Compare to other known watersheds.

- There are 63 different rivers and streams that flow into Lake Tahoe. Find the one where visitors live or are staying.
- Lake Tahoe's only outlet, the Truckee River, is located in Tahoe City. From here, water flows down through Reno and to Pyramid Lake. Pyramid Lake is known as a terminal lake because there is no outlet to carry the water further. Water from Lake Tahoe does not flow to the ocean but ends its journey in a desert lake.
- The Upper Truckee River flows through South Lake Tahoe and is the most urbanized part of the basin. It is responsible for 1/3 of the inflow into Lake Tahoe.

Formation of the Tahoe Basin

- Lake Tahoe and the surrounding mountains, streams, meadows, and cliffs offer a fascinating glimpse of geologic history. Our region was morphed by plate tectonics and sculpted by volcanoes and glaciers. Research continues re-writing that story and the exact timeline is still up for debate.
- One hundred million years ago, all the materials that would become the Lake Tahoe Basin and surrounding mountains, valleys, and formations sat at the bottom of a vast inland sea in a subduction zone.
- That sediment and a series of volcanoes sat on top of a massive magma chamber that would form the Sierra Nevada Batholith. Eventually, the batholith rose up from underneath the volcanoes and sediment, exposing the granite rock for which the Sierra Nevada is now famous in places like Yosemite, Desolation Wilderness, and Donner Summit.
- The Tahoe Basin began forming about 2 to 3 million years ago through fault movements of Tahoe's 3 main faults – the West Tahoe Fault, from modern-day Emerald Bay to Dollar Point, the Stateline Fault running south from Crystal Bay, and the Incline Village Fault running south from Incline Village.
- Normal faulting lifted the Carson Range on the east and the Sierra Nevada on the west.
- Between these two ranges, other blocks also dropped down forming a valley that would eventually become the Tahoe Basin.
- Volcanic uplifting events in the basin from Mt. Pluto to Mt. Rose also occurred.
- Glaciers sculpted the modern Tahoe's shape by cutting valleys and glacier moraine lakes.

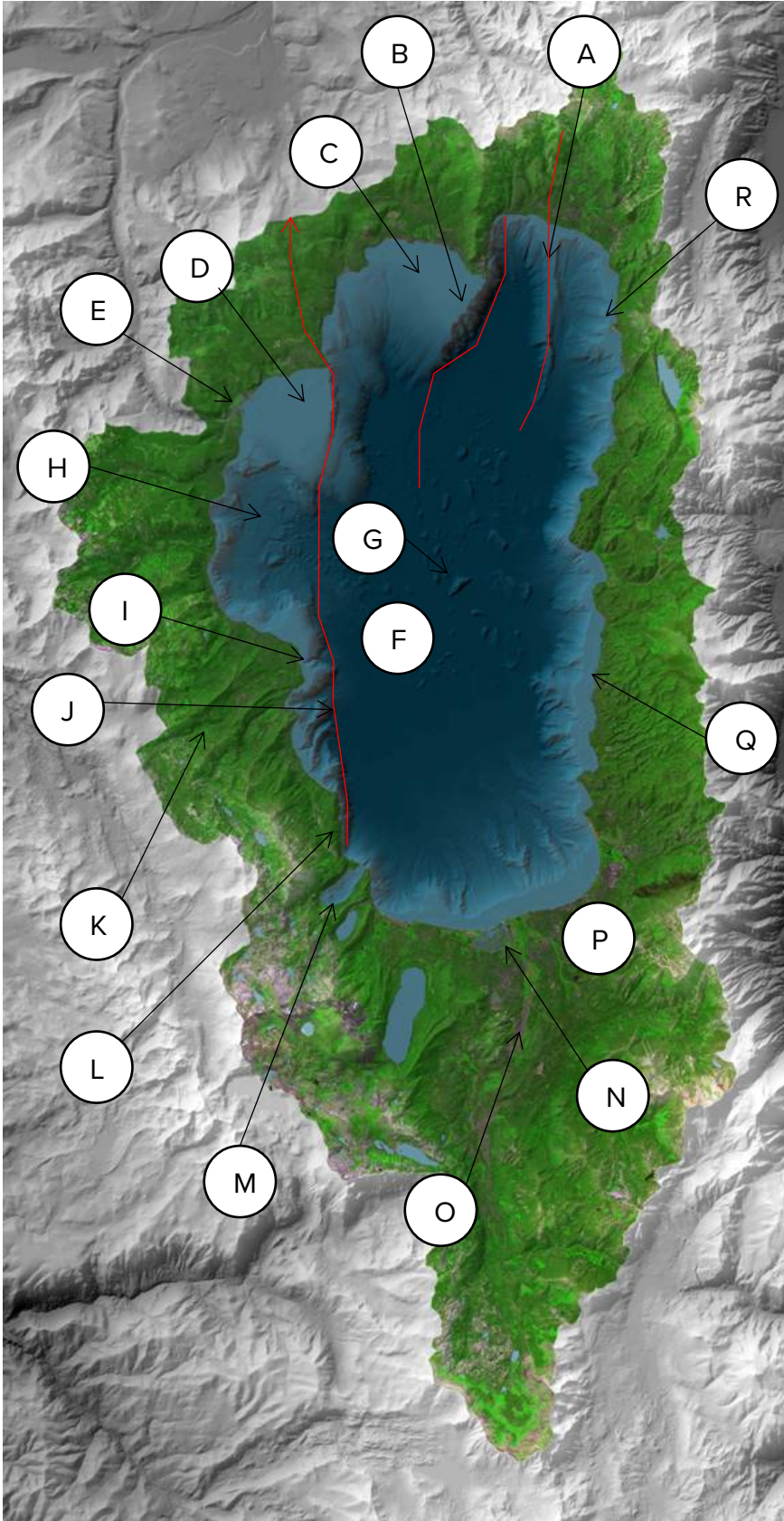
You Can Point Out:

- 3 normal faults run through the Tahoe Basin:
 - Incline Village Fault (runs through the middle of Crystal Bay)
 - Stateline Fault (runs along the west shore of Crystal Bay, with a very steep, straight 1,400-foot fault scarp (a steep bank or slope) from Stateline Point)
 - West Tahoe Fault (between Emerald Bay and Dollar Point)
- McKinney Bay Landslide/Tsunami and debris in the lake – Somewhere between 12,000 and 21,000 years ago an enormous underwater landslide started in McKinney Bay and sent tons of boulders, rocks, and soil plunging 1,500 feet to the lake bottom. The force scattered rock debris all the way across the lake floor. The energy released from this landslide resulted in a tsunami which destroyed every living thing surrounding the lake.
- The Gondola Fire, visible on this map, was a destructive fire in South Lake Tahoe which burned more than 600 acres in July 2002. The cause was a discarded cigarette butt tossed from the Heavenly Ski Resort Gondola.
- Angora Burn Area - The Angora Fire was a wind driven fire that started near North Upper Truckee Road subdivision near Angora Lakes, Fallen Leaf Lake, Echo Lake, and South Lake Tahoe, California on June 24, 2007, because of an illegal campfire. The fire burned 3,100 acres, destroyed 242 residences and 67 commercial structures, and damaged 35 other homes.
- Tahoe Keys in South Lake Tahoe - The Tahoe Keys is a housing development on the south shore constructed in the mid-1960's within the Upper Truckee Marsh. The Upper Truckee River once flowed through the Tahoe Keys, but was diverted to prevent flooding. The developed property is over 150 acres in size and contains two separate marinas.

Questions

- Can you find the burn scar left from the July 2002 Gondola Fire near Heavenly Valley?
- The largest wetland area in the basin used to be located where the Tahoe Keys is now. How has the loss of this large wetland affected Lake Tahoe?

Key Physical Features of the Tahoe Basin



- A. Incline Village Fault
- B. Stateline Fault
- C. Underwater Shallow shelf near Kings Beach
- D. Tahoe City Shelf
- E. Truckee River Outflow
- F. Sediment at the Bottom of Lake Tahoe
- G. Underwater Blocks
- H. McKinney Bay Underwater Landslide
- I. General Creek Sediment Plume
- J. West Shore Fault
- K. Glacially Carved Valleys
- L. Steep Area of D.L. Bliss State Park
- M. Emerald Bay
- N. Tahoe Keys
- O. Upper Truckee River
- P. South Lake Tahoe
- Q. Cave Rock
- R. Sand Harbor

Key Physical Features of the Tahoe Basin

- A. **Incline Village Fault:** *Heading south past the fault is the deepest part of the lake at 1,645 feet. You will notice giant ripple marks, some with 50 meters between them.*
- B. **Stateline Fault:** *Amazing snorkeling and a ~1,400-foot underwater cliff.*
- C. **Kings Beach Shelf:** *Underwater shallow shelf near Kings Beach*
- D. **Tahoe City shelf:** *Remaining shelf after landslide. May not have slid due to being composed of volcanic material instead of sediment, although could possibly be disrupted in a large (7.0 magnitude) earthquake.*
- E. **Truckee River:** *Tahoe's only outlet, 63 streams and rivers flow into the lake.*
- F. **Sediment at the bottom of the lake:** *The bottom is mostly flat but after years of sedimentation the layer of sediment that makes up the bottom is estimated to be almost double the depth of the water level.*
- G. **Underwater blocks:** *The largest block from the landslide is 1 km across. The blocks are composed of consolidated sediment.*
- H. **McKinney Bay underwater landslide:** *The McKinney Bay underwater landslide occurred somewhere between 12,000 and 21,000 years ago. A 7.0 magnitude earthquake is thought to have caused this land area to collapse. The displacement would have caused a large tsunami with waves as high as 100 to 300 feet tall. Seiche waves (where water would slosh back and forth) are estimated to have lasted for 24 hours following the initial tsunami.*
- I. **General Creek sediment plume:** *Clearly shows sediment coming from stream into lake and fault scarp cutting through it. Sediment plume to the left does not have fault cutting through it indicating a younger age.*
- J. **West Tahoe Fault:** *Runs the whole west side of the lake. See evidence of fault "slippage" or movement. This distinct fault through the sediment is evidence that the fault ruptured relatively recently as the fault cuts through it.*
- K. **Glacially carved valleys:** *Glaciers came through here in the Tahoe (100,000 years ago) and Tioga (50,000 years ago) ice ages. The land pushed by a glacier and deposited is called a "moraine" which you can see prominently above General Creek sediment plume.*

- L. **Steep area of D. L. Bliss State Park:** *great hiking spot.*
- M. **Emerald Bay:** *Just south of Emerald Bay is Cascade Lake, the larger lake is Fallen Leaf Lake. The ridge on the south side of Fallen Leaf Lake is Angora Ridge, the site of the 2007 fire that burned 260 homes. Observe that these are also glacially formed, and moraines are present here as well.*
- N. **Tahoe Keys:** *former wetland developed in the 1960's. Loss of filtering and warmer water creates favorable habitat for invasive species, some of which may have been dropped in lake from fish tanks.*
- O. **Upper Truckee River:** *Responsible for approximately one third of the inflow to the lake.*
- P. **South Lake Tahoe:** *Airport, Mackinaw/Lake Trout fishing just offshore. The fish also spawn here as they are exposed to the photic zone but are still protected by the erosional feature of the shelf. Sediment shelf here is similar to the west shore pre- landslide.*
- Q. Continue along east shore. Point out **Cave Rock:** *the remnant of a volcanic plug considered to be sacred by the Washoe Tribe.*
- R. Point out **Sand Harbor** and **Mount Rose** as you head back to Incline Village

For additional information, see the Geology Section of your Docent Manual (located in Additional Resources) for details about the Tahoe Timeline, Tahoe Geology, Sierra Nevada Geologic Time Scale and the Tsunami at Lake Tahoe.

Turning on the Science Center

Front Desk Computer

To use the front desk computer, press the two small power buttons on the computer and computer screen. The small computer unit is located on the floor below the desk (Fig. 1) and the power button will light up white. The monitor power button can be found on the right side of the computer screen behind the power button symbol (Fig. 2). Reach your finger around the right side to turn on. The username to access the computer is “TERCuser” and should already be selected. The password is keptahoeblue.

To turn off the front desk computer: Shut down all your programs. Go to the Windows icon on the bottom left of your screen and select [Shut Down]. Press the same power button on the computer screen to turn it off (Fig. 2) as well.



Figure 1



Figure 2

“Lake Tahoe in Depth” Touchscreen Exhibits

To turn on “Lake Tahoe in Depth” exhibits (Fig. 3), find the power button by running your hand along the bottom back underside of the touchscreen monitor. You can either feel for the slightly raised dot on the rightmost button on the underside of the TV or look underneath the TV monitors for a printed arrow sticker pointing to the location of the power button (Fig. 4 and 5). Press this button to turn on the touchscreen (Fig. 4). The monitor takes time to boot up so please be patient. Do the same on the other touchscreen monitor. Both exhibits should have a full screen display and look like the picture in figure 3.



If the internet browser window is visible, press the green maximize button on the browser once or twice as required to return it to full screen.

Turning it off: Find the same button used to turn on the monitor and press it one time to turn it off at the end of the docent shift (Fig. 3). The screen should go black.



Figure 3



Figure 4



Figure 5

“Shaping Watersheds” Augmented Reality (AR) Sandbox

To turn on the AR Sandbox, press the power button once on the projector above the exhibit (Fig. 6). It takes a while for the projector to warm up to full brightness, so give it time. It is working properly when there is a topographic map projected on the sand and virtual water flows onto the landscape when your hand is open above the virtual

landscape (five fingers separated and held about 1 foot above the sand). Turning it off: Press the power button twice to turn it off (Fig. 6). The projector should turn off and the topographic map projection will disappear when it is off.

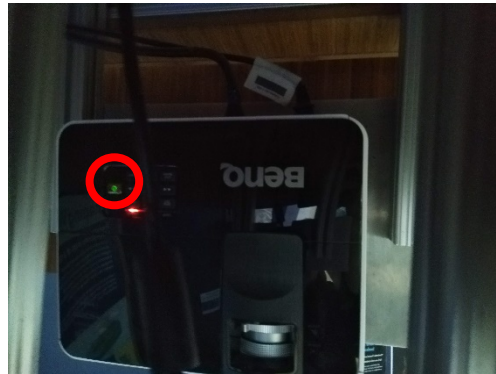


Figure 6

Aquarium Lights

To turn on the aquarium lights, hit the power switches located on the back right side of each tank light. There are four light switches total for the two aquariums against the wall) as shown in Fig. 7. The tank light on the lab counter is a sliding switch in the center (Fig. 8).

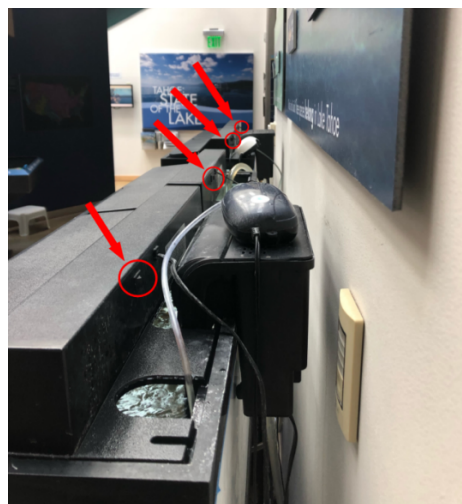


Figure 7



Figure 8

Microscope (Lab side)

First, remove the red dust cover from the microscope. Check the dial on the top left of the microscope and ensure that it is turned to the **DOC** position (Fig. 9). Place the object for magnification on the glass tray.

To turn on the TV screen above the microscope, press the power symbol (Fig. 10) on the bottom right of the screen.

To adjust the clarity of the image that is projected on screen, use the fine-tuning dial located at the neck of the microscope (Fig. 11). Alternate the dial back and forth and use trial and error to find the clearest image.



Figure 9

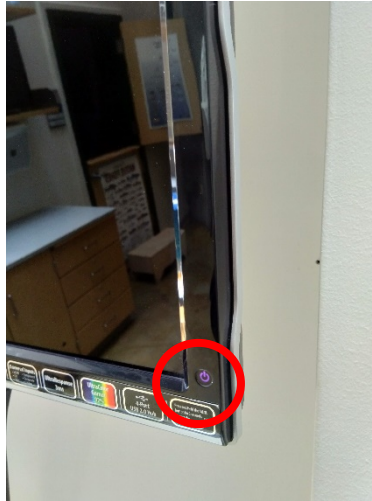


Figure 10



Figure 11

Use the forward most dial on the right side of the base of the microscope to adjust lighting by rotating and positioning the mirrors to reflecting the optimal lighting (Fig. 12, on the next page). Adjust these mirrors until you can see the figure on the TV. This is optional.

For additional lighting, you can turn on one or more lights. To turn on the microscope light, turn the dial on the back left side of the microscope toward the wall until it clicks, and the light comes on (Fig. 13). The more you turn it the brighter the spotlight becomes. If even more lighting is needed, turn on the extra lights to the left side of the microscope (Fig. 14).

Turning it off: If you turned on any of the lights, please turn these off (Fig. 13 and Fig. 14). For the TV press the power button (Fig. 10). Then place the red dust cover carefully on top of the microscope.

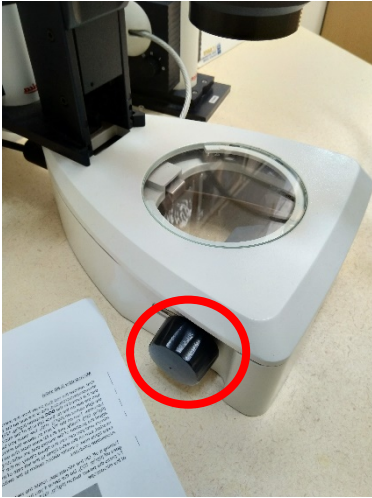


Figure 12



Figure 13



Figure 14

Large TV Monitor Next to Elevator

The large TV on the lab side located next to the elevator plays a muted continuous loop of field research video footage. The remote for this TV is located in the bottom drawer of the lab exhibit (Fig. 15).

To turn the TV on: Use the remote shown in Fig. 15 and 16 to turn on the TV. Push the green TV button and look for two very small green lights at the bottom right of the screen to turn on. Alternatively, the TV can be turned on by pressing the “Power” button located on the right side of the TV. Give the TV time to turn on.

To start the Blu-ray Player: The screen will either give you an option to select DVD-R VIDEO (as shown in Fig. 17) to start the video or remain blank. If the screen remains blank, the Blu-ray disc player is not on. To turn it on, press the “BD” button on the remote followed by the green “POWER” button and wait for the “Starting Blu-ray disc unit” screen to appear (Fig. 18). When it appears, select the DVD_R VIDEO icon and then press the play button. Sometimes you have to press the PLAY button more than once to cycle through the different options (BD Data, Video, and finally DVD-R VIDEO). When you have selected it, make sure it starts the video (Fig. 20).

You can use the double arrows above the play button to skip to the next or previous chapter. Note that the chapters are marked on the lower left side of the screen (Fig. 20). Make sure to return the remote to its original spot in the bottom drawer.

Turning TV OFF:

Press the green TV (Fig. 18) on the remote while pointing at the TV and then return the remote to its original spot. Alternatively, press the “Power” button on the right side of the TV.



Figure 15



Figure 16



Figure 17

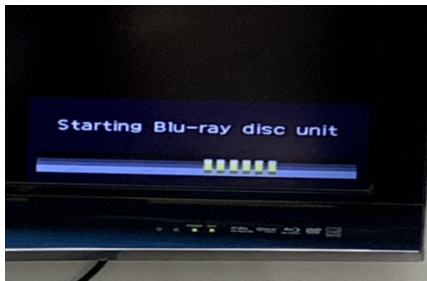


Figure 18



Figure 19

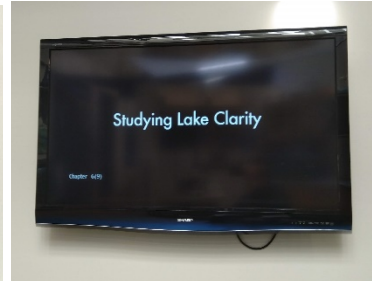


Figure 20

Operating the Video Exhibits

Control Panels for Exhibits: The small touch screens function as the new control panel for the video exhibits. Each exhibit has three videos you can choose from, but only staff and docents have access to change the settings, such as volume and subtitles.

Staff Access settings:

- ***[MASTER VOLUME +/-]** – controls volume level, recommended to use the volume on the main screen, not the master.
- [DISPLAY POWER]** – Turns the screens on and off. The “left” button is the smaller TV and the “right” is for the larger TV. You can turn these on or off separately.
- [SUBTITLES]** – Turns on English or Spanish subtitles or turns off subtitles.
- [QUIT PROGRAM]** – Stops the video that is playing.

**These buttons are currently disabled or not recommended for use.*



Figure 21

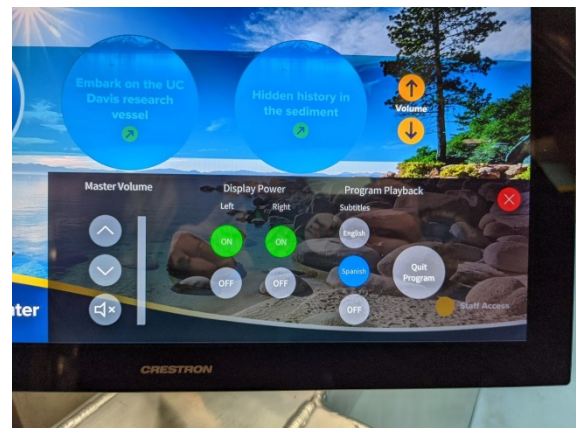


Figure 22

Turning the System On and Off

Tap on the touch screen to begin (Fig. 21). Once the screen wakes up you can select one of the three videos to watch. In order to access the video settings, press and hold the yellow circle next to “staff access” at the bottom right corner of the screen. After a few seconds a number pad will appear that says, “Enter PIN to continue”. The PIN is 2-5-8-3 (this spells BLUE on a phone number pad). The numbers will change order to prevent others from learning the pattern of the pin. Once you have typed in 2583 hit “Enter”, the bottom left button. The control settings will appear (Fig. 22). In the settings you can turn the screens (left and right) on or off. You must select the settings you want prior to playing a video. If you start the video and then try and change the settings, they will not apply. If a video begins playing and your settings have not been applied, you can press the “Quit Program” button to stop the video (Fig 22).



LAB SIDE



BOAT SIDE

There are a couple of things to remember when using the equipment:

- 1) **Changing subtitles**: Press either 'Spanish' or 'English' before starting a video. This must be done before playing one of the videos.
- 2) **Volume control**

Troubleshooting the Exhibits

Below are two possible problems that may occur. If something unprecedented has occurred, please call Alison (ext. 7566) upstairs for assistance.

Problem #1: One of the large "Lake Tahoe in Depth" touchscreen exhibits freezes.

Solution: Retrieve a proper step stool in the field-trip room and locate the Mac Mini behind the top of the screen. Press and hold the power button for ten seconds to restart the program (Fig. 23).



Figure 23

Problem # 2: There is nothing showing up on the TV screen above the microscope. The TV screen is blank or showing the message “No Connection”.

Solution: Most likely the input set has been changed. To change it back, press the main menu button above the power button (Fig. 24). Select the “Input Select” option (Fig. 25) and select “S-Video” (Fig. 26).

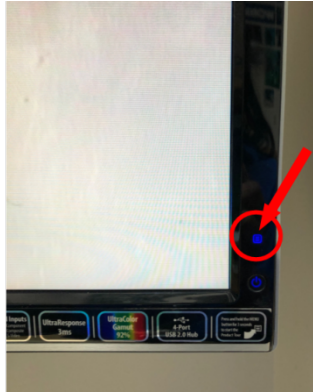


Figure 24

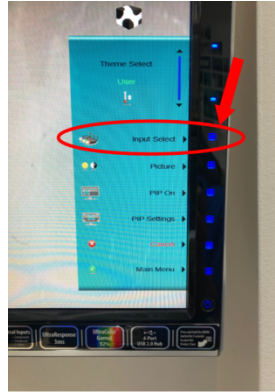


Figure 25

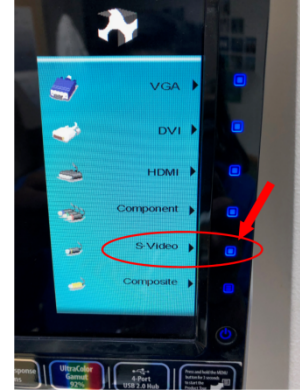


Figure 26

Problem #3: For any other problems...

Solution: Call upstairs for assistance.

- Alison ext. 7566
- AmeriCorps ext. 7474 and 7483
- Heather ext. 7562

Virtual Research Vessel Video Exhibit

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats (fine sediment and algae).

Exhibit Video Script

Hello and welcome aboard the UC Davis research vessel John Le Conte. Watch your step. Since 1976, scientists aboard the Le Conte have been taking measurements in Lake Tahoe. In fact, most of what is known about the lake has a connection with this boat.

Nature has set the conditions for Lake Tahoe's famously clear waters. The lake was formed more than 2 million years ago when a block of the earth's crust dropped down, forming a huge valley. The valley was blocked when volcanoes erupted on the north shore, and water started to fill the lake. Since that time, earthquakes, glaciers, and huge landslides have all played a role in shaping the mountains and the lake.

One thing you need to know is that Lake Tahoe is big! Lake Tahoe is 1,644 feet deep, making it the second deepest lake in the United States and the 11th deepest lake in the world. It is 22 miles long and 12 miles across and holds 41 trillion gallons of water.

If you took all the water out of the lake and spread it over California, it would cover the entire state up to your knees. And it would take over 600 years for the lake to refill. That is really big!

Take a look at the screen to your left – our friends at NASA have some great pictures of Lake Tahoe looking back from space.

Did you know that Lake Tahoe was once one of the clearest and bluest lakes in the world? That's because there were so few soil particles and algae in it. These are what make the water of most other lakes seem cloudy. Let me show you what I mean.

See these two beakers of Lake Tahoe water? Adding just one spoonful of stormwater clouds the water on the right with very fine particles. Can you read the sign now? This is what flows into the lake every time it rains.

The large volume of water in Lake Tahoe compared to the small size of the mountain basin, or watershed, that surrounds it helped to keep Lake Tahoe clear for thousands and thousands of years. Meadows and marshes also helped keep nutrients and fine particles out of the lake because they functioned as filters.

In the last 30 to 40 years, the clarity of Lake Tahoe has decreased, and you cannot see as far down as before. There are also many other changes in the lake. It's still beautiful and still clearer than most lakes, but if nothing is done to stop what is happening, we risk losing our beautiful clear blue lake.

The research at Lake Tahoe is aimed at restoring the lake's clarity. What we learn here is also being used at other lakes around the world. Many of the country's top limnologists (that's what people who study lakes are called) started as college graduate students like me, working here at Lake Tahoe.

I need to get back to my experiments, but stick around to hear about some of the research we do. Maybe I will see you later on if you visit the lab.

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats.

Talking Points

General features of the Tahoe Basin

- Lake Basin formed more than 2 million years ago.
- Graben faulting – grabens are produced from parallel normal faults. Lake Tahoe is considered a “half graben” resulting from a major fault along only one boundary and producing a valley with a distinct scarp (a steep cliff formed by movement along a fault).
- Volcanic activity occurred on the north shore.
- Earthquakes, glaciers, landslides, and erosion have all played a role in shaping the watershed.
- Lake Tahoe is 1,644 feet deep at deepest point.
- Average depth is 1,000 feet.
- The lake is 22 miles long, 12 miles wide, and 72 miles to drive around (75 miles of actual shoreline).
- Surface area is 192 square miles.
- Lake Tahoe holds about 39 - 41 trillion gallons of water: enough to cover an area the size of California to a depth of 15 inches.

Loss of lake clarity

- In the last 50 years, clarity has been reduced from 100 feet to around 63 feet.
- The waters of Lake Tahoe were clear to an average depth of 62.7 feet in 2019, according to UC Davis scientists who have monitored the lake since 1968. The lowest value was recorded in 2017, when clarity was 60 feet.
- More than 70 percent of the Tahoe Basin’s wetlands and marshes have been lost to development.
- Wetlands act as a filter to reduce the amount of nutrients and fine sediments (particles) that enter the lake.
- Local restrictions now prohibit construction within wetland or stream environmental zone (SEZ) areas. Limnology – the study of lakes.

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats.

Discussion & Questions

Question: What do you call scientists who study lakes and other freshwater resources?

Limnologists. Limnology is the study of freshwater (as compared to oceanography, or marine science, which is the study of oceans).

Discuss: What makes Lake Tahoe so special?

Discuss: What do you think would happen if Lake Tahoe turned green or brown?

Discuss: What do you think contributes to loss or gain of clarity in a lake?

Discuss: What has the human impact been on Lake Tahoe Basin over the last 200 years?

Question: Why is Lake Tahoe blue?

Part of the light you see is a surface reflection of sky light. The amount of reflection depends on things such as your viewing angle. Much of the color you see comes from the water's depths. Water absorbs longer wavelengths of light. Most of the longer wavelengths of light disappear within a few feet of the surface. The shorter wavelengths of light (the blue end of the spectrum) penetrate the water surface and are scattered by the water molecules. This scattered blue light is what we see.

As we add more things to the water, more scattering occurs. The light that enters our eyes is coming from shallower and shallower depths, and we see more reflection and less scattering. Clay and silt reflect red light strongly, and many algae reflect green light strongly. The more fine silt and algae in Lake Tahoe, the less blue it will look to us.

Question: Does the lake ever freeze?

No, Lake Tahoe is such a large body of water, and the climate is so mild, that temperatures never get down low enough for the lake to freeze (except around the edges in very cold years). The coldest that Lake Tahoe gets is about 41 °F (5 °C).

Virtual Research Vessel Video Exhibit

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Video Script

Hi there. Did you know that Lake Tahoe has been losing clarity? Because we have been measuring water clarity in Lake Tahoe for a long time, we know for sure that it has been getting worse. Do you see that white disk hanging from the wire?

[Points to his left] That is called a Secchi disk, and it is just one of the instruments we use to measure water clarity.

Let's head out on the lake. I'll leave you with captain Brant to see what a limnologist does...

Welcome aboard the UC Davis Research Vessel John LeConte. Today out here on the lake I'm going to be doing a Secchi disk reading... and the way we do this is to slowly lower the disk into the lake... and I measure the line, how much line has gone out off this meter wheel, so I know how deep it has gone. So, I am going to start sending this down into the lake. So as the disk goes down into the lake, it gets more and more difficult to see. The reason for this is that there are fine particles and algae floating around in the water column, and as the disk gets deeper, these particles scatter the light and make it harder to see the disk.

There is a small white glow where I can still see the disk, so we keep an eye on it till it gets down to where it is just about to disappear. Then I have to be real careful about stopping the line at the right place. And right there, it just went out of view. So that is going to be our Secchi reading today. If I look at the meter wheel, I am at 18 meters and that is a good reading for today. That is 59 feet. I'm going to go ahead and bring it back up and we'll move on to some other tests.

This is another commonly used piece of equipment here at Lake Tahoe. It's called a Van Dorn Sampler. We use this to collect water from a specific depth in the lake. We lower the bottle down to the depth that we need to sample, and once it has reached that depth, we send this weight down the line to close the bottle. As soon as the bottle closes, we've captured water that we need for analysis. This sample came from 15-hundred feet deep in the lake. I'm going to send it back to the laboratory so they can analyze it for nutrients, fine sediment, and algae.

You see that research buoy over there? There are six of those on the lake. Each one is loaded with scientific equipment. That one is used by NASA and UC Davis scientists to check satellite data and to study water currents in Lake Tahoe. It is just about noon; that means the TERRA satellite ought to be passing by pretty soon.

[Plankton net] This is my favorite part of the sampling day. I'm bringing in the plankton net and in here we have the tiny creatures that eat the algae. Those creatures are called zooplankton. If you look in the end of the net, you'll be able to see zooplankton jumping around. These guys are the tiny food for the fish that live in the lake.

Thanks Brant. Check out the equipment used on the boat. By taking all those measurements every ten days, we can see how the lake is changing over time. This graph shows how the Secchi depth has changed since 1968 when Dr. Charles Goldman began regularly taking these measurements.

Each of the white circles represents the average Secchi depth for that year. Back in the 1960's, the number was about 100, Meaning we could see down into the lake 100 feet. Now we can only see down about 70 feet. That is a loss of about 30 feet of clarity.

Look up to the skylight above you. The distance from where you are to the top of the skylight is about 30 feet. Now you know why we are worried.

Check out some of the other information around you or ask one of the docents to tell you what else is being done.

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Talking Points

Virtual Research Vessel Exhibit

- This “replica” represents a two-thirds scaled model of the stern of the real vessel.
- See “The Research Vessel (R/V) John LeConte” in the Additional Resources section.

The Boat Captain

- Captain Brant Allen is the captain of the research vessel.
- Prior to Brant, our boat captain was Bob Richards who retired after 37 years of working for the Tahoe Environmental Research Center.

Secchi Disk

- Point out the Secchi disk hanging from the rope (or pass around the extra disk).
- Father Angelo Secchi, scientific advisor to the Pope, was asked by Commander Cialdi, head of the Papal Navy, to test a new transparency instrument. He lowered a large canvas covered disk from the papal steam yacht, L’Immacolata Concezione in the Mediterranean Sea on April 20, 1865.
- Today, a similar instrument is used to measure water clarity at Lake Tahoe. Our “Secchi disk,” a 10-inch opaque white disk, is lowered into the lake until it can be no longer seen by the observer. This depth of disappearance, called the Secchi depth, is a measure of the transparency of the water.
- Transparency decreases as suspended sediments or algal abundance increases.
- The readings are taken every ten days and are not precise. The main focus is the general trend of the readings.

Secchi Depth Measurements

- Measurements are taken approximately every ten days.
- Question: How many Secchi disk readings (individual measurements) are taken each year? Approximately 36 measurements ($=365/10$)
- Some measurements are discarded due to rough surface waters or cloudy

skies.

- All Secchi disk measurements are taken within the two-hour window around “solar noon” when the sun is directly overhead. The water needs to be relatively calm because waves cause difficulty for reading measurements.
- Boat captains are required to have their eyes checked regularly. Their results are regularly compared to results from other people.
- See “The Secchi Disk” in the Additional Resources section.

Other instruments (tools) used to measure clarity

- The Secchi disk may not seem like the most high-tech way to measure clarity, but it never fails, batteries never die, and it never requires technical support!
- Because this instrument has been used since the 1960s, the data can be compared across the years.
- In addition to the Secchi disk we also use the following more high-tech instruments which are mounted on the “Seabird” profiler:
 - (1) transmissometer measures how much light of a certain wavelength is received over a fixed path length (30 cm).
 - (2) optical backscatter (OBS) sensor measures how much light from a LED is scattered backwards by particles.
 - (3) photosynthetically active radiation (PAR) sensor measures the solar radiation (light) reaching different depths in the lake.
- Solar radiation at three different depths is measured at Buoy TB3 continuously throughout the day.
- Satellite remotely sensed images and instruments are also used to measure the lake “color” from space.

The clarity chart (also called the Secchi disk chart)

- Point to clarity chart.
- The graph has “zero” at the top unlike other graphs. The “zero” line represents the surface of the water. If the trend line goes up, it means clarity is reduced.
- We began collecting these measurements in 1968.
- Note the inter-annual variation due to differences in weather each year.
- Loss of clarity appears to be leveling off – The waters of Lake Tahoe were clear to an average depth of 62.7 feet in 2019, according to UC Davis scientists who have monitored the lake since 1968. In 2007, UC Davis reported that data since 2001 suggested lake clarity was not declining as fast as it had been.

Water sampling – Van Dorn Sampler

- Point to Van Dorn Sampler.
- This instrument allows us to collect water from a specific depth by lowering the open sampler on a line.
- Instrument uses a “messenger” (usually a brass weight) which is sent down the line. It releases a “rubber band” inside that snaps the sampler shut.
- Samples are regularly collected from various (i.e. 5m, 10m, 20m, 50m ... 500m) depths.

Plankton net

- Net allows water to pass through it but retains the small zooplankton in the collection cup at the bottom.
- Standard size of the ring allows us to calculate how much water is being filtered for each sample (area of ring x depth of collection = total volume of filtered water).
- Zooplankton are preserved in a collection cup. Have a hand lens available to take a closer look.
- Mention you will have a chance to look at the zooplankton more closely in the Lab!

Research buoys

- Point to the buoy on photo mural.
- The University of California, Davis (UC Davis) and the National Aeronautics and Space Administration Jet Propulsion Lab (NASA/JPL) have 6 large research buoys on Lake Tahoe.
- Measurements are used to understand the factors affecting the health of the lake.
- Location of research buoys are shown on the map, although positions may vary by up to 500 feet depending on wind conditions.
- All buoys are equipped with navigation lights (1 flash every 4 seconds) and radar reflectors.
- Measurements include wind speed, wind direction, air temperature, atmospheric pressure, and water temperature.
- Real-time data is available online (<http://www.laketahoeindepth.org>) and at the “Lake Tahoe in Depth” touchscreen.
- There are also 6 meteorological stations on shore around Lake Tahoe.
- See “Research Buoys on Lake Tahoe” in the Additional Resources section.

NASA Collaboration

- Research buoys have a very sensitive radiometer (long arm pointing at water surface) which measures the surface temperature (“skin temperature”) of the lake.
- NASA uses Lake Tahoe as a calibration site for its Earth Observation Satellites (EOS), such as TERRA, AQUA, ASTER, MODIS, etc. (See <http://earthobservatory.nasa.gov> for more info).
- Why Tahoe?
 - Large lake (35 km x 16 km)
 - High elevation (~2km), less interference
 - Available year round (does not freeze in winter)
 - Large annual temperature range (5-25 °C)
 - Freshwater (kind to instruments)
 - Good infrastructure (easy to access)

Glider

- TERC deploys an autonomous underwater yellow glider that oscillates up and down the water column from the surface level to a depth of 150 meters across the lake.
- Sensors measure temperature, light, algae, and dissolved oxygen.
- Data shows highly complex spatial structure exists in lake water quality (mixing, churning, swelling, and upwelling)
- Takes continuous measurements and provides real-time information to TERC’s network of instrumented buoys, chase storm events to ultimately help round out the picture of the processes and impacts affecting Lake Tahoe.

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Discussion & Questions

Question: If Secchi disk readings are taken every 10 days, how many readings are taken in a year?

Approximately 36 readings are taken over the course of a year. While many of the readings are thrown out (bad weather, outliers, etc.), the remaining readings are averaged, and that number represents the annual average clarity observed for the lake that year. The annual average is represented on the Secchi disk chart here.

Question: What accounts for the inter-annual variability (changes from year to year) seen in Lake Tahoe's clarity?

Numerous events, such as drought and flooding, can affect Tahoe's clarity from year to year. In 1997 the area experienced a large flooding event which decreased clarity by dumping a large amount of sediment into the lake in a relatively short period of time. During times of drought, the lake's clarity actually improves as less sediment makes its way into the lake.

Question: Why are water quality measurements important?

Water quality measurements provide a scientific basis to study Lake Tahoe as a living laboratory for studying freshwater lakes and their ecosystems.

Question: Why is it important to have a long-term data set (measurements over a long period of time)?

Forty years of research has shown that Lake Tahoe is threatened by loss of water clarity. It allows identification of the variables that impact clarity and allows for wise public policy decisions.

Discuss: How and what would you measure at Lake Tahoe in order to detect changes to the ecosystem?

Discuss: How would you measure clarity? Set up sampling protocols?

Discuss: What other research questions can you think of?

Virtual Research Vessel Video Exhibit

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

Exhibit Video Script

Hello. We all know how big Lake Tahoe is. What amazes me is that it is the very smallest things in the lake that are causing it to lose its clarity. Particles... tiny pieces of nonliving things like dust, soil, the stuff that comes out of your car's exhaust pipe... are the most important cause of clarity loss. Most of these particles are so small that we can barely see them with a microscope. To count the particles, we need to use special instruments that bounce laser beams off these tiny particles.

Another way to learn about the particles that go into Lake Tahoe is to study what went into it in the past. All the particles that have ever fallen into Lake Tahoe eventually fall to the bottom of the lake and become part of the sediments. The very oldest particles are at the very bottom of the sediment layer. The newest ones – those that came in recently -- are closer to the top. In that way, the sediment layers are a history of Lake Tahoe.

Researchers use special hollow tubes, which are driven into the soft bottom sediments to collect sediment.

Hey Alan, what is that?

[ALAN – Winch noise] This is a sediment core... from the bottom of Lake Tahoe that we just took out here in the lake... bring it up and we'll put it down. Okay, down.

This is the type of mud that you see in the bottom of the lake. It accumulates a little bit at a time year by year, and it layers up just like rings on a tree. We're concerned about the state of the lake now and the effects of houses and urbanization on the lake. But by looking at the sediments we can reconstruct what happened in the past and we know that the lake recovered from past disturbances, like the logging. So, since the lake recovered then, we believe it can recover now if we do the right things.

That's really encouraging Alan. Our latest computer models show the same thing. Water quality could improve within 20 to 30 years if we reduce less than half of the particles and nutrients currently entering the lake.

Did you know that a single inch of sediment represents around 25 years of accumulation?

Each foot represents 300 years. So, if I were a sediment core, the soles of my feet would be 1800 years old. Time to change my socks, I guess!

Please continue to look around the center and check out all the other displays. Remember to ask questions – that is what scientists do!

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

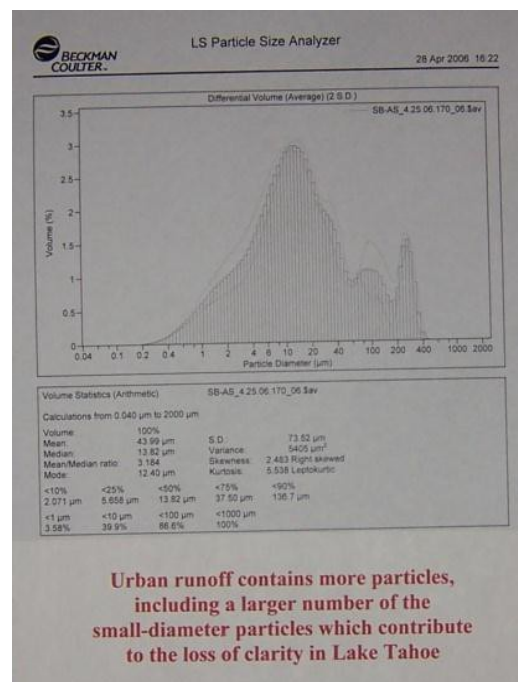
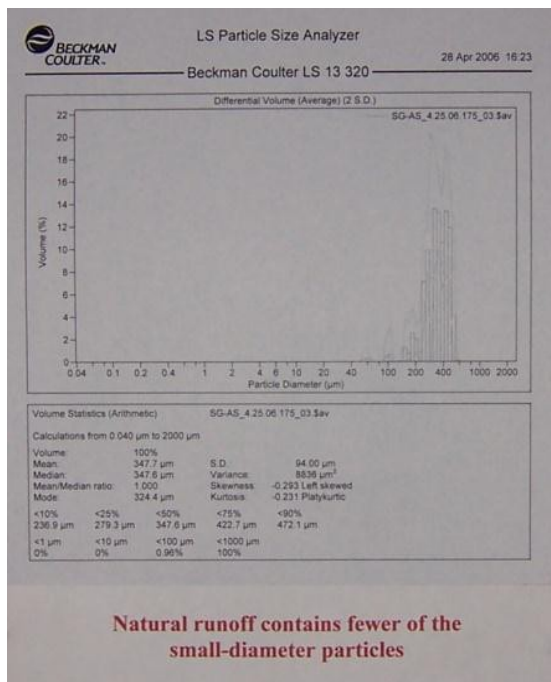
Talking Points

Particles are causing Lake Tahoe to lose clarity.

- Particles come from dust, soil, automobile exhaust, etc. (stirred up by wind, leaf blowers, cars, etc.)
- Particles scatter the light and make it harder to see the Secchi disk in the water.
- It is the very small (less than 20 microns in size), microscopic particles which scatter light and stay suspended in the water for a long time.
- Micron = micrometer (μm), one millionth of a meter. For comparison, the diameter of human hair ranges from 25 - 175 microns.
- Over time, fine particles can aggregate and become large enough to settle.

Laser Diffraction Particle Size Analyzer

- Laboratory equipment measures particle size in a water sample, to produce a particle size distribution (PSD).
- Compare measurements from natural forest storm water with urban storm water:



Sediment core

- Sediment accumulates at the bottom of the lake.
- Sediment currently accumulates about 1 inch per 25 years (or 1mm per year).
- Sediment cores are used to compare historical sedimentation rates such as after the Comstock Logging, to the recent period of urbanization.
- See also Sediment Core Talking Points.

Lake Clarity Modeling

- Computer model shows lake clarity could improve within 20 to 30 years if we reduce fine particle load into the lake by 70%.

Sediment Core Talking Points

This simulated core sample represents the Lake Tahoe sediment core taken by Alan Heyvaert when he was working on his Ph.D. with UC Davis. Dr. Heyvaert's research included a reconstruction of the paleolimnological (history of the lake) conditions using bio-geo- chemical analysis.

Why not use a real sample? Since the sediment core would be extremely wet upon extraction from the lake; it would get moldy inside the plastic tube. In addition to the possibility of creating a rather stinky exhibit, a wet sediment core would change colors over time and no longer look like the sediment core pulled from the lake. (Please note that this dry simulated sediment core is slowly compacting over time.)

How deep do sediments go? Estimates indicate that the sediment layers could be over 1,000 feet deeper than the bottom of the lake. In other words, the lake basin is approximately half filled with sediment.

Layers of sediment – the sediment accumulates at a rate of approximately 1/25-inch per year. However, over time the lower sediments are compressed by the weight of the sediment and water above and so this 6-foot core actually represents about 8,000 years.

Looking at the sediment core from the top to the bottom:

- 1) Dead Zooplankton: Above the sediments you may see some dead zooplankton, including the large (by comparison) Mysis shrimp. These zooplankton fall to the bottom and eventually become part of the sediments.
- 2) Oxidized Top Layer: The top layer of sediment is dark in color, orange-ish,

granular, and oxidized. Lake Tahoe is unique in that it has oxygen in the water all the way down to the bottom of the lake (average depth 1,000 feet). This oxygen allows the top layer of the sediment to remain oxidized, which appears as a “rusty” orange color. This oxidized layer on top of the sediment acts like a cap, holding the iron- phosphorus precipitates down and preventing the deeper layers of sediment from releasing phosphorus to overlying waters during deep mixing or turbulent storm events.

- 3) Redox Layer: Mixed black and dark granular-redox zone is not very visible in sediment core. Manganese (Mn) precipitates account for the black color. Iron precipitates account for dark reddish-brown granules.
- 4) Comstock logging/slash and burn charcoal period: Over two-thirds of the Tahoe Basin was clear-cut during the Comstock Era (1858-1900) as the lumber from Tahoe Basin trees were used to shore up the silver mines near Virginia City/Carson City areas. During this time, there was greatly increased deposition (7 to 12-fold). The Truckee Dam and the flume trail were constructed to move logs and water during this period. Trees that went unused were burned to create another layer of ash seen in the core. Wood chips, pine needles and saw dust are sometimes visible within this one to two inch portion of the sediments where the Comstock logging period is represented.
- 5) Natural Lake Sediment: Olive green sediment appears throughout the majority of the sample. This is what the sediment looks like in the absence of a disturbance. The greenish color is due to a lack of iron.
- 6) Drowned trees near Camp Richardson (first coarse layer from the bottom): Submerged tree stumps off Baldwin Beach are carbon dated to approximately 5300 years old. Trees are found 120 feet underwater in Fallen Leaf Lake. It is believed that these trees all died around 800 years ago when water levels rose above this historic lower level. Both indicate severe drought periods throughout history.
- 7) Past Disturbances: Turbidites are a mixture of sediment particles and water that flows down the steep side slope creating high density currents that can reach great speeds. These generally erode loose sediments from the lake floor beneath them. Flooding and earthquakes also create disturbances which all appear in the core as a coarser turbidite layer. There are three occurrences of these disturbances reflected in the sample.
- 8) Mt. Mazama Ash Layer (white ash layer near bottom): This series of catastrophic

eruptions occurred approximately 7,700 years ago and created Crater Lake (the deepest lake in the United States at 1,949 feet). While Crater Lake is a caldera, it has a similar geologic history to Tahoe; both have a history of volcanic eruptions and glaciers sculpting the landscape. Crater Lake is part of the Cascade Range Volcanic arc which stretches from British Columbia to Northern California. The whitish ash layer is tephra (fragments of volcanic rock and lava) from one of the series of eruptions that created Crater Lake, which Mt. Mazama was a part of. Winds during the eruption spread ash for roughly 500,000 miles. This actual Mt. Mazama ash sample was taken from West Central Nevada and provided by Desert Research Institute geologist Ken Adams.

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

Discussion & Questions

Discuss: Where do these “particles” come from?

Particles come from dust, soil, automobile exhaust, etc. (stirred up by wind, leaf blowers, cars, etc.).

Question: What would cause particles, or sediment, to accumulate in the lake faster?

Bigger rainstorms, flooding conditions (such as rain on snow events), urbanized areas such as large parking lots, roads and urban drainage ditches can carry sediment pollution very quickly in “run off.”

Question: What could slow sedimentation down?

Protect sensitive wetlands, stream zones, meadows and vegetated areas. Build constructed wetlands to filter stormwater. Install Best Management Practices (BMPs) to help control runoff. Low water years (drought conditions) also result in reduced sedimentation. There have also been environmental improvement projects (EIP) that look at stopping direct runoff from roads and urbanized areas that have also slowed sedimentation.

Question: Compare the size of sediment (< 20 microns) to other objects (e.g., hair, dust, etc.).

A micrometer or micron (symbol μm) is one millionth of a meter, or equivalently one thousandth of a millimeter. As a comparison, a strand of human hair is about 100 μm wide. Red blood cells are 7 μm in diameter. The size particles we are most concerned about are those less than 20 μm in diameter!



**A Micron-Size Dust Particle
on a Pin Head**

Virtual Laboratory Video Exhibit

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Video Script

Welcome to the UC Davis laboratory at Lake Tahoe. Actually, it is not just one lab, but several different types of labs. In the biology lab, we study the different types of plants and animals that live in the lake, streams, wetlands and forest.

See those microscopes on the bench? We use those to look at the phytoplankton and zooplankton that live in Lake Tahoe. Phytoplankton are also called algae. They are tiny little floating plants – the “phyto” part of their name means they need sunlight to grow, just like any other plant. The zooplankton are tiny little animals that live in the water and eat the phytoplankton.

There are many kinds of phytoplankton and zooplankton. Monika is an aquatic ecologist – she studies things like how and where the phytoplankton live, how they get their nutrition and which kind of zooplankton eat them. Hi Monika, what are you looking at?

Hello, I'm looking at lake water samples from Lake Tahoe. Right now, I'm looking at phytoplankton samples that have been collected from 200 feet down. That's where a lot of the phytoplankton are in Lake Tahoe because that's where the nutrients are. So come on and let's see what we find there.

That must be a very powerful microscope. I can see lots of diatoms. Diatoms are the most common type of algae in Lake Tahoe. Zooplankton like to feed on them because they are very nutritious. There are so many other types of algae we can see – there are Cryptomonads, Chrysophytes, and Dinoflagellates. Zooplankton can be easily seen through a microscope without very much magnification. What do you see Monika?

[MONIKA] There are a lot of zooplankton. And right now, I am looking at the zooplankton samples that have been collected with the plankton net in Lake Tahoe. Zooplankton are generally very important in lakes because they feed on algae.

By feeding on algae the zooplankton help to keep Lake Tahoe from turning green! You can see two different species that look as if they are jumping around. The red one is called Diaptomus and is very common during the summer in Lake Tahoe. The red

pigment acts like a sunscreen and protects them from harmful sunlight. The grayish one you see is called Epischura.

There are also other less common zooplankton. This one is called Bosmina. And... what a surprise! There is a Daphnia. Daphnia are very important animals in lakes because they provide high quality food for fish and the fish really like to eat them. Nowadays, we don't find them very often because of changes in Lake Tahoe's food web caused by the introduction of the Mysis shrimp.

Speaking of which, this big guy is a Mysis shrimp. Let's ask Bob Richards, world renowned expert on Mysis shrimp, where this big-eyed creature came from.

[BOB] The Mysis shrimp were introduced into Lake Tahoe back in the 1960s to hopefully provide a food source of intermediate size to supplement the foods available to the different fishes in the lake. It turned out probably to not be such a great thing and the reason is that those zooplankton that were already here were providing a majority of the food sources for some of the Kokanee salmon and the juvenile fishes that live in the lake. So, when Mysis came along and started preying on these other zooplankton, they actually cut these food sources down instead of increasing the food source available for other fishes. The main lesson learned was that you really need to do good hard scientific research on things, especially if you are going to change the environment by introducing a foreign organism into the water, because they do bring about a lot of changes that you don't expect.

Thanks Bob, that's actually a great lesson for all ecosystems. Species introductions can have irreversible effects.

There are other introduced species in Lake Tahoe, many of which were accidentally introduced. Water milfoil is an aquatic plant that first appeared in the Tahoe Keys, but has now spread to other shallow bays and marinas around the lake. It's a constant battle to keep it from spreading further.

Sudeep Chandra has been studying the fish that have been accidentally introduced to Lake Tahoe. Sudeep, what do we know about these species?

[SUDEEP] The Bluegill and Bass species have been introduced into the lake sometime in the last ten to fifteen years and we are concerned about these species because they affect native species by feeding on them, they can also compete with native fish species by eating their food. You really have to ask yourself a question, it is really more of a moral question. And the question is "do we want these non-native species within our Lake Tahoe?" We are already fighting pretty hard to protect the lake to keep it clear. And so, what I like to think about is we should also protect the lake by keeping its native biology intact.

Something to think about. Well, I need to prepare some more samples. See you next time you stop by the lab.

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Talking Points

Microscopes – for viewing phytoplankton and zooplankton

- Diatoms – most commonly found type of phytoplankton.
- Daphnia (preserved sample, stained).
- Live sample of Daphnia from Daphnia Culture – Use pipette to collect. Recommend collecting one (1) Daphnia in one (1) drop of water.
- Live sample of Diaptomus and/or Epischura (if available from recent collection) – Use pipette to collect. Can be viewed with microscopes, ViewScopes, Loupes, or other similar tools.

Aquatic Species of Lake Tahoe – Point out poster on “door” of laboratory

- Fish, including non-native fish
- Zooplankton
- Phytoplankton

Phytoplankton (also commonly called algae)

- Algae are microscopic plants living in the water column or attached to surfaces (i.e. rocks, plants, sediments) which are at the base of the aquatic food web. Scientists measure the amount of chlorophyll, which is the green pigment that allows plants to carry out photosynthesis. Chlorophyll can be used as a measure of the amount of algae. The amount of algae in the water column affects Lake Tahoe's clarity.
 - Tiny, floating plants
 - Need sunlight to grow
 - Bottom of the food chain
 - Nutrients (nitrogen and phosphorus can stimulate growth)
 - Can grow in upper 300 feet of the lake
 - Over 300 species found in Lake Tahoe
- Primary types include:
 - Diatoms
 - Chrysophytes (golden algae)
 - Cryptophytes
 - Dinoflagellates
 - Chlorophytes (green algae)

Zooplankton

- Zooplanktons are tiny animals that live in the open water. They provide an important food source for fish and graze on algae, helping to keep the water clear.
 - Rotifer – requires special microscopes to see
 - Diaptomus – red with antennae
 - Epischura – gray with antennae
 - Bosmina – small hook “nose”
 - Daphnia – round, hard carapace shell, also called the “water flea” because of the type of movements it makes, you can see the green algae inside its stomach
 - Mysis Shrimp – larger, introduced non-native species. Mysis will swim 1000 feet each day and night (“diurnally”)

Mysis Shrimp

- Introduced non-native species. Mysis will migrate 1000 feet vertically each day and night (“diurnally”).
- Introduced by the Dept. of Fish & Game in the 1960s to provide a food source for game fish.
- However, this had the opposite effect... Mysis shrimp actually reduced the available food for fish, by eating many of the Bosmina and Daphnia.
- View Mysis shrimp preserved in formalin in jar.

Non-native Species Introduction Poster – located on corkboard on the side wall

- Non-natives introductions include Mysis shrimp.
- Several species of fish were purposely introduced as game fish, including lake trout, rainbow trout, brown trout, Kokanee salmon.
- Others were accidentally introduced, including bass, carp, bluegill, and sunfish.
- These are mostly found in warmer shallow embayments such as marinas, the Tahoe Keys, etc.
- View Asian clams in a jar or petri dish.
- View Quagga mussels in a petri dish. These are not yet in Lake Tahoe!
- Rack cards (e.g., Don’t Move a Mussel, Tahoe Boat Inspection, Tahoe Keepers) are available in the brochure rack near the front desk.

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Discussion & Questions

Question: What are the components of Tahoe's aquatic food web?

Phytoplankton → Zooplankton → little fish → bigger fish → osprey/bears/humans

Question: Describe the various native and non-native fish of Lake Tahoe. How many fish are native? Non-native?

See *Species of Lake Tahoe's Aquatic Food Web* poster.

Question: Why is it important to protect the native food web?

Each species has a special place within the food web. These species have evolved together over millions of years. If you take one species out, the entire food web can collapse or be modified forever. Extinction is forever and some non-native species can also become invasive and change the food web forever.

Discuss: Why would Mysis shrimp reduce the available food source to fish even though they were introduced in order to increase it?

Discuss: How do you think those accidentally introduced fish got into Lake Tahoe?

Some "introduced species" were purposely placed into the lake by Fish and Game. Others probably entered the lake accidentally from anglers' bait buckets, boat bilge pumps or from people dumping aquariums or goldfish tanks.

Question: How is climate change affecting Lake Tahoe's food web?

Climate warming is causing a shift in phytoplankton species composition because water in Lake Tahoe is unable to mix as intensely. This allows for less nutrient availability and makes it difficult for larger-sized diatoms to stay suspended. Small-sized diatoms have flourished with lake warming and have become more prevalent. This may affect clarity because smaller species stay at the surface longer, scattering light and making the water appear greener.

Question: How do invasive species affect Lake Tahoe?

Aquatic invasive species harm Lake Tahoe by:

- Competing with native species.
- Severely decreasing recreational uses, such as swimming, boating, water-skiing, and fishing.
- Degrading boats by clogging propellers and cooling intakes.
- Facilitating invasions of other non-native species.
- Altering nutrient cycles and increasing algal growth in the lake by adding phosphorous to the water column thus contributing to clarity decline.

Aquatic invasive species (AIS) such as the Asian clam and Eurasian watermilfoil (aquatic plant) can also have negative impacts to Lake Tahoe's ecosystem. Researchers are currently studying benthic (bottom dwelling) ecologies to learn more about the potential impacts invasive species can have on native aquatic plant and animal species as well as on water quality.

Question: About Mandatory Watercraft Inspections.

Starting in 2009, all motorized boats and watercraft require inspection for AIS prior to launching into Lake Tahoe. The boat inspection program at Lake Tahoe is designed to intercept and decontaminate boats coming from outside the Tahoe Basin that might inadvertently carry AIS. This program is also educating boat owners on how to best clean their boats to avoid transporting AIS to any lake or waterbody. Knowingly transporting AIS into Lake Tahoe is against the law, and violators may be subject to fines.

Boaters are encouraged to Clean, Drain, and Dry their boats prior to arriving at inspection stations in order to save everyone time and money. Visit TahoeBoatInspections.com or call (888) 824-6267 for updates, details and information or follow @TahoeBoating on Twitter for real-time updates.

Question: What about Non-Motorized Watercraft?

Non-motorized watercraft such as kayaks, canoes, rafts and other inflatables must also be free of aquatic invasive species. A coalition of local and visiting Lake Tahoe paddlers, business owners and Tahoe Basin environmental groups are helping to stop the spread of aquatic invasive species by becoming Tahoe Keepers. Tahoe Keepers are paddlers who inspect and decontaminate their boats and gear every time they haul out and move between new waterbodies. Non-native species, such as quagga and zebra mussels could irreparably damage the Lake Tahoe watershed. These invasive species are spread through water and debris that can collect in cockpits and hatches, cling to outer hulls, rudders and paddles, and even hide out on footwear and gear long after paddling. Paddlers can learn how to self-inspect and decontaminate their canoes, kayaks, paddleboards and inflatables at TahoeKeepers.org.

Question: What potential impacts could invasive Zebra mussels or Quagga mussels have on Lake Tahoe?

Quagga and Zebra mussels are especially problematic, as they are known to multiply quickly and colonize underwater surfaces, including docks and piers, water supply and filtration systems, buoys, moored boats and even the beautiful rocky shoreline. They destroy fish habitat, ruin boat engines, and can negatively impact water quality and the local economy, recreation and ecosystem.

Invasive mussels have caused many ecological problems in other water systems. Lake Tahoe could face these same ecological problems if these invasive mussels found their way into the lake. Zebra and Quagga mussels are voracious filter feeders and remove large amounts of phytoplankton from the water column causing a reduction in food for native zooplankton species. Both can colonize on the surfaces of many things such as watercraft, docks, water pipes and native mollusks. Invasive mussels also cause biofouling which clogs water intake structures, such as pipes and screens, therefore reducing pumping capabilities for water treatment/pumping plants, costing industries, companies, and communities. Imagine sharp shells on the beaches of Lake Tahoe...you could no longer walk barefoot.

In January 2007, a Quagga mussel was found for the first time west of the Mississippi in Lake Mead, Lake Havasu, and the Colorado River. Most recently it has entered waterbodies in California. Once established, these mussels can cost millions of dollars to control. To report a sighting or for more information, call the Tahoe Aquatic Nuisance Species Hotline at 1-888-TAHO-ANS or visit <http://www.tahoercd.org>.

Question: What, if anything, is being done about the Mysis Shrimp in Lake Tahoe?

A 2018 UC Davis TERC project aims to reduce the abundance of Mysis shrimp to levels where they no longer impact the ecosystem of the lake. If the number of Mysis are reduced, native zooplankton species will be able to recover to levels not seen since Mysis was established. This could lead to a significant improvement in water clarity – one of the long-term goals for the lake.

Using Emerald Bay as the location of this pilot project, real-time remote sensing will be used to locate the position of high-density Mysis patches. TERC can then map out the natural variability in the distribution and migration of these organisms. Using a special zooplankton net specifically sized to the Mysis shrimp, field researchers can then remove these specific populations. If successful, the developed technology and tools will be used to provide real-time guidance for harvesting Mysis in the rest of the lake.

Virtual Laboratory Video Exhibit

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Video Script

Hello. Some of the most important chemical analyses we do in the lab are the nutrient measurements. Nutrients are what the algae, or phytoplankton, need to grow – just like your lawn needs fertilizer to stay green. There are two main nutrients that algae need – nitrogen and phosphorus.

See how we take samples of slimy periphyton to bring back to the lab? Periphyton is the algae that attaches itself to rocks in the shallow water near the edges of the lake. Periphyton blankets the rocks and can be slippery if you step on it on your way to go swimming. It is an indicator of where excess nutrients are coming into the lake.

Lakes that are clear usually have very small amounts of nutrients and very few phytoplankton – they are called oligotrophic lakes. If you add more nitrogen and phosphorus to an oligotrophic lake, it will very quickly grow more algae and start to look green.

Most lakes are green in color because they have so much algae growing. Such lakes are called eutrophic. It is a natural process for a lake to change from being oligotrophic to eutrophic, but it would normally take tens of thousands of years or longer.

What we are worried about here is that many of the activities that people do in the Tahoe Basin (like construction, driving cars, using fertilizer on lawns and golf courses) accelerate eutrophication.

The lake has changed a lot in just the last 40 years and eutrophication is one of the big concerns. The good news is that there are many things being done to reduce the amount of nutrients entering the lake... so that it doesn't turn green.

Ask what you can do to keep the nutrients out of Lake Tahoe and keep it looking clear and blue!

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Talking Points

Nutrients – There are two main nutrients:

- Nitrogen (N)
- Phosphorus (P)
- Both are needed for algae to grow

Nutrients - Compounds of nitrogen and phosphorus dissolved in water which are essential to photosynthesis (the process of converting sunlight into plant matter). Too much nitrogen and phosphorus act as pollutants and can lead to unwanted consequences - primarily algae blooms that cloud the water. Fertilizers, vehicle exhaust, atmospheric deposition, and runoff from streams and urban areas are possible sources of nutrients.

Algae – or phytoplankton or plankton. Simple microscopic plants that grow in bodies of water. Periphyton algae (“attached algae”) is attached to rocks or hard surfaces.

Oligotrophic - Refers to water bodies or habitats with low concentrations of nutrients and consequently low concentrations of algae.

Eutrophic - Describes an aquatic system with high nutrient concentrations. These nutrient concentrations fuel algal growth. The algae eventually dies and decomposes, which reduces the amount of dissolved oxygen in the water.

Eutrophication - the process of excess nutrients accelerating the growth of algae, oftentimes ultimately depletes the water of oxygen.

Additional Information about Nutrients and Nutrient Pollution

What are nutrients? Nutrients, like nitrogen and phosphorus, occur naturally in water, soil, and air. Just as the nitrogen and phosphorus in fertilizer aids the growth of agricultural crops, both nutrients are vital to the growth of plants within the lake, streams and rivers.

How are nitrogen and phosphorous used in the ecosystem? Nitrogen is essential to the production of plant and animal tissue. It is used primarily by plants and animals to synthesize protein. Nitrogen enters the ecosystem in several chemical forms and

also occurs in other dissolved or particulate forms, such as tissues of living and dead organisms.

Some bacteria and blue-green algae can extract nitrogen gas from the atmosphere and transform it into organic nitrogen compounds. This process, called nitrogen fixation, cycles nitrogen between organic and inorganic components. Other bacteria release nitrogen gas back into the atmosphere as part of their normal metabolism in a process called de-nitrification.

Phosphorus is another key nutrient in the ecosystem. Phosphorus occurs in dissolved organic and inorganic forms, often attached to particles of sediment. This nutrient is a vital component in the process of converting sunlight into usable energy forms for the production of food and fiber. It is also essential to cellular growth and reproduction for organisms such as phytoplankton and bacteria.

How can nutrients become pollutants to Lake Tahoe and surrounding streams? Although nutrients are essential to all plant life, an excess of these same nutrients can be harmful. This is called "nutrient pollution." Nutrients have always existed in the lake, but not at the present excessive concentrations. When the lake was surrounded primarily by forest and wetlands, very little nitrogen and phosphorus ran off the land into the water. Most of it was absorbed or held in place by the natural vegetation. Today, much of the forests and wetlands have been replaced by roads, urban areas, homes, etc. As the use of the land has changed and the watershed's population has grown, the amount of nutrients entering the Lake's water has increased tremendously.

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Discussion & Questions

Discuss: What can you do to keep nutrients out of Lake Tahoe?

Reduce fertilizer use, very careful fertilizer use, pick up after pets, stop erosion, BMPs, etc.

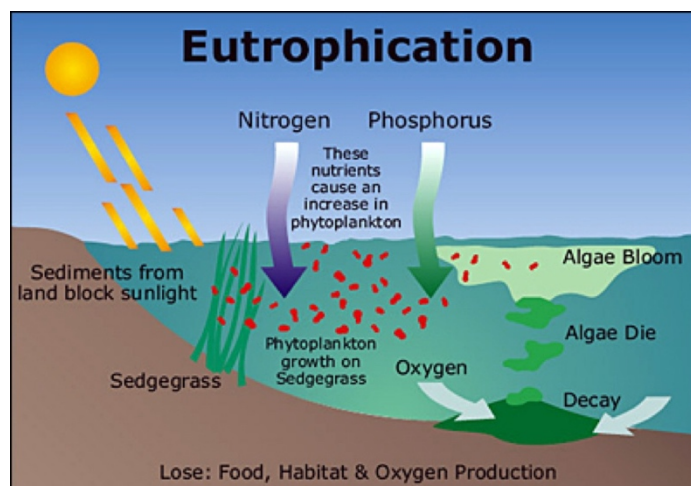
Question: If eutrophication is a natural process, why do we care about it happening at Lake Tahoe?

The speed at which the eutrophication of Lake Tahoe that would occur under normal (natural) conditions would be millions of years... we are seeing changes occur within our lifetimes.

Discuss: What other problems would the eutrophication of Lake Tahoe cause?

Eutrophication decreases the resource value of lakes resulting in reduced recreation and aesthetic enjoyment. If Lake Tahoe were to turn green or brown, this would lower property value, reduce tourism, and hurt the local economy. Water treatment plants would need to be installed to filter the water used by many in the Tahoe Basin for drinking water and would cost millions. Health-related problems can occur where eutrophic conditions interfere with drinking water treatment.

There would also be many occurrences of bad odor coming from the lake, mats of algae washed upon the beaches, and midges and other insects invading the near shore. Lake Tahoe is a long way from these conditions, but they are what typify a eutrophic lake.



The figure above is a visual of the eutrophication

Virtual Laboratory Video Exhibit

Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

Video Script

Did you know that there are 63 streams that flow into Lake Tahoe? Only one – the Truckee River – flows out. It flows out at Tahoe City and ends up in Pyramid Lake, Nevada. Scientists monitor creeks and streams by collecting water samples and performing other measurements. Let's go visit Scott to see what's involved.

Hi Guys, I'm at Ward Creek on the West Shore of Lake Tahoe. The flow right now is about four cubic feet per second. That's about typical for the summer baseline condition.

A lot of this erosion that you see here happened during the 1997 flood. We had very high flows; it was flowing about 1200 cubic feet per second, it caused a lot of the banks to be under-cut and a lot of these boulders fell in the stream. And you could actually hear the boulders rolling along the stream bottom during the flood, it was incredible. So, this is some of the fine silt that erodes away from the stream bank at Ward Creek. It will eventually erode down into the stream and out into the lake.

What I do to take a sample is I set a line across the stream and use a depth integrated sampler that allows you to take a water sample up and down the water column, I'll move across the stream at equal widths and that allows you to get a representative sample of the stream flow. We are studying streams because they input both nutrients and fine sediments into the lake. The nutrients cause the algae to grow, and the fine sediments cloud the water and both of those impact the clarity of Lake Tahoe.

Thanks Scott. The samples are taken back to the lab where the amounts of fine particles and nutrients from each stream are measured. Fine particles and nutrients can also come from other places. They can flow directly from the land into the lake. This often happens in populated areas during storms. We call this urban storm water.

My name is Andrea, and I am a storm water hydrologist. This is an automated sampler. Automated samplers make it very easy for us to sample storms because you don't have to be out here to take every single sample by hand. We have tubes that suck water up into the sample bottle that we then take back to the lab to analyze for nutrients and sediments.

...And with information about the levels of pollution in the stormwater we can alert authorities to the biggest problem areas. One way to reduce the amount of polluted

stormwater getting into the lake is to build new wetlands. These are called constructed wetlands. Our measurements have shown that wetlands can remove the pollutants before they enter the lake – turning that brown water into clean water. Unfortunately, many of the wetlands were lost to development and now there simply is not enough flat land around Lake Tahoe to build all the wetlands we would need.

Research has shown how important wetlands and streams are to the health of the lake. That is why local regulatory agencies have implemented building regulations that protect these sensitive and important areas from further development.

The other important source of fine particles and nutrients is, believe it or not, the air. Where do the pollutants in the air come from? All sorts of places - highway dust, car exhaust, wood burning stoves or fireplaces, forest fires, leaf blowers, and agriculture from the central valley.

We have air samplers at many places around the lake and even on the research buoys on the lake.

Thanks for visiting the Tahoe Environmental Research Center. We hope you can use some of the things you have learned here to keep Tahoe blue and to keep all lakes, streams, wetlands and the air healthy. See you next time.

Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

Talking Points

Lake Tahoe is a closed watershed system

- Lake Tahoe has 63 streams (sub-watersheds) that flow into the lake.
- Only 1, the Lower Truckee River, flows out.
- Truckee River flows to Pyramid Lake (water never reaches the ocean) - Pyramid Lake is called a “terminal lake.”
- The watershed can be compared to a bowl; this is why it is called a basin. The map in the entrance lobby illustrates the Lake Tahoe Basin watershed boundaries.

Stream Monitoring

- TERC researcher, Scott Hackley, monitors three streams along the west shore of Lake Tahoe (Ward, Blackwood and General Creeks) and the Truckee River just downstream of the dam at Tahoe City.
- Regular sampling is done monthly with more frequent sampling during the spring runoff and rain events.
- Water samples are analyzed for nutrients, suspended sediment, temperature and dissolved oxygen.
- Information from this monitoring is used to estimate the annual nutrient and particle loads from streams and to discern trends in tributary water quality.

Atmospheric Deposition Monitoring

- Atmospheric Deposition: Gases and particles from combustion sources in the atmosphere settle as dust or fall in rain and snow.
- Historical data collected by TERC shows that atmospheric deposition of nitrogen (and to a lesser extent phosphorus) is an important source of nutrients to the lake.
- TERC currently monitors atmospheric deposition at four stations within the Tahoe basin. Two stations are located in Ward Valley, and two are located on research buoys near the middle of the lake.
- Data collection from the stations on land in Ward Valley includes precipitation amount, timing, nutrient (N and P) content and pH. From the lower Ward Valley station, both “wet” deposition (rain and snow) and “dry” deposition (deposition occurring during dry periods) are collected.
- The atmospheric deposition monitoring program provides ongoing information

on nutrient loading via this important source of nutrients to the lake.

Sampling Equipment

- Integrated sampler – allows you to take a water sample from up and down the water column to get a representative sample of the stream flow.
- Urban stormwater sampling uses automated sampling equipment.

USGS Gage System

- The quantity and quality of water in most of the United States' rivers, streams, lakes, and reservoirs is monitored by the U.S. Geological Survey. The monitoring program is a cooperative effort that is funded jointly by numerous Federal, State, and local agencies.
- Real-time data for river and streams throughout the nation are available at <http://waterdata.usgs.gov/nwis/rt>.

Wetlands

- Wetlands are very important to Lake Tahoe.
- Wetlands contribute to flood control, for example, by collecting excess rainfall and releasing it slowly over time rather than in a torrent. Wetland soil and vegetation filter contaminants out of water as it percolates through, returning cleaner water to rivers, lakes, and underground aquifers. In addition, wetlands provide indispensable habitat for hundreds of species of amphibians, birds, mammals, and plants.
- Urbanization of the Lake Tahoe Basin has eliminated 75 percent of its marshes, 50 percent of its meadows, and 35 percent of its stream zone habitats.
- See “*Wetlands Q&A*” below and/or “*Wetlands 101*” in your Docent Manual.
- “Additional Resources” section.

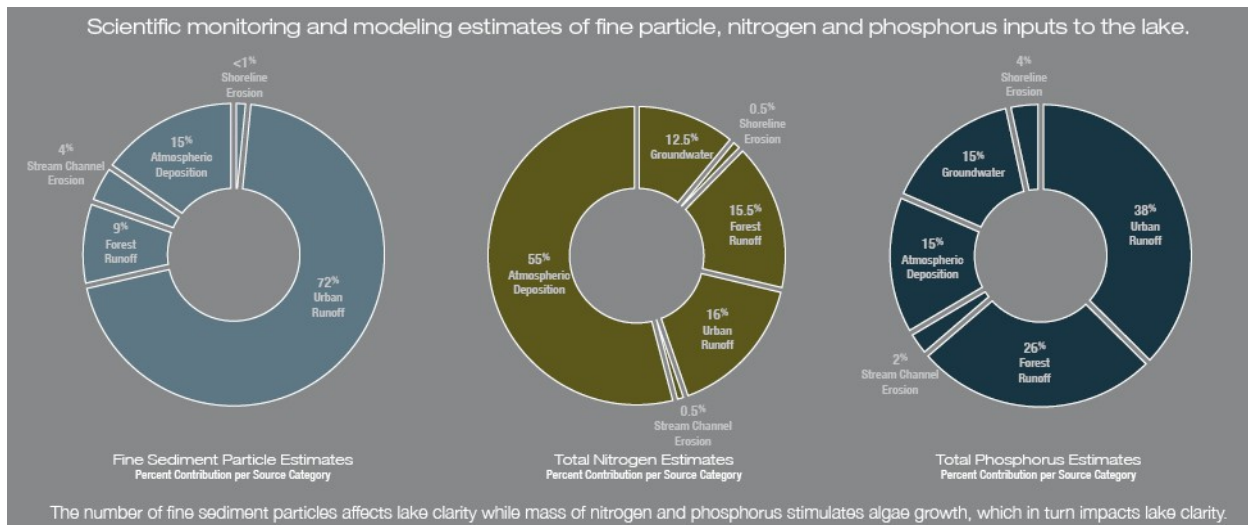
Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

Discussion & Questions

Discuss: Why do we regularly monitor streams, urban runoff, and the air?

It is important to know what is coming into the lake and streams in order to track sources of pollution. Urban runoff and atmospheric deposition are the main sources of pollution to the lake.



Source: Charting a Course to Clarity: The Lake Tahoe Total Maximum Daily Load, 2008-09

Question: Why are wetlands important to the Tahoe Basin?

They are the filters that remove pollutants from stormwater runoff and help to keep Lake Tahoe clear and blue. Wetlands also provide valuable habitat for many species.

Question: Do you know the location of any constructed wetlands near you?

Tahoe City “Y,” Tahoe Vista, South Lake Tahoe Cove East

Discuss: What can you do to protect wetlands?

Stay out of these sensitive areas. Do not ever drive through, bike, or hike through the wetlands. Never build in wetlands, do not remove vegetation or mow grasses, and use your vote to protect this valuable resource. Local Tahoe ordinances and regulations now prohibit construction within wetland or stream environment zones.

Discuss: What are your ideas about ways to keep Tahoe blue and to keep all lakes, streams, wetlands and the air healthy?

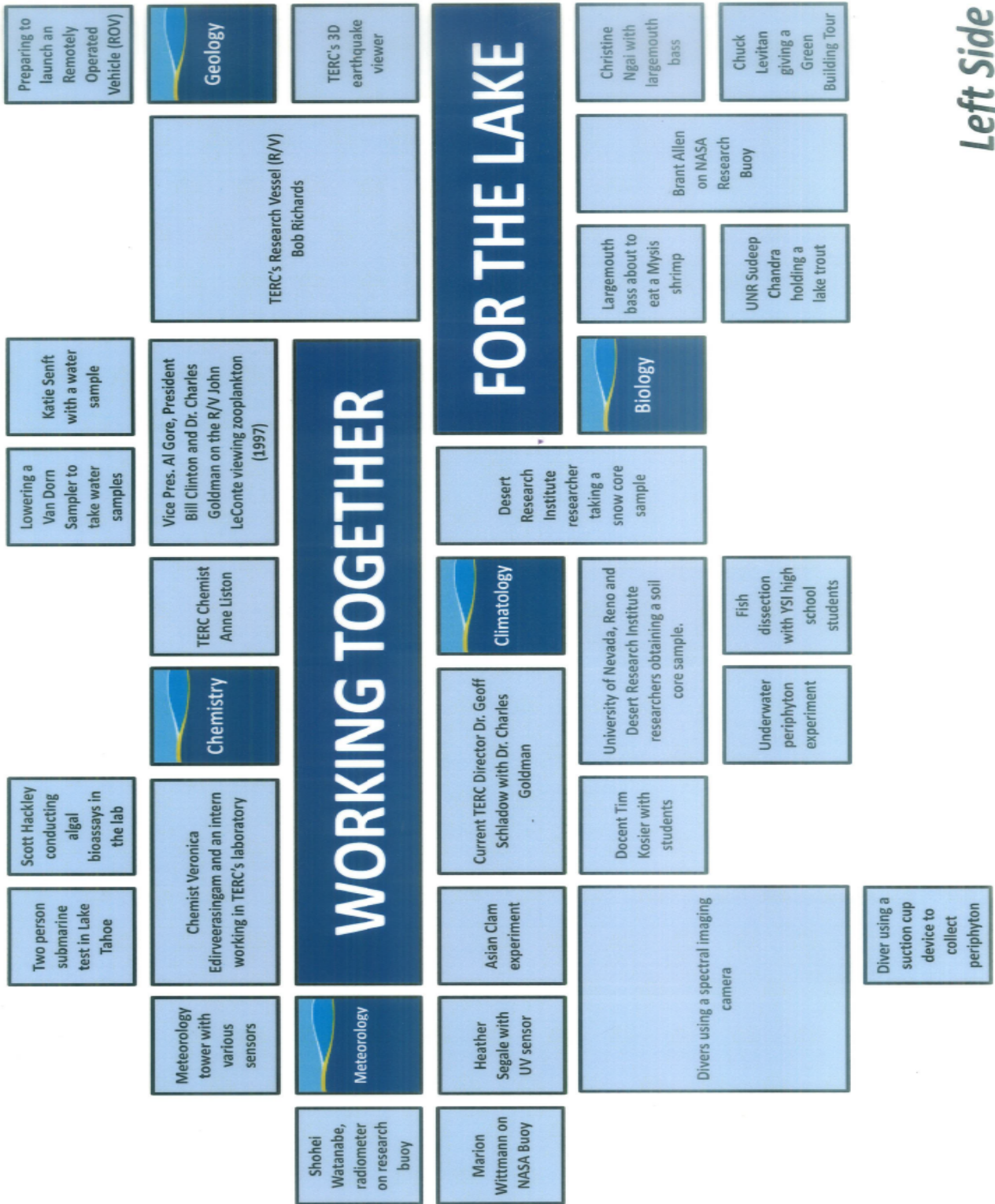
Research Photo Wall

Photos of researchers from UC Davis, UNR, DRI, Scripps Institution of Oceanography and others are included on the wall to show visitors the broad range of scientific research conducted at Lake Tahoe. Descriptions of each photo are available on a separate laminated card in the Docent Room.



Student field trips sometimes include a scavenger hunt activity where students are acting as “visiting researchers” from the following research fields:

- Ecology: The study of where living organisms are found, and the interactions between these organisms and their environment.
- Geology: The study of the physical history of the earth, the rocks it is made of, and the changes the earth goes through.
- Biology: The study of life and of living organisms, including their structure, function, and growth.
- Chemistry: The study of matter and its interactions.
- Hydrology: The study of water, its effects on the earth’s surface (soil, rocks) and in the atmosphere.
- Limnology: The study of bodies of fresh water, such as lakes and ponds.
- Meteorology: The study of the atmosphere, especially weather and weather conditions.
- Climatology: The study of the weather over long periods of time.
- Physics: The study of matter and energy and their interactions.



Left Side

Scripps researchers launching a lake floor seismometer to determine Lake Tahoe's seismic activity	Students at a hands-on Science Expo (Earth & Space) station	Flow sampling in a stream	Students looking at zooplankton through a microscope	Christine Albano backpacking from the field	Underwater diver with Asian clams in hand	Summer interns displaying water density demo	Underwater diver with Asian clams in hand	Raising a sediment collector from the bottom of Lake Tahoe	Suite of optical instruments measuring water clarity		
Inside Incline Village trench viewing fault displacement	Divers with Asian clams in hand	Hydrology	Students exploring benthic macro-invertebrates	Bob Richards taking a Secchi disk reading	Downloading data collected by the Sea-Bird profiler	Derek Roberts working on Nearshore Network instruments	Brant Allen showing Asian Clams	Close up of a Autonomous Underwater Vehicle (AUV)	Alex Forrest with drifters— instruments used to track Tahoe's surface currents		
Water sampling to understand water chemistry changes due to Asian Clams	Allison Gamble with zooplankton sample	Andrea Parra inside a storm water vault	Scott Hackley performing a stream transect	Diver cleaning an optical instrument (used to measure Lake Tahoe's blueness)	Diver cleaning an optical instrument (used to measure Lake Tahoe's blueness)	Derek Roberts working on Nearshore Network instruments	Brant Allen showing Asian Clams			Close up of a Autonomous Underwater Vehicle (AUV)	Alex Forrest with drifters— instruments used to track Tahoe's surface currents
Forest Ecologist Patricia Maloney		Alison Toy pulling invasive bull thistle from Tahoe City Demo Garden	Brant Allen looking for periphyton	Secchi Disk reading	Releasing a drogue to track water currents	Derek Roberts working on Nearshore Network instruments	Brant Allen showing Asian Clams			Autonomous Underwater Vehicle (AUV) known as a glider	Lowering rebar needed for rubber clam mats
		Martin Fry with a dendrometer (measures tree growth)	Collin Strassenburgh at the Tahoe City Constructed Wetland	Alan Heyvaert analyzing sediment cores	Autonomous Underwater Vehicle (AUV) known as a glider	Derek Roberts working on Nearshore Network instruments	Brant Allen showing Asian Clams			Physics	
			Ecology	Limnology							

Right Side

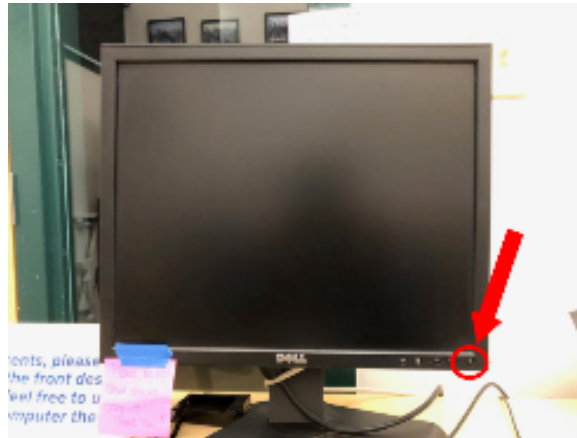
Operating the 3D Visualization Lab

Turn System On

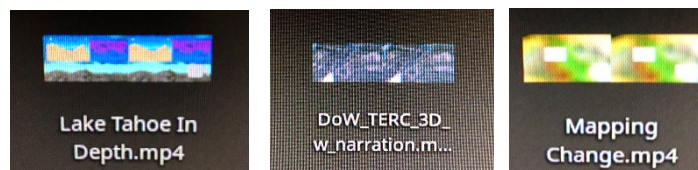
Both projectors are controlled by one remote control.

- Stand near the projector screen and point the remote at both projectors. Try and aim at the input infrared remote (IR) sensor is located at the bottom/front of each projector. If you stand directly below the projectors, you might miss the IR sensor.
- Press the green [ON] button ONCE to turn both projectors on. If only one projector turns on, aim as best as you can at the one that isn't on and press the green [ON] button once more. This can be done repeatedly until both projectors are on.
- It will take a minute or two for the projectors to warm up, look for the light emitting from both projectors.

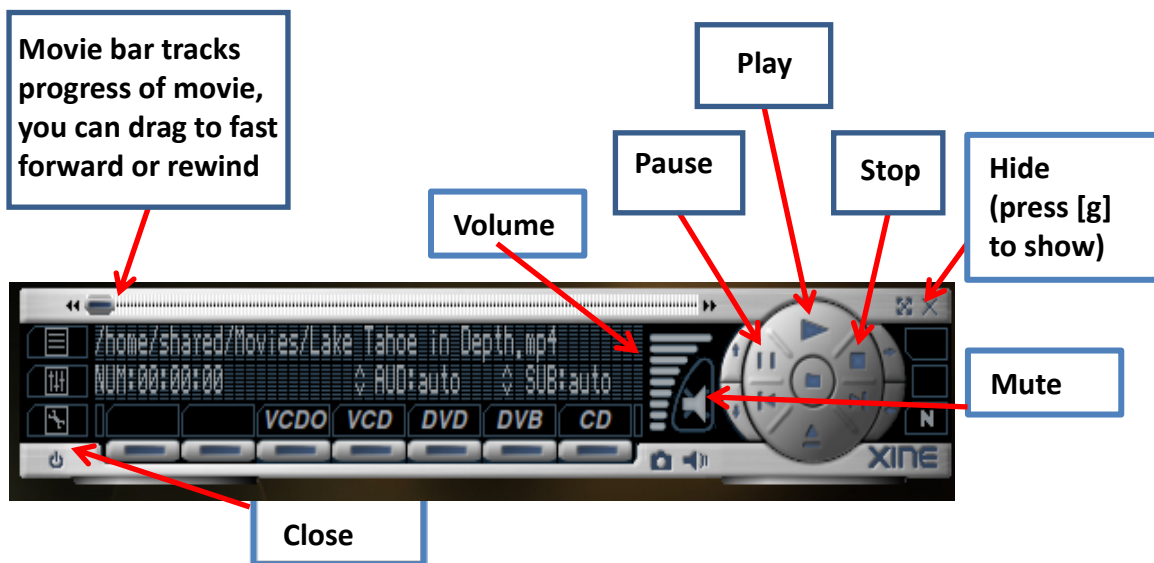
Computer procedure is minimal as the TERC education team always tries to have the education center fully functioning before the docent arrives. Make sure the monitor is on by pressing the small button on the lower right-hand portion of the screen, it will be lit when on.



- If the computer screen prompts a login, use the following:
 - Login username: TERC user
 - Password: 1q2w3e4r5t
- See printed instructions taped onto the docent desk for the most up-to-date instructions to operate the 3D theater. **Note: instructions are subject to change.**
- Several movies are available on the desktop. Double-click on “Lake Tahoe in Depth” icon or any of the following icons to start a movie.



- A control bar that looks like a car radio console will appear and allow you to control the movie(s) as indicated below.
- Press Play.



- The player works best if the control bar is left open after every showing. You can hit “stop” and “play” between each viewing.
- If the system has reset itself (the projector screen says “no signal” on a blue screen or the desktop is blank with no desktop icons) then call upstairs to the TERC staff member for help.
- For all other troubleshooting issues, please call the TERC staff for help

Turning System Off

Projectors: After your shift is completed stand in front of the projectors and point the remote control at the projectors. Press the red [OFF] button at least once to turn both projectors off. One turns off immediately and one projects a notice that it is turning off. If only one turns off, try to position yourself so you can point directly at IR sensor area of the projector and press the red [OFF] button again. Repeat process if necessary. Look for the lights to shut down. You will still hear the projector fans operating to cool the system down.

Computer: Turn the monitor of the computer off using the small button on the lower right-hand portion of the screen. The desktop computer located on the ground under the desk should be left on.

Self-Guided Exhibits for Science Center Tour Extensions

“Tahoe’s Plastic Problem” Microplastics Exhibit

This exhibit was installed January 2021 as part of a Nevada Division of Environmental Protection (NDEP) grant to reduce source-water microplastic pollution. It is intended to be self-guided, but students and adults may benefit from additional guidance if they have questions. The exhibit progresses from left to right and includes five wall panels and five corresponding hands-on table activities.



Wall Panel Highlights:

- Tahoe’s Plastic Problem
 - 91% of plastic is never recycled
- A Day at the Beach
 - Plastic is a problem even somewhere as beautiful at Lake Tahoe
 - Tie into the flip signs below
- Plastics Are Forever
 - Plastics break apart, but they don’t break down. The pieces get smaller and smaller, but they never biodegrade or decompose.
 - When they break into pieces smaller than 5 millimeters, they’re called microplastics.

- Microplastics in Lake Tahoe
 - UCD is currently (2021-22) doing research on microplastics in Tahoe
 - Looking into the fate of microplastics; where microplastics end up in the environment (water column, sediments, animals, etc.)
- It's Time for Solutions
 - More than “reduce, reuse, recycle”
 - Community-based solutions

Hands-on Activity Highlights:

- Help Clean up the Beach
 - Materials:
 - Sandbox filled with sand and large pieces of plastics
 - Seven metal buckets with “bookmarks” of RIC numbers
 - Put plastics back into the sandbox after sorting them by number
 - Key Talking Points:
 - The “chasing arrows” symbol or Resin Identification Code (RIC) does not necessarily mean that plastic is recyclable. It only indicates the type of polymer used to make it.
- Flip Signs
 - Materials:
 - Seven flip signs attached to table
 - Key Talking Points:
 - Only #1 and #2 plastics are “widely” accepted (and only 25-35% at that!)
 - Recycling is not a solution and the plastic industry knew this all along. The “Chasing Arrows” symbols were used as a tool of plastic lobbyists looking to stave off perceived threats to their industry.
 - Go over local recycling rules for TTSD, IVGID, etc.
- Shake it Out
 - Materials:
 - One metal lid, three metal sieves organized from largest to smallest grid size, and one metal collection pan at the bottom
 - Metal pitcher
 - Sample of sand and plastics (to be kept in the pitcher for the next guest to pour through the sieves)
 - Caliper and rulers for measuring plastic sizes
 - Key Talking Points:
 - Plastics are harder to sort out from sediment the smaller they get
 - It is very difficult to clean up plastic once it enters the environment
 - We should stop plastic from getting into the environment in the first place
- Zoom in on Microplastics
 - Materials:

- Two microscopes (plugged in, turned off when not in use, pre-adjusted to the correct magnification)
 - Five samples of different shapes in sealed petri dishes
 - Be careful not to spill, especially with young children
 - Key Talking Points:
 - Microplastics come in different shapes, depending on their source material
 - Can visitors trace the microplastic back to its source?
 - Styrofoam might be easiest to recognize
- Take Action
 - Materials:
 - Two iPads should be set to <https://www.breakfreefromplastic.org/> and <https://www.arcgis.com/apps/webappviewer/index.html?id=9c2cd4575624417fa56fd084a7ee4dd9>
 - Postcards
 - Key Talking Points:
 - The burden of change should be on the corporations that caused the problem not on the individual

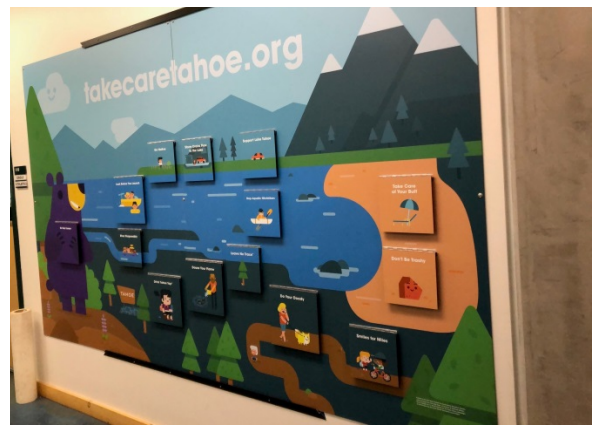
Take Care Tahoe Exhibit

Take Care Tahoe is a collective group of more than 30 organizations that love Lake Tahoe and want to see more people connect with this beautiful natural environment. For more information on the program, visit www.takecaretahoe.org.

The display on the left side of the hallway is a pledge board. The messages for Take Care were created to address the key impacts humans are having on our environment: litter, dog waste, bears, fire safety, and aquatic invasive species. Visitors can pledge to participate by placing a bead in the one or more category. Take Care stickers and postcards are also available at this exhibit.



Pledge Display



Take Care Flip Panel Display

The informational Take Care Tahoe flip panel display is located on the right side of the hallway. Visitors can learn more about each initiative by flipping the panels on the flip chart exhibit.

Green Building Exhibits



The Green Building Exhibit highlights the U.S. Green Building Council LEED Categories. It also discusses specific green features of the Tahoe Center for Environmental Sciences building including energy-saving, water-conserving, and indoor environmental air-quality features, and includes samples of recycled building materials used. Visitors are welcome to go on

a more in-depth Green Building tour upon request. More Green Building information is located at the last section of this chapter.

Forest Health and Fire Exhibit

The Forest Health Exhibit contains information concerning tree pathology, forest fire risk and prevention, and Tahoe's forest history. Visitors can receive alerts and view wildfire cameras at <http://www.alertwildfire.org/tahoe/>.



Tree Identification Exhibit

This exhibit displays the eight evergreen trees native to the Tahoe basin (Sugarpine, cedar, red fir, white fir, whitebark pine, lodgepole pine, Jeffrey pine, and Ponderosa pine). Visitors can examine the needles, bark, cones, and read information cards to learn more about each variety.

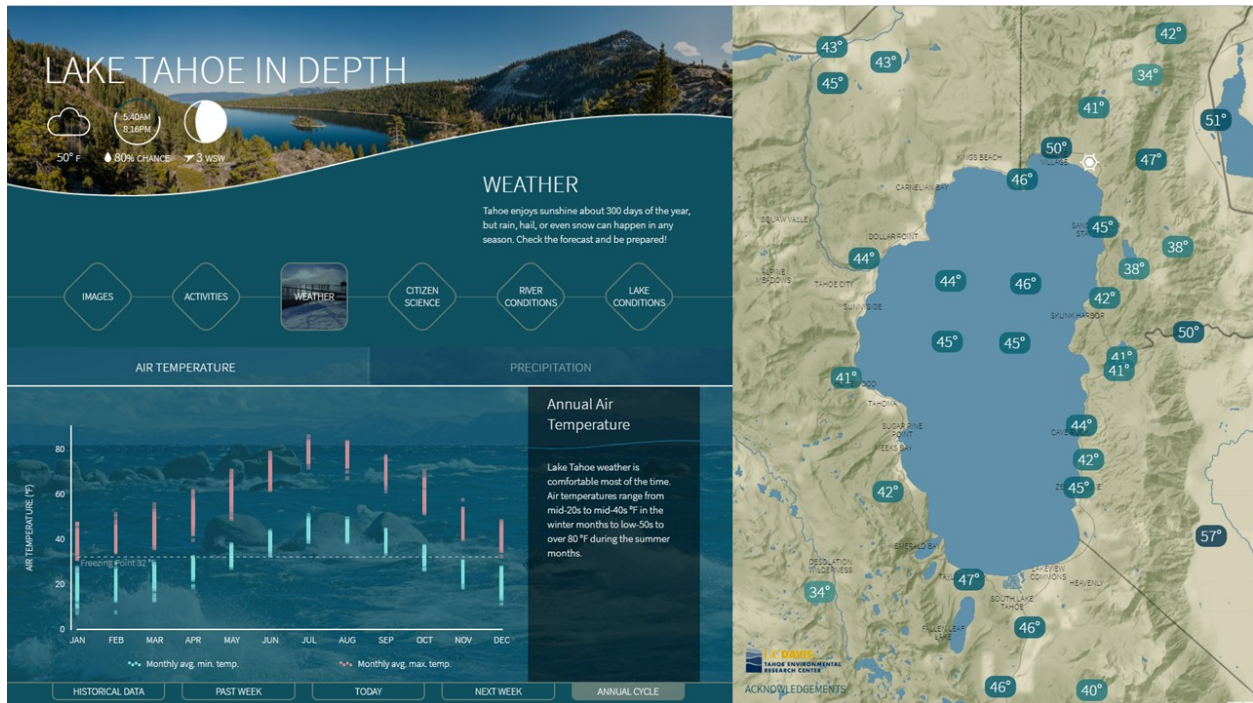


Lake Tahoe In Depth Touchscreen Exhibits

The “Lake Tahoe in Depth” touchscreen exhibits are available at the UC Davis Tahoe Science Center, Tahoe City Visitor Center, and Tahoe Maritime Museum.

The categories include the following:

1. **Images** - From professional photographers to Instagrammers, everyone loves to photograph Lake Tahoe. Explore these images and check out the live streaming videos from the mountaintops!
 - a. Seasonal photos from around the lake
 - b. Live videos with 24-hour time-lapse
2. **Activities** - Tahoe is one of America’s primary destinations for fun! Explore the many activities you can enjoy here, while protecting this pristine environment.
 - a. On the water
 - b. On the mountain
3. **Weather** - Tahoe enjoys sunshine about 300 days of the year, but rain, hail, or even snow can happen in any season. Check the forecast and be prepared!
 - a. Air temperature
 - i. The Zephyr Cove air temperature gauge is located on the black-top and so regularly records a much higher air temperature.
 - b. Wind speed
 - c. Historical cycle
 - i. Air temperature - Have weather patterns changed over time? Tahoe researchers have recorded weather patterns since 1910 at Tahoe City and the trends are apparent. Climate change, especially here, is measurable.
 - ii. Precipitation varies greatly from year to year. Since 1910, annual precipitation has ranged from less than 10 inches in 1977 to nearly 70 inches in 1982 at Tahoe City. Over the past century, snowfall as a percentage of total precipitation has declined by almost 20 percent. Precipitation has been measured at Tahoe City since 1910.
 - d. Annual cycle
 - i. Air temperature - Lake Tahoe weather is comfortable most of the time. Air temperatures range from the mid-20s to the mid-40s °F in the winter and between the low-50s to over 80 °F during the summer.
 - ii. Precipitation varies by season and location. Over 75 percent of the precipitation occurs between November and March. Summers are dry with less than a 10 percent chance of significant precipitation.



4. **Citizen Science** - Non-scientists contribute to our understanding of the Lake by recording water, land, and air conditions. Join the fun! Contribute to the results and discussion of science by downloading the “Citizen Science Tahoe” app.
 - a. Algae observation - Algae follows a natural cycle encircling the lake’s rim, but human-related inputs such as lawn fertilizer, dog poop, and detergents can increase the growth of algae and harm lake clarity. What can you see here about current and recent algae conditions observed by citizen scientists to Lake Tahoe?
 - b. Beach conditions - Tahoe has the best freshwater beaches in the world! But some people seem to think that the beach is their ashtray or wastebasket. Do you notice any patterns in citizen scientist observations about beach trash over the course of the past year?
 - c. Water quality - Lake Tahoe’s water is known for its clarity and its bold blue colors that darkens as it deepens. Sometimes, though, the water can appear brown, green, or even yellow. What causes these color changes? Check out our citizen scientists’ observation to discover correlations between human activities and water clarity.

5. **Rivers & Creeks** - There are 63 streams that feed into Lake Tahoe. The Truckee River, the only outflow from the lake, allows rafting if the lake level is high enough to flow out at the Tahoe City dam.
 - a. Historical - No two years are ever the same. Wet years correspond to the higher peaks. Drought years can result in little to no streamflow. Peaks in the streamflow usually coincide with the snowmelt in late spring.

- b. Past Year - Rainstorms can be seen as sharp “spikes” or high, short-duration flows when they occur. Most of the streamflow occurs during the spring and early summer, coinciding with snowmelt.
 - c. Previous Week
 - d. Current Conditions
6. **Lake Conditions** – The combination of wave height, water temperature, algae concentrations, clarity, and lake levels create a complex and ever-changing freshwater environment.
- a. Wave Height - Lake Tahoe can be perfectly flat and serene, or blustery winds blowing across the lake can churn up six-foot high waves. The highest waves occur on the downwind side of the lake, which is typically the north and east shores at Lake Tahoe. Wind and waves are usually higher in the afternoon, so be prepared and stay safe.
 - b. Water Temperature - Lake Tahoe water is cold for most swimmers, with surface temperatures ranging from 42 degrees in the winter to over 70 degrees in July and August. Though refreshing on a hot day, a plunge into Lake Tahoe can literally take your breath away. Swimmers should always prepare for dangerously cold conditions.
 - c. Algae - Underwater instruments measure the interaction of light with chlorophyll from free-floating algae (phytoplankton) in the water. The apparent daily declines in algae concentrations are due to the interference from bright sunlight.
 - d. Clarity
 - i. Historic: Annual Average Secchi Depth - Water clarity measurements have been taken every 10 – 15 days by UC Davis TERC since 1968, when a white disk, called the Secchi disk, could be seen at a depth of 102.4 feet. Secchi depth is the most widely used method of clarity measurement.
 - ii. Current - Turbidity is a measure of how cloudy the water is. Sediment from erosion makes the water less transparent. In most areas of Lake Tahoe, the water is generally very clear (turbidity values near zero), but afternoon waves can stir up sediment and increase turbidity in the nearshore.
 - e. Lake Level
 - i. Historic - The natural rim of the lake is at an elevation of 6,223 feet above sea level. When the lake is below the rim, outflow via the Truckee River ceases. The maximum legal limit for the lake is 6,229.1 feet. The 6.1 feet above the natural rim provides a reservoir for downstream users.
 - ii. Current - Lake level varies throughout the year. Lake level rises due to high stream inflow, groundwater inflow, and precipitation directly on the lake surface. The level falls due to evaporation, water withdrawals, groundwater outflows, and outflow via the Truckee River at Tahoe City.

What Can You Learn From TERC’s Nearshore Network?

Within the “Lake Tahoe in Depth” exhibit you will see the patterns of water quality data, including:

Wind/wave patterns – The prevailing winds at Lake Tahoe blow out of the southwest. This pattern results in 2 to 8-inch (5 to 20 cm) waves along the north and east shores of the lake. Winter/spring conditions may be very calm for days on end, but when storms hit the lake, the winds tend to be much more powerful. We have recorded waves as high as 6 feet (1.8 m) at Tahoe Vista and Dollar Point during winter.

Sediment resuspension – When waves are large enough, the sensors record increases in turbidity, algae, and dissolved organics, as waves re-suspend sediments and churn particles and attached algae up into the water column. Wind waves are the dominant driver of turbidity in the nearshore of Lake Tahoe.

Upwelling – Upwelling occurs when strong, sustained winds drive surface waters to the downwind end of the lake, slightly increasing the lake depth (about 1 inch maximum). There is a compensating back-flow and deep-water flows toward the upwind end of the lake and rises to the surface. Since Tahoe’s deep water is (comparatively) rich in nitrate, upwelling plays a role in internal nutrient cycling in the lake (see information on Project UPWELL).

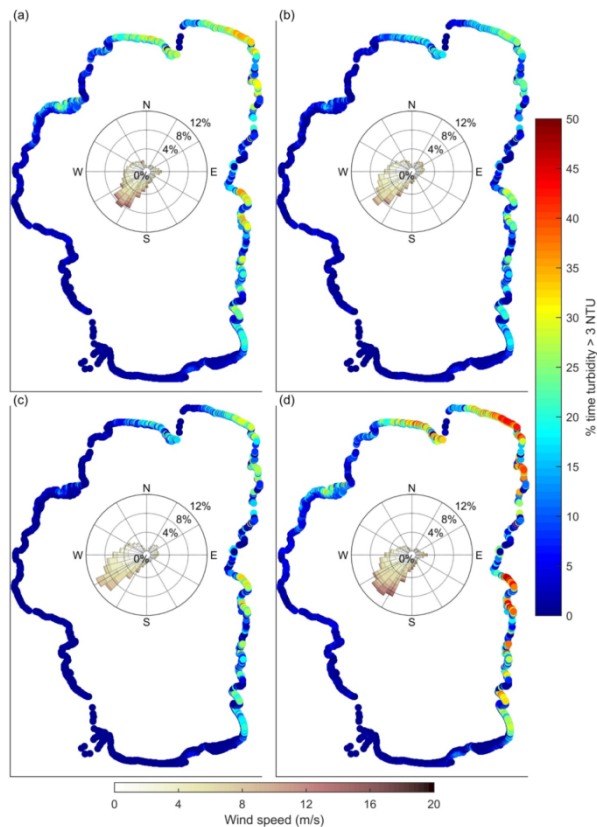


Figure 1 – Seasonal percent-time exceedance of 3 NTU turbidity due to wind-waves. 2016 seasons: (a) January 1 – March 31; (b) April 1 – June 30; (c) July 1 – September 30; (d) October 1 – December 31. Wind rose coloring corresponds to wind speed; length corresponds to percent-time of wind data at a given direction.

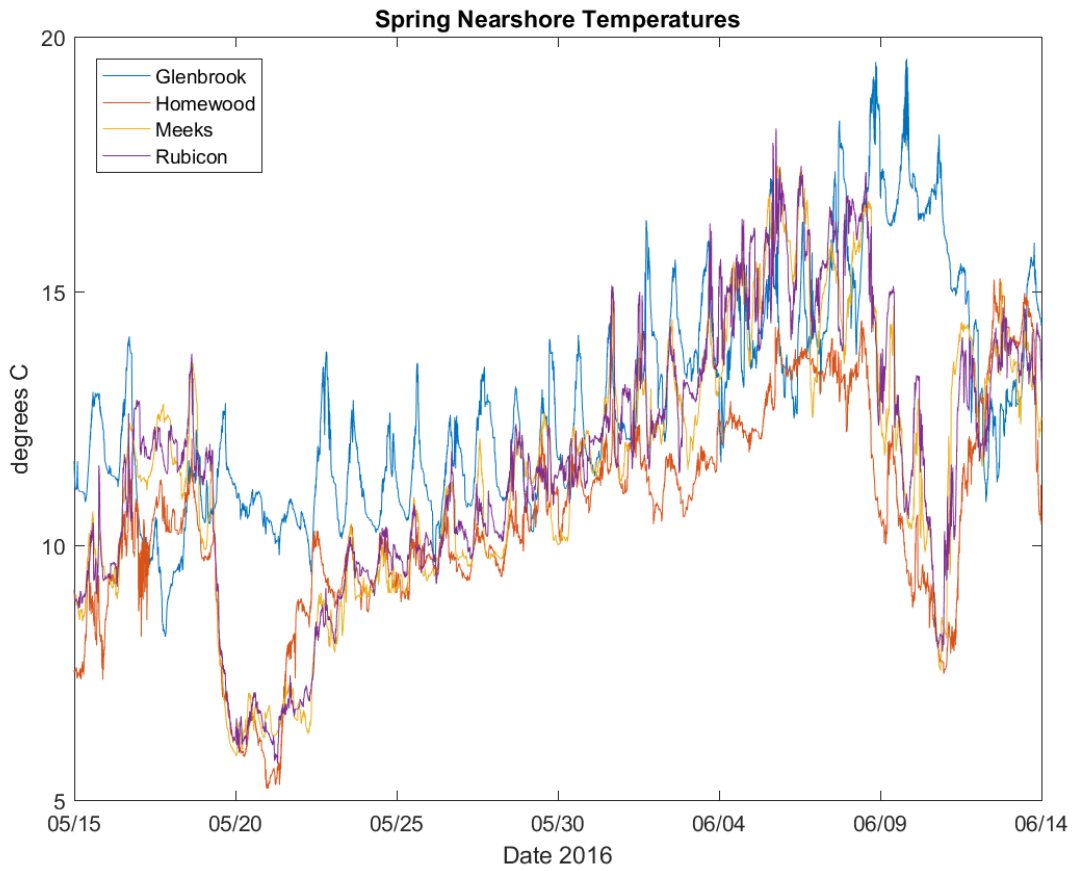
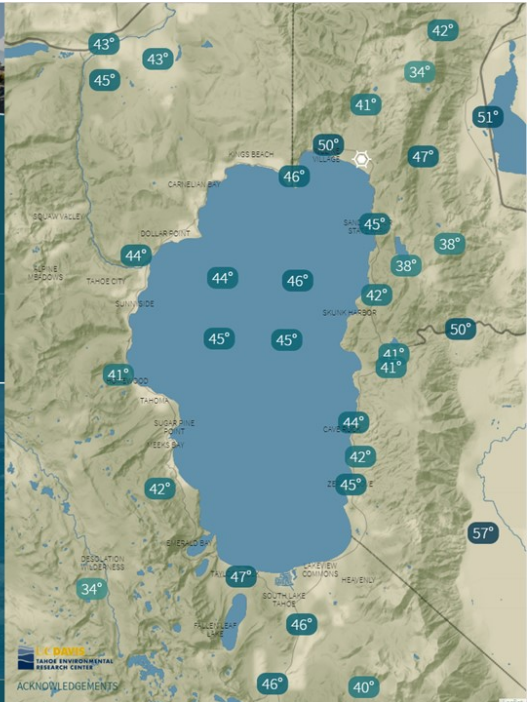
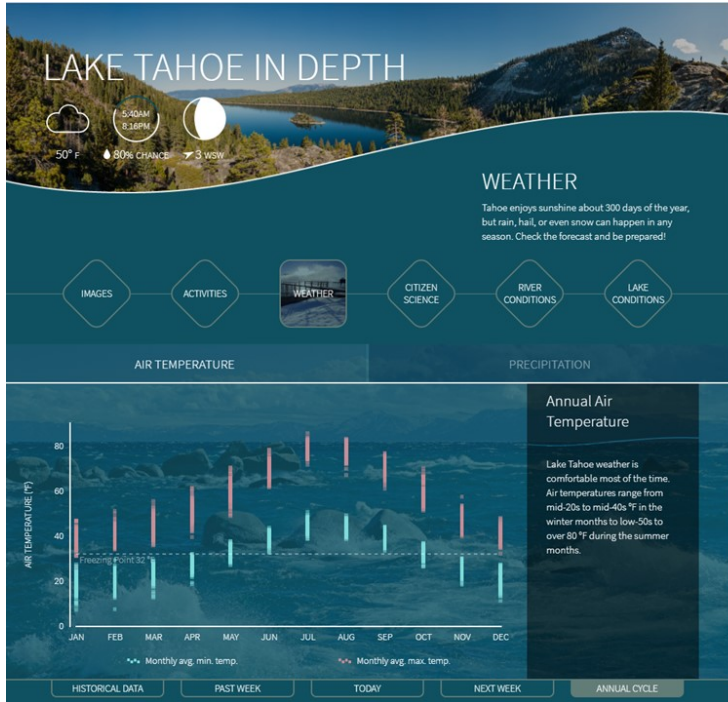
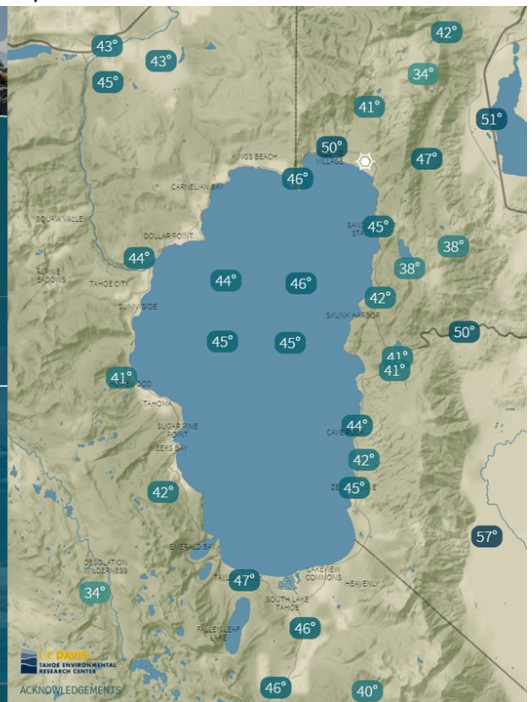


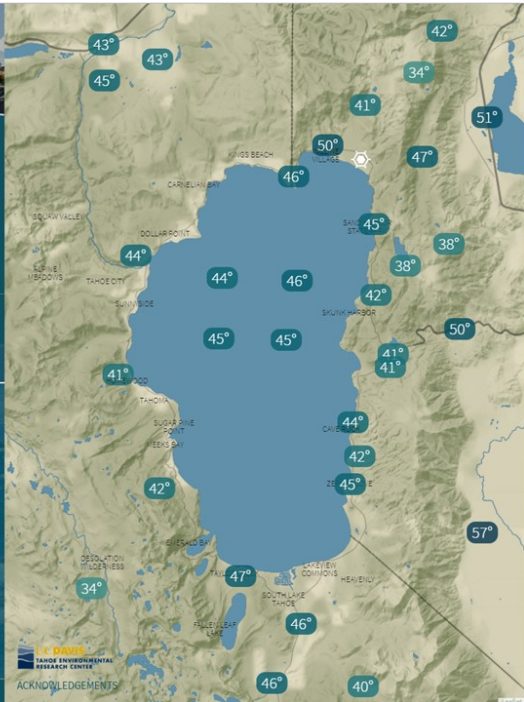
Figure 2 – Nearshore temperatures at three west-shore stations (Homewood, Meeks, and Rubicon) and one east-shore station during two upwelling events in late-spring 2016. Note how the west shore temperature drops rapidly while the east shore temperatures remain stable.



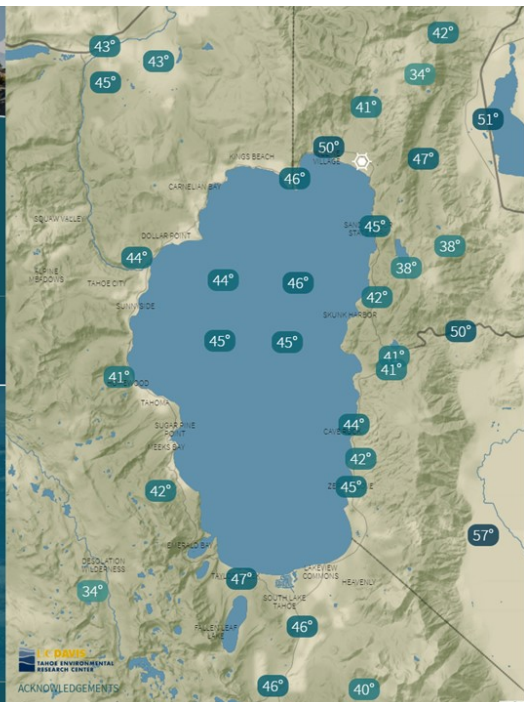
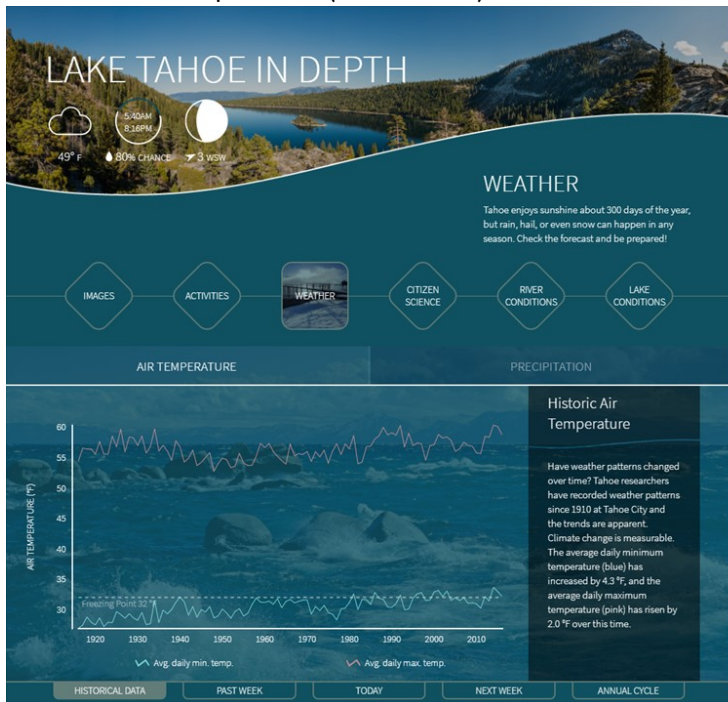
Annual Cycle of Air Temperature (by month since 1910)



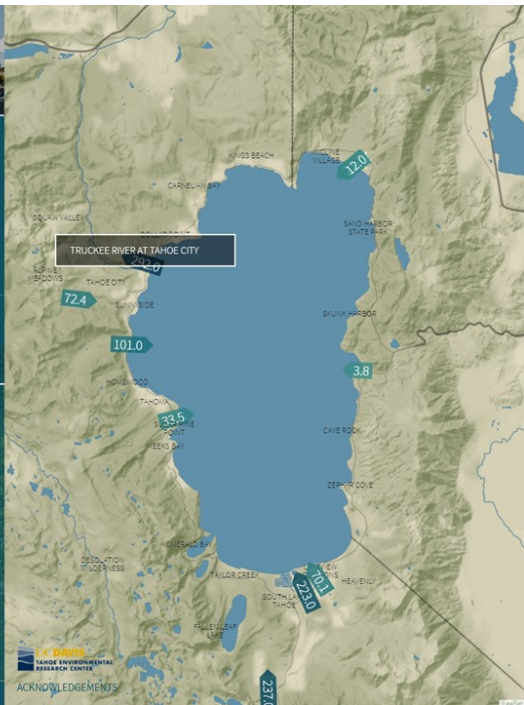
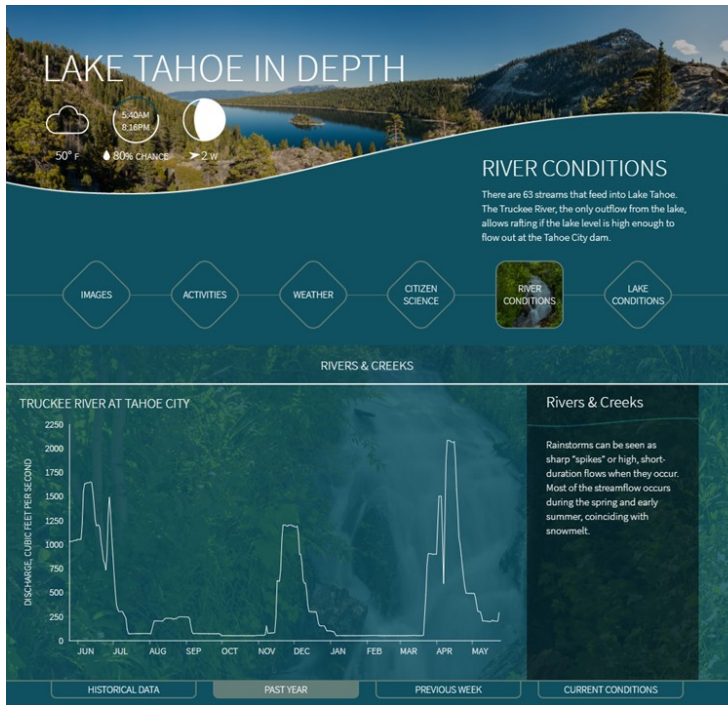
Annual Cycle of Precipitation (by month since 1910)



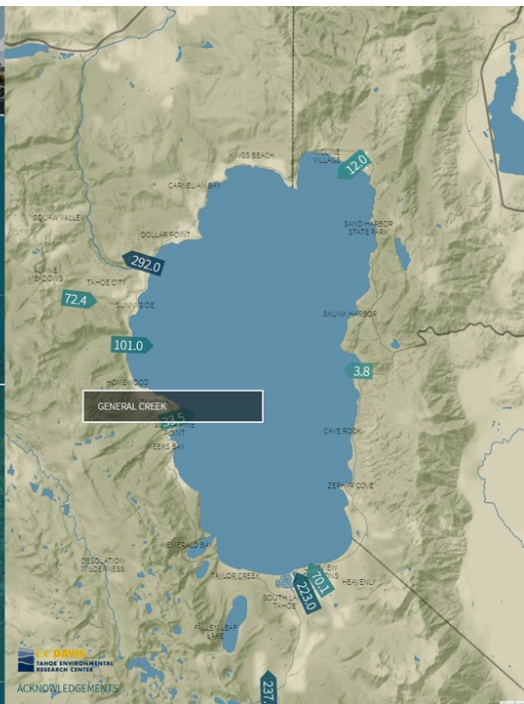
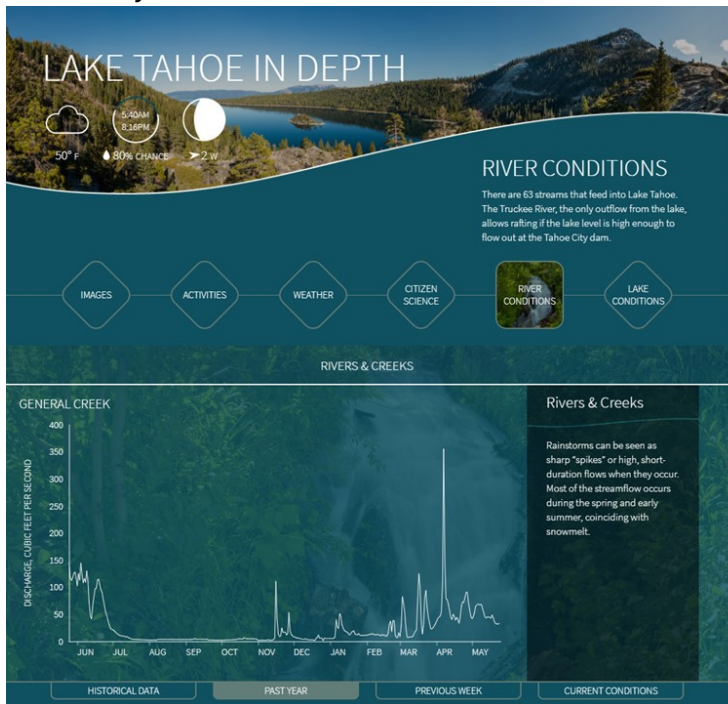
Historical Precipitation (since 1910)



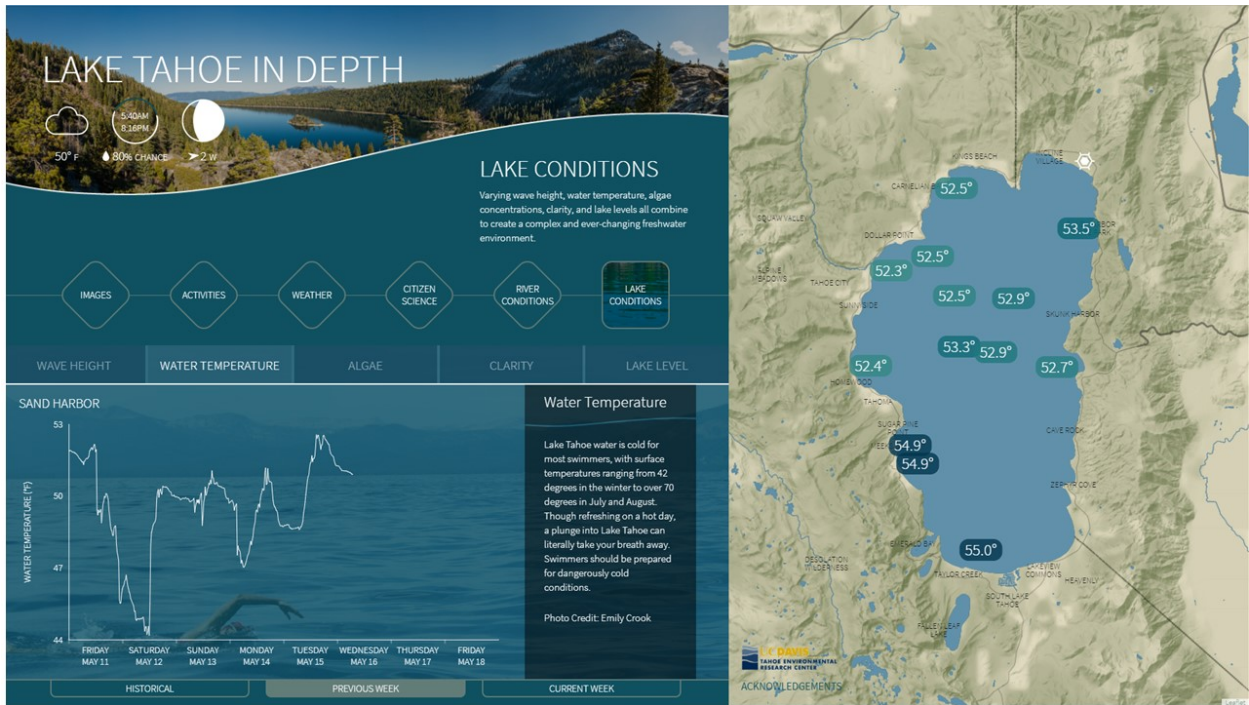
Historical Air Temperature (since 1910)



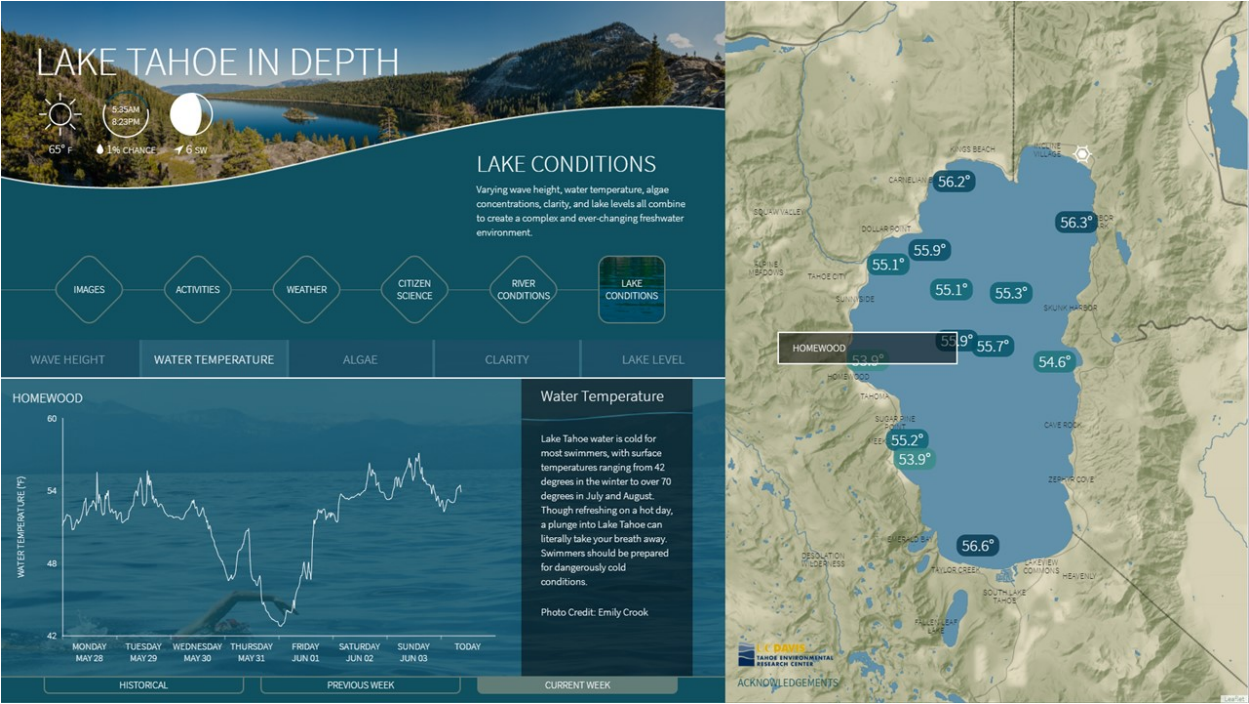
Annual Cycle of Creek Flow



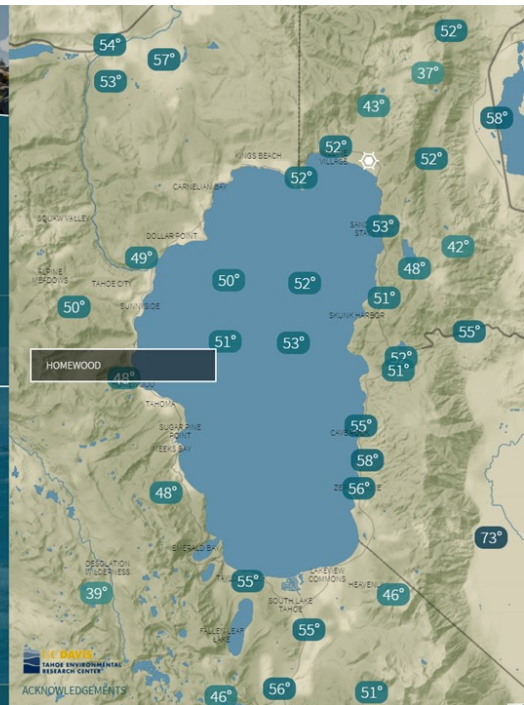
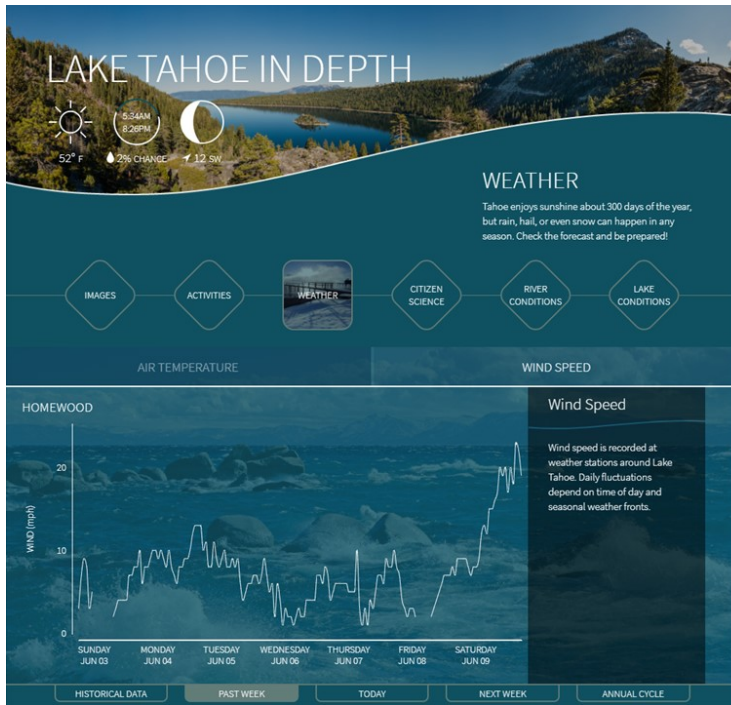
Annual Cycle of Creek Flow (General Creek)



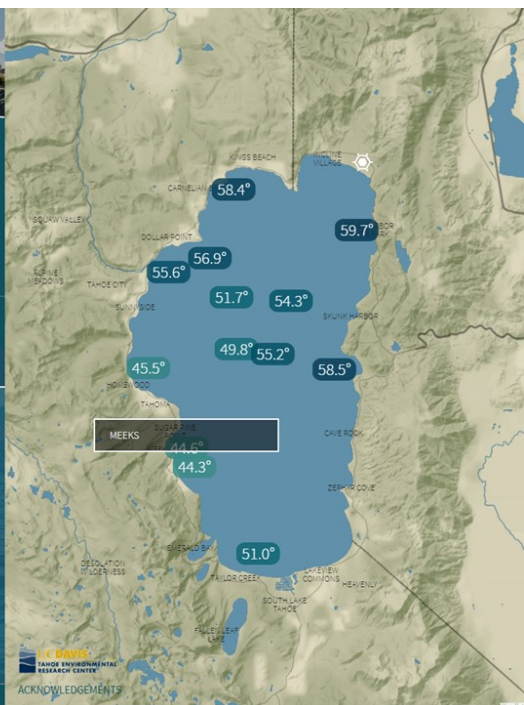
Water Temperature Shows Upwelling Event (Sand Harbor, May 11-12, 2018)



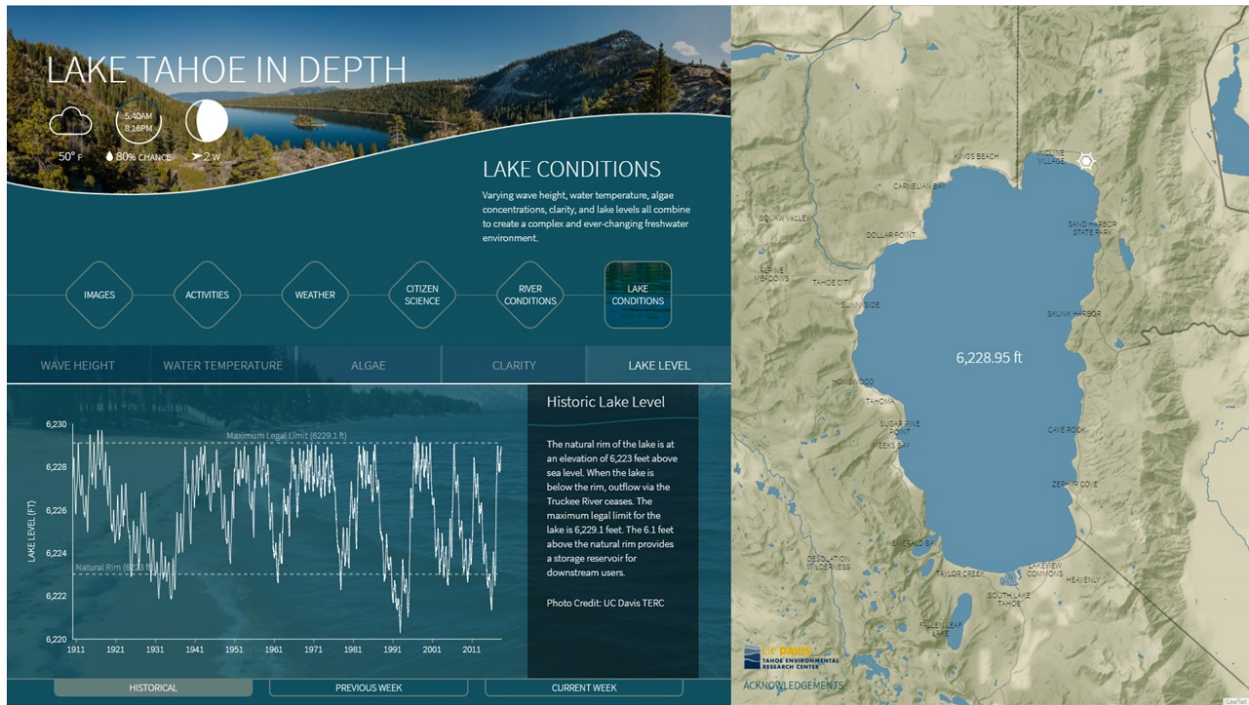
Water Temperature Shows Upwelling Event (Homewood, May 30-31, 2018)



Wind Causes Upwelling Events (June 9, 2018)



Water Temperature Shows Upwelling (Meeks Bay, June 9, 2018)



Historic Lake Levels, shows periods of drought and lake recovery

North Tahoe Demonstration Garden Tour Cheat Sheet

Welcome

- Start tour at the Trees of Tahoe exhibit and the Forest Health exhibit (or greenhouse) if TCES is open
- If TCES is closed, start the tour outside the front doors of the building
- Bathrooms needed? Make sure all visitors needs are met and start discussing the relationship between UC Davis TERC and SNU until everyone is ready
- Where are you from? How much time do you have available?
- What is a demonstration garden?
- Brief history of the garden's ownership and management

Land acknowledgement/indigenous use of plants

- Acknowledge that we are walking on the traditional territory of the Washoe Tribe

Trees of Tahoe (theme: understanding Tahoe's forests)

- What are the four most common types of trees found in Lake Tahoe? What are the eight most commonly seen trees in Lake Tahoe?
- How to identify pines, firs, cedars, junipers, and aspens
- What does a healthy forest look like?
- What affects forest health/what are the biggest threats to Tahoe's Forest health?
- What are UC Davis TERC forest ecologists studying?
- How can forest health affect Lake Tahoe?
- History of forest management and the role it has played in CA wildfires

Defensible space (theme: Be fire prepared)

- What is defensible space?
- Defensible space zones, perimeter spacing, clear room
- Which plants are flammable? Which are fire resistant?
- Ladder fuels, flying embers

Why Garden?

- Green spaces in grey places - good for physical and mental health
- Gardens have environmental and economic benefits as well
- Appreciation for the environment/environmental stewardship

Phenology (theme: Impacts of climate change)

- What is phenology?
- Phenology citizen science project, data collection to track the shift in timing
- If there is time, walk through the data collection for green-leaf manzanita
- How can phenology data collection help scientists understand the effects of climate change on our native species? (Use supplemental images of plants in different phases that are laminated to help convey different stages of life, e.g., manzanita)

Native species (theme: What thrives in Tahoe?)

- Point out some of the native plants in the garden (this will vary depending on early, mid, or late season)
- What adaptations do the plants have for living in Tahoe's climate?
- Since they are adapted to Tahoe's climate, they are better choices for local gardens
- Local pollinators often will only pollinate native plants

Pollinators (theme: Tahoe's native pollinators)

- What are the main pollinator species in Tahoe?
- What type of plants attract pollinators?
- What plants are certain pollinators attracted to?
- Selecting plants that bloom in each season to attract different pollinators throughout the spring and summer

Best Management Practices (BMP's)

- What are BMPs? What are some examples of BMPs?
- What is erosion? How can it be controlled? Why are we concerned about erosion especially in the Tahoe Basin?
- Go through the other BMP examples in the garden and why they are considered best management practices

Demonstration Garden Tour Introduction

Welcome to the North Tahoe Demonstration Garden. UC Davis TERC took over management of the garden in 2018, but it is located on Sierra Nevada University's property and is partially managed by IVGID (Incline Village General Improvement District). Maintaining the garden is a collaborative effort between these entities. Since UC Davis TERC took over management and maintenance of the garden, they have created new interpretive signs and utilized it as a space for outdoor education.

The North Tahoe Demonstration Garden is broken into sections to demonstrate different environmental topics including pollinators, native species, wildfire, and best management practices. The garden serves as a place to grow fruits and vegetables, and an educational space for the community.

The learning objectives of the tour are for visitors to learn:

- Common tree species found in Tahoe's forests
- Factors of a healthy forest/forest ecology and how forests impact the lake
- Forest health and management as it relates to wildfire
- Impacts of wildfire and implementing defensible space practices
- Importance of gardens and gardening
- Native plant species to the basin and why choose native plants
- Indigenous land, uses of native species, and acknowledgement of their culture
- Pollinators and their importance
- Best Management Practices and their importance

Included in the docent manual is a Garden Tour Cheat Sheet, talking points, and relevant images. Most talking points are accompanied by an interpretive sign in the garden (not all the information needs to be utilized, so pick your favorite topics or the ones you feel most comfortable talking about or the ones relevant to your visitors' interests). The order of the tour can be adjusted based on the audience or the docent, however the order of the talking points and cheat sheet is based on the layout of the garden and the interpretive signs which will flow the easiest.

Demonstration Garden Tour Talking Points

Welcome and History of the Demonstration Garden

To begin the tour, cover the information on the “Welcome to the North Tahoe Demonstration Garden” interpretive sign whether you are beginning the tour at the Trees of Tahoe exhibit, or outside TCES/while walking to the demonstration garden. This details the shared management of the demonstration garden, what a demonstration garden is, and a map for navigating the garden if anyone would like to complete a self-guided tour.



Land acknowledgement

We have drafted a land acknowledgement to highlight the significance of the Washoe and other Indigenous Tribes living in harmony with the land. It is our goal that by acknowledging the traditional land we live and rely on. We intend to educate our visitors about living in harmony with the land while building a relationship with indigenous people. This land acknowledgement has not been approved yet, but we expect it to be finalized and will be included as a separate information sign at the demo garden.

Trees of Tahoe

Discussion of the various trees of Tahoe can take place either on the walk from the science center to the garden, or near this interpretive sign:

The Importance of Forests

We depend on forests for our survival, from the air we breathe to the wood we use. Besides providing habitat for animals, forests also offer ecological functions including watershed protection, water and air purification, and carbon storage.

The Sierra Nevada forest boasts native trees such as sugar pine, Jeffrey pine, ponderosa pine, lodgepole pine, white-bark pine, red fir, white fir, incense cedar, and aspen. These trees thrive and grow to splendor despite a harsh environment.

UC Davis TERC is also working to restore Tahoe's sugar pines. Thousands of seeds collected from drought-survivors have grown into seedlings. These mighty little trees carry genetic information that we hope will enable them to better survive future events of longer droughts and more intense beetle infestations.

Color foliage are lush with the branch in the form of flattened sprays of scaly leaves.

Fir needles are soft and flat and are individually attached to the branch.

Pines can be identified by the bundles of needles fastened to each branch by a "fascicle."

TERC Lath House

Bark Beetle Gallery

Bark Beetle

UC DAVIS
Tahoe Environmental
Research Center

Photos by Charles Adams, Ed Summers, Matt Smith, and Allison Toy

Tree identification:

There are four common trees found in Tahoe's forests, pines, firs, cedars, and aspens. You might also see a juniper which is less common but can be easily found on this campus. On the walk to the garden, point out an example of each type of tree and how to identify it. If the science center is open, you can use the Trees of Tahoe exhibit to demonstrate the different branches, pinecones, and bark.

Below are some of the key identifying features of each tree:

- Pine: needles attached in bundles (fascicles) of 2,3, or 5
- Fir: shorter needles attached individually to the branch
- Incense cedar: flat, scaly, segmented needles, cinnamon red bark
- Quaking aspen: deciduous tree, rounded leaves that come to a point, white bark
- Juniper: Spiny, scaly needles, that grows in a circular fashion, berry-like cones

There are four common pine trees:

- Ponderosa: needles in bundles of 3, pokey pinecones (the spines face out), puzzle piece bark
- Jeffrey: needles in bundles of 3, gentle cones (the spines face in), bark smells sweet like vanilla or butterscotch

- Lodgepole: needles in bundles of 2 (makes L shape), cornflake bark, small pinecones
- Sugar: needles in bundles of 5 (5 letters in the word S-U-G-A-R), foot long pinecones

There are 2 common fir trees:

- White: needles spread out wide from the branch, found at lower elevations (all the firs in the demonstration garden are white fir)
- Red: needles go around the branch, found at higher elevations

Here are some example questions you can ask during this section:

- Find examples of each type of tree on the way to the garden. Point out the key traits and how you know what tree it is. After going over the basics you can quiz them - what kind of tree do you think this is?
- Pick up a pinecone - what tree do you think this fell from?
- Find a Jeffrey pine and have them smell the bark - what does it smell like?
- Why is it important to be able to correctly identify trees?
 - It gives you a new-found awareness of the forest and allows you to assess forest health
- Why are trees important? - you can discuss these facts with them or give them time to read “The Importance of Forests” interpretive sign on their own.
 - They provide the air we breathe by producing oxygen and they are “carbon sinks”, which means they pull CO² out of the air and store it for an indefinite period of time.
 - Wood from trees also provides us with resources like fuel, paper, cardboard, etc.
 - They provide shelter for wildlife

Forest health:

Just like people, forests can be healthy or unhealthy. Forest ecologists can determine the health of a forest by assessing a few key features:

- Biodiversity - the variety of tree species
- Age diversity - the variety of age groups
- The amount of tree mortality - how many dead trees are present in the forest
- Other types of life in the forest - plants, animals, and fungi

Ask visitors if they can see these various factors in the forest around them as you all go through the tour and revisit this question at the end of the tour to see what observations they made and what conclusions they have come to.

A healthy forest has high biodiversity, high age diversity, most of the trees and plants are alive, and there are signs of other types of life living in the forest. These are all factors that the forest is more resilient to change, reproducing well, alive, and able to sustain other types of life.

A healthy, resilient forest can withstand stressors, however, if the forest is dealing with multiple stressors at once, it can become unhealthy and at risk of higher levels of tree mortality. The biggest threats to Tahoe's forest health are:

- Drought
- Wildfire
- Parasites
- Pathogens
- Competition for space and resources

What are UC Davis forest ecologists studying?

UC Davis TERC's Forest and Conservation lab studies forest health, population dynamics of forest tree species, ecological genetics, and restoration and conservation biology. Forest health and population dynamics pertains to the information we just discussed about the different trees found in the basin and how to assess factors that affect forest health.

The ecological genetics project focuses on collecting pinecones from trees that survived stressful events, such as wildfire, drought, and bark beetles. Basically, in a stand of dead trees we are looking for the survivors, assuming that the key to surviving catastrophe is in their genes. Researchers collect pinecones from those surviving trees as their seeds potentially hold the genetic material that enabled them to survive. By collecting their cones, we can selectively breed more resilient trees and plant them in the forest with the hope that they will be better adapted to surviving stressful events. The cones collected for the genetics conservation project are from Sugar Pine trees, which are one of the most common trees found in the basin. They are chosen because their population size has been declining due to increased mortality from the recent four-year drought (2011-2015) and non-native, invasive fungus called white pine blister rust. Adverse effects of white pine blister rust are on cone production and survival of smaller, intermediate-sized trees. This project aims to increase forest resilience in the future by having traits that are selected to tolerate stress and to increase biodiversity by increasing the sugar pine tree population.

How can forest health affect Lake Tahoe?

Forests stabilize soil by anchoring it in place with their roots, preventing eroding soils from running off into nearby streams, rivers, and lakes. By preventing erosion, forests are reducing the amount of soil and sediment particles that would enter the lake and be suspended in the water, thus preventing lake clarity from declining. Sediment

cores taken from the bottom of Lake Tahoe show an increase in sediment and plant debris erosion into the lake during the Comstock Logging Era that clear cut $\frac{2}{3}$ of the trees in the basin providing evidence on the erosion impacts of not having as many trees. Trees also absorb nutrients from the soil. Without trees and other flora, those nutrients would enter the watershed and could cause algal blooms, which change the lake from clear blue water to a murky green color. The trees in our forest prevent those nutrients from entering the lake, which helps maintain the crystal-clear water that Tahoe is famous for. Additionally, trees can sequester carbon through photosynthesis which reduces the amount of carbon in our atmosphere contributing to climate change. Healthy, robust forests can sequester more carbon than deforested areas or areas that have a higher percentage of dead than alive trees.

History of forest management:

The need for forest management in the Tahoe Basin was made clear after the Comstock mining era. Over two-thirds of the Tahoe Basin was clear-cut from 1858-1900 as the lumber from Tahoe Basin trees were used to shore up the silver mines near Virginia City/Carson City areas (during this time, the loss of trees was also shown to increase sedimentation into Lake Tahoe). Many of the trees that survived the Comstock era were fir's, which left behind a low biodiversity, fir-dominated forest. The forest also had low age diversity since the trees all grew back at the same time. And a period of fire-suppression led to a dense and unhealthy forest, which eventually led to the need for new strategies of environmental policy and forest conservation and management that is responsive to a changing climate.

The way our forests are managed also has a large impact on forest health and resiliency and how we manage our forests has changed over time. When indigenous people had control over their native land, they managed the forests by doing prescribed burns, also known as indigenous burns. These were forest fires they set intentionally to promote the growth of certain plants and to recycle the dead plant material back into the soil. This method of forest management reduced the amount of severe wildfires since the fuels that lead to larger, more intense wildfires were burned in the prescribed fires. However, when indigenous people lost the rights to their land, their practices were banned, and prescribed burns stopped. This led to fuels, in the form of vegetation, plant debris, and dead trees, building up on the forest floor, which in turn led to more intense wildfires when they came through the area.

After indigenous burns were banned, forest management switched to a fire suppression policy. At the time, scientists and environmentalists thought that the best way to "save the forest" was to stop it from burning at all. Prescribed burning was banned and any natural wildfire that started was put out. This led to more and more fuels building up on the forest floor, which led to more intense and large wildfires that were harder to extinguish. It wasn't until the last decade that forest management has changed to reflect the practices that indigenous cultures had been utilizing for hundreds to

thousands of years. Now the forest service unit in the Lake Tahoe Basin implements an ecological management practice that utilizes prescribed burns during colder wet seasons, paired with forest thinning. This management strategy creates a less dense, healthier forest that is more likely to be resilient during wildfire season.

Defensible Space

You can use the “Be Fire Prepared” interpretive sign to help assist you in this section. Use the visitors as a resource by asking questions, such as, what is defensible space? What kinds of things can you do to minimize the risk wildfire may pose to your home?



What is defensible space?

Defensible space is the natural or landscaped area around your home that is cleaned and maintained specifically to improve your home's chance of surviving a wildfire. Plants and trees are selected and placed intentionally to reduce the possibility of ladder fuels - low hanging branches and shrubs that would allow fire to climb higher and burn higher on trees - and to remove highly flammable, dry vegetation directly adjacent to your home. This also includes keeping combustible material, such as firewood and lumber away from any highly flammable vegetation and your house. “The most important person in preventing a house from being destroyed by wildfire is the homeowner.” - Tahoe Living with Fire. Proper defensible space helps firefighters safely protect your home as well as improving your home's chance of survival without assistance.

There are two defensible space zones. Zone 1 includes anything that is 30ft from your house, zone two includes anything that is between 30 to 100 ft from your home (or to the property line). *You can point to the diagram on the interpretive sign* It is recommended that you reduce or eliminate anything flammable in Zone 1. Do not store firewood up against or near your house. Flying embers are the main cause of homes burning down during wildfires. Wind and fire whirls can carry embers for over a mile and start new fires by landing on flammable material, which is why it is important to keep flammable materials away from your home. In Zone 2, try to thin out the trees and create space between any vegetation to help reduce the spread of the fire. Plant selection is also an important part of landscaping your yard to create defensible space.

While there are no plants that are “fire-proof” certain plants are more flammable than others. Anything fleshy and green that retains water such as an aloe plant or any other succulent that retains water is fire-retardant. In this garden, things like strawberry, sage, and lavender are all fire-resistant. The Green Leaf Manzanita is a common shrub found in Tahoe’s forests. *Point out a large nearby manzanita and have them feel the bark. Contrary to what some people believe, the bark is covered in a waxy resin that protects it from fire, making this a good fire and drought resistant plant to have in your yard, however their leaves catch fire quickly which is why people tend to remove shrubs that grow directly below a tree. *Point out a tree with dead branches* picture that large manzanita directly under that tree, what will happen if the leaves catch fire? This is called ladder fuels. Tree bark on evergreen trees is fire resistant, which means that the limbs are more prone to burning than the trunk. Trees grow upwards leaving the lower dead branches below. This is an adaptation older trees must protect themselves from fire. If you “limb” those dead branches and remove close shrubs to prevent ladder fuels, it decreases the chance of the fire from moving up the evergreen tree and increases the likelihood of the bark’s ability to protect the tree from fire.

Living With Fire has a “Tahoe Plant Guide” if you want to learn more about plant choice and defensible space: https://www.livingwithfire.com/wp-content/uploads/2018/10/Tahoe-Plant-Guide.final_.pdf

At the shed:

This is a defensible space model *gesture to the shed*. The shed represents a home in the Tahoe landscape. You can ask the following questions:

- What things do you notice about this model?
- Is this modeling good or bad defensible space?
- If this was your home, would you feel safe?
- What would you change about the landscape here to make it safer?

Why garden?



Why Garden?

Keeping a fruit, vegetable, and flower garden at home adds major benefits to your life, wallet, and the world around you!

Physical

- Expose yourself to beneficial soil microbes, helping you resist infection
- Increase the likelihood of eating your fruits and veggies

Mental

- Excellent for stress relief and exercise
- Decrease depression and anxiety by spending time in green spaces
- Wonderful for meditative practices

Economic

- Increase property value
- Harvest more food from seed – far cheaper than the grocery store

Environmental

- Remove and store atmospheric carbon dioxide through plant growth
- Reduce industrialized farming, as well as meat and dairy consumption, which are linked to about 30% of human-caused climate change
- Grow many varieties of flowers, shrubs, and trees to mimic a healthy functioning ecosystem, resilient to disturbances
- Keep it local. Growing food in your own backyard is about as local as it gets; and there's no plastic packaging!

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Photos by Adam Toy

There are many benefits to gardening. Studies have shown that gardening can improve your mental and physical health. According to a study published by Clinical Medicine, “several trials have revealed the beneficial effects on mood and mental health of simply observing nature, or even images of natural scenes. In a Japanese study, viewing plants altered EEG recordings and reduced stress, fear, anger, and sadness, as well as reducing blood pressure, pulse rate and muscle tension.” Your body can feel the positive effects by just being in a garden and observing nature. Having access to green spaces and gardens is beneficial to people, as well as the environment.

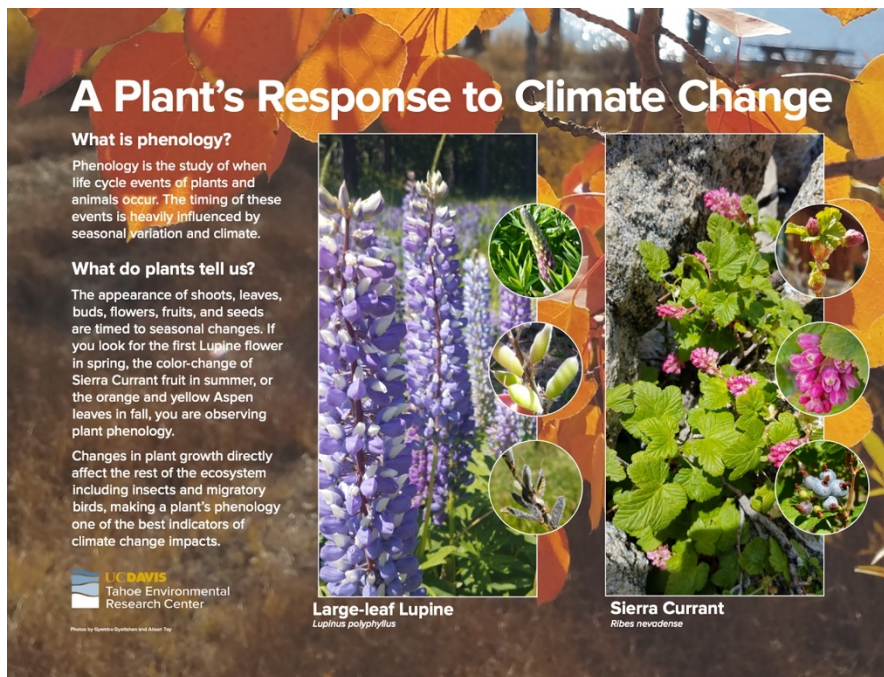
Gardening can limit your carbon footprint in a variety of ways. Plants sequester carbon dioxide naturally during photosynthesis. They pull CO₂ out of the atmosphere and use it to create the energy they need to live and the oxygen we need to breathe. Having more gardens and green spaces decreases the amount of carbon dioxide in the atmosphere, which helps counteract climate change and air pollution.

When you grow your own food in a garden, you are also reducing the amount of carbon dioxide in the atmosphere. Buying fruits and vegetables at a grocery store typically means that you are purchasing produce that was grown at a farm, packaged, and then transported to your grocery store. Produce can be transported from a town away, or a state! 90% of avocados in the US are grown in California. Which means if you are in New York and you buy an avocado at the grocery store, it requires a significant

amount of energy (and carbon) to get it to you. If you grow your own fruits and vegetables though, you can greatly reduce your carbon footprint.

If this hasn't made you want to start your own garden, there are economic advantages as well. Seeds are much cheaper than produce at the grocery store, which is how a productive garden can end up saving you money in the long run. Having a garden at home can also increase your property value. A well landscaped yard or garden can increase your home's "curb appeal", which increases the amount that your property is worth. It also makes your home more appealing, increasing the number of buyers which helps your home sell faster.

Phenology



What is phenology? How can phenology data collection help scientists understand the effects of climate change on our native species?

Phenology is the study of when life cycle events of plants and animals occur and is heavily influenced by variation in the seasons and climate. When you walk through the garden and see flowers blooming in spring, or aspen leaves changing color in fall, you are witnessing phenology. According to the National Phenology Network, “[c]hanges in phenological events like flowering and animal migration are among the most sensitive biological responses to climate change.” For example, if climate change reduces the winter season, spring weather will start earlier in the year, causing flowers to bloom earlier and animal migration to start sooner. Scientists can monitor the shift in timing of life cycle events to determine how climate change might affect plants and animals.

Questions to ask:

- How do you think we witness phenology in this demonstration garden?
- If our winter seasons start shrinking, how do you think this will affect the plants in the garden? And the animals who rely on those plants?
- How do you think we can monitor these changes?

National Phenology Network - Citizen Science Project

You can collect phenological data on a variety of native plant species in our garden to help scientists understand how climate change is impacting the timing of life events. *Find the Greenleaf manzanitas that are being monitored* The Greenleaf manzanita is one of the plants you can collect data on and contribute to the National Phenology Network citizen science project, Nature's Notebook. You can create an account online to input the data you collect. Here is what the datasheets look like *show guests the manzanita datasheets*. Phenology data for this shrub requires you to look at the leaves, flowers, and fruits and determine what stage each of these parts are at. By collecting data on the same plants every year throughout the seasons, scientists can determine if there has been a shift in the timing of any key life cycle events, like the leaves budding, flowers blooming, or fruit ripening.

Have the guests help you fill out the datasheet. The data can be input after the tour is over.

Not all species are adjusting to the changes in life cycle events at the same rate, which can disrupt how species interact with each other. One example that can be observed in the garden is the timing of plants blooming with butterfly migration. If the plants bloom before butterflies begin their annual migration, they might not get pollinated. If caterpillars emerge from their cocoons early, they might not be available as a food source for birds when they are feeding their young. Both examples show how species interactions can be disrupted, which can impact the health of the whole ecosystem. This is why it is important to study and determine how the changing climate is impacting the native plant species, and thus the pollinators and other animals that interact with them.

Native species

Some Plant Choices Are Wise, Some Are Otherwise

Native Plants
Native plants include the green grasses, flowering shrubs, and fruiting trees indigenous to the local ecosystem.
Native plants keep Tahoe's ecosystem healthy by providing food and shelter for local wildlife and pollinators.
Plants native to Tahoe need less water because they are adapted to Tahoe's dry climate. They also need less fertilizer, because they are more efficient at cycling nutrients back into the soil.

Native Creeping Phlox
Phlox subulata

Greenleaf Manzanita
Arctostaphylos patula
Manzanita is a common native shrub with value to native wildlife. Due to its horizontal leaves, we recommend thinning dense areas. As you wander through the garden, discover what kind of data citizen scientists are collecting.

Thimbleberry
Rubus parviflorus
This plant is a member of the rose family and bears fruit resembling a fermented raspberry. The fruit does not contain its shape which makes it difficult to transport correctly. However, its large berry leaves and leaf of thorns are ideal for landscape education.

Shasta Daisy
Leucanthemum maximum
The adopted Shasta daisy is easy to propagate, but be aware, the Owyhee daisy looks identical and is highly invasive! The Shasta daisy has a root ball. The Owyhee daisy has a creeping root system that allows it to spread rapidly and crowd out other plants.

Invasive Plants
Invasive plants alter the natural cycle of water and nutrients, disrupting the ecosystem. By overspreading or over-seeding, they dominate the landscape, choking out native species, reducing plant biodiversity, and decreasing habitat for native pollinators.
Non-native plants are those that have been introduced (on purpose or accidentally) from other parts of the world. They can either adapt to the local environment or become invasive if they outcompete native plants and alter ecosystems.

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Special thanks to Tisha Cooper Long, Mimi Kowalski, Sheila LeDine, Margaret Solomon, and Janet Steinmann for content advising.
Photo: Bob Lee

Point out some of the native plants in the garden (this will vary depending on early, mid, or late season)

- Early Season flowers:
 - Creeping/Spreading Phlox (pictured on interpretive sign): a popular landscaping ground cover. You can also find it on rocky slopes in Tahoe. It is one of the first flowers to bloom in Tahoe and the dense clusters of flowers change colors from white to pink-purple which can assist pollinators in identifying the unpollinated flowers.
 - Mahala Mat (another ground cover with purple flowers): found in Tahoe's dry, open forest areas, does not transplant well. While it's found in people's yards, it is naturally occurring, not a result of landscaping efforts. The small, dark evergreen leaves are holly-like in shape, and they carpet the forest floor. In the early season, they are studded with blue to purple flowers with bright yellow stamens. Flowers fruit in mid- to late- season with wrinkly looking capsules that are yellow to tan in color with reddish tips.
 - Greenleaf Manzanita: a common shrub easily identifiable by its smooth, resinous branches that are cool to the touch. The layers of outer bark will peel off over time. It is common at lower elevations in the Tahoe Basin and has oval-shaped evergreen leaves and in the early season, it has clusters of white to pink hanging urn-like flowers with 5 lobes at the tips. These flowers turn to reddish-green then brown fruits in the mid- to late-season.

- Mid-season flowers:
 - Blue/Mountain flax: it has brilliant, satiny blue flowers that droop on thin, graceful stems that wave gently in the breeze. It is also a very popular ornamental plant. These blooms lose their unfused petals quickly after a full bloom and has cultural uses of weaving and making strings and cords.
 - Large Leaf Lupine: bumblebees love this plant, found abundantly throughout the Tahoe Basin and a very popular landscaping choice. Grows large and bushy with large dark purple flowers on long, tall inflorescence stalks and has the distinctive palmate leaves.
 - Woolly Mule's ears: a well-known showy yellow flower. Its large namesake leaves are covered in fine matted hairs and are shaped and taper down like the ears of a mule. They are found in large populations in open fields. They are often confused with Arrowleaf balsamroot, which flowers in early season and has glabrous leaves that are cordate rather than tapering down like the Woolly Mule's ears.
- Late-season flowers
 - Shasta daisy: a tall flower with a classic daisy appearance with white ray flowers and a yellow center of individual flowers. This is a popular cultivated plant that is the recommended flower of choice over the invasive oxeye daisy.
 - Western Aster: it has small (but many) flower heads that range from pink to violet-blue in color. These blooms with yellow centers are tiny, densely packed individual flowers. The plant grows in clumps with solitary flowers at the end of their stems.
 - Fireweed: a bright showy pink inflorescence with light hair-like seeds that can easily be wind-dispersed for a hundred kilometers. This easy dispersal method coupled with its ability to quickly spread through rhizomes makes the fireweed (while native) invasive. Its common names stem from its ability to quickly re-establish its population following a burn event.

What adaptations do native plants have for living in Tahoe's climate?

You can ask visitors:

- Why do you think it is important to utilize and plant native species rather than non-native plants?

Native plants to the Tahoe area and the Sierra are adapted to the sub-alpine environment. Native plants require less water and fertilizer to grow, which helps protect the Lake Tahoe Watershed. They require less water to grow because they are adapted to areas that frequently experience drought. These plants require less watering and typically rely on rainfall for their water needs, which reduces the amount of irrigation needed in a garden.

Non-native plants may require more fertilizer to grow in this area. Fertilizer can run off into nearby water sources, like creeks and streams or by running off directly into the lake. Fertilizer provides nutrients to plants, and helps aquatic plants grow the same way it helps land plants grow, therefore aiding the growth of algae in the watershed. Tahoe has a higher potential to switch from its famous blue color to shades of green if too much algae grows in the water. Planting native species reduces your need to use more water and fertilizer than necessary and protects the health of the aquatic Tahoe ecosystem.

Another benefit of planting native species is that local pollinators for these plants are already here. The plants attract the right pollinators to spread their pollen, increasing their chance of reproduction, and creating habitat for local pollinators. You will attract a wider variety of butterflies, hummingbirds, and bees with a native garden than a non-native one.

Pollinators

The Garden is Abuzz with Pollinators

The relationship between flowering plants and pollinators is mutually beneficial. The pollinator helps approximately 75% of the world's flowering plants produce fruits and seeds, while the plants provide food and shelter for the pollinators.

Unfortunately, human impacts such as habitat loss, fragmentation, pesticides, and climate change are leading to declines in pollinator populations.

Plant the right plants!

Choose plants that have not been treated with pesticides or insecticides. Think beyond the summer growing season, pollinators need nectar starting in early spring and sometimes through fall.

Leafcutter Bee
Megachilidae sp.

Anna's Hummingbird
Calypte anna

Northern Checkerspot
Chlosyne palla

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Photos by Kimberly Beaman and Adam Top

What are pollinators?

Pollinators are animals that forage for food in flowers to eat nectar. They spread pollen from plant to plant as they feed. The most common types of pollinators are birds, bats, bugs, and bees. The Tahoe Institute for Natural Sciences explains how animals pollinate flowers, “As they visit each flower, dusty pollen from the anther, or male part of a flower, attaches to their bodies. The pollen on the pollinator’s body then spreads to the pistil, or female part of the flower. The transfer of pollen helps plants to create seeds and

fruits resulting in more flowers.” This is an extremely important process because without pollinators, many flowers wouldn’t be able to fruit, which would decrease the amount of food available across the world.

What are the main pollinator species in Tahoe?

Some of the main pollinators found in the Tahoe area:

- White-lined Sphinx Moth
- Longhorn beetles
- Rufous hummingbird
- Anna’s hummingbird
- California sister Butterfly
- Northern checkerspot butterfly
- Painted lady butterfly
- Honey bees
- Leafcutter bees

*Tahoe has many species of bats, but they are all insectivores and do not feed on nectar. Therefore, they are not pollinators.

Have you noticed any of these pollinators in the garden?

What type of plants attract pollinators?

- Coneflower, *Rudbeckia californica* (attracts bees and other pollinators)
- California fuschia, *Epilobium cancum spp. Canum* (attracts hummingbirds)
- Creeping mahonia, *Mahonia repens* (attracts pollinators and birds)
- Scarlet Bee Balm, *Monarda didyma*
- Blanket flower, *Gaillardia pulchella*

You can select plants that bloom in each season to attract different pollinators throughout the spring and summer. Additionally, by ensuring you have blooms all season long, this ensures that pollinators have food all season long!

Best Management Practices (BMPs)



What are BMPs?

BMPs are practices that homeowners can implement to help reduce and prevent water pollution. These practices can be structural, vegetative, or managerial. Below are examples of BMPs that help protect the water in Lake Tahoe.

- Rock-lined swales are channels lined with rocks that carry stormwater runoff to a location where the water can be stored until it can soak into the soil.
- Vegetated swales are channels lined with vegetation (usually grasses) that carry stormwater runoff to another location where the water can be stored until it can soak into the soil.
- Infiltration systems catch and hold stormwater runoff allowing more time for it to soak into the ground.
- Slotted channel drains are metal-grated devices that intercept surface runoff and convey it to location for infiltration.
- Subsurface conveyance pipes collect and transport runoff underground to appropriate locations for better treatment or discharge.
- Riprap (slope stabilization) includes large, angular rocks or cobbles used to protect soil on bare, eroding slopes. Other stabilization methods include retaining walls, terraces, vegetation, and erosion control blankets.
- Dripline rock armoring helps prevent soil erosion caused by roof runoff.

- Vegetation under drip lines stabilizes the soil and infiltrates roof runoff. It is important to use fire-wise plants in these areas. For more information, visit www.livingwithfire.com.
- Native and adapted vegetation in landscaping requires less maintenance and uses less water.
- Lean, Clean, and Green. Keep all flammable material and vegetation away from structures. Remember to be lean, clean, and green. For more information, visit www.livingwithfire.info.
- Defensible space is the area between a building and an oncoming wildfire where the vegetation has been managed to reduce the wildfire threat and allow firefighters to safely defend the house. Defensible space also improves the likelihood that a house can survive without assistance. For more information, visit www.livingwithfire.info.
- Forest thinning: As a stand of trees grows, individuals compete with one another for sunlight, space, water, and nutrients. Thinning can improve tree health for remaining trees and be an effective tool for wildfire hazard reduction.
- Butterfly Garden: Choose specific plants that are attractive to various butterfly species, and you can create a habitat and a beautiful garden too.
- Groundcover alternatives: Choosing native groundcover instead of lawn saves water, reduces the number of harmful chemicals in our environment (e.g., pesticides, fertilizers, and herbicides), and takes less effort... all while you protect the lake.

Questions to ask visitors:

- What BMPs do you notice in the garden?
- Do you have any BMPs at your home?
- Are there any BMPs that you could install at your home?

What is erosion? How can it be controlled? Why are we concerned about erosion especially in the Tahoe Basin?

Erosion is the process of something slowly being broken down by wind, water, and other natural agents. When erosion occurs, it can break up rock and soil and move it from one place to another. This process can transfer soil and other material from land into water, which can act as a source of pollution. In the Tahoe Basin, BMPs are used to prevent erosion from polluting the water, which helps improve lake clarity.

Go through the other BMP examples in the garden and why they are considered best management practices

Point out the BMP examples in the demonstration garden. There are:

- (Slope stabilization) includes large, angular rocks or cobbles used to protect soil on bare, eroding slopes.
- Infiltration systems catch and hold stormwater runoff allowing more time for it to soak into the ground.
- Groundcover alternatives: Choosing native groundcover instead of lawn saves water, reduces the number of harmful chemicals in our environment (e.g., pesticides, fertilizers, and herbicides), and takes less effort... all while you protect the lake.

Green Building Information

Adapted from Green Building Communication from Bill Starr, UC Davis Architects & Engineers and lead UC Davis architect on the Tahoe Center for Environmental Sciences Building project

Why Green Building?

While fundamental to human activity, buildings and their associated land development dramatically alter existing ecosystems, consume energy, use water and deplete resources. Present-day designs consume large quantities of physical resources such as materials, energy and money in their construction, maintenance, and use.

Data from the US Energy Information Administration illustrates that buildings are responsible for almost half (32%) of all energy consumption and global greenhouse gas (GHG) emissions annually; globally the percentage is even greater. Each day 5 billion gallons of drinking water are used to flush toilets.

Construction and building operations consume tremendous amounts of raw materials and their associated waste streams use landfill space, increase eutrophication of water bodies, and degrade soils. In addition, the quality of indoor environments is fundamental to people's health and well-being, with people in the US on average spending upwards of 90% of their time indoors.

Green Building practices offer tremendous potential to improve the overall environmental performance of buildings while increasing the quality of the indoor environment for the occupants. Applied in an integrated manner, these practices also can generate operational savings as well.

Tahoe Center for Environmental Sciences (TCES)

Because of their focus on environmental science, Sierra Nevada University and the UC Davis Tahoe Environmental Research Center strove to create a world class teaching and research facility that would be a model of best practices in Green Building.

LEED

The United States Green Building Council's Leadership in Energy and Environmental Design (LEED) program was the tool used during design and construction to measure the environmental performance of the building's design and construction.

The TCES is the first building in Nevada to earn a LEED Platinum Certification, the highest certification level available. With exemplary performance in major categories that include:

- Energy and Atmosphere
- Water Efficiency
- Materials and Resources
- Indoor Environmental Quality
- Sustainable Sites
- Innovation and Design

U.S. Green Building Council (USGBC)

LEED CATEGORIES

Green Tours Available • Ask at the Front Desk

Leadership in Energy and Environmental Design (LEED)



Energy and Atmosphere

Buildings account for more than 1/3 of energy use in the U.S. Most of this use relies on fossil fuels. Reducing energy consumption, using alternative sources, and recycling waste heat, cuts down on costs and greenhouse gas emissions.



Water Efficiency

Less than 1% of the world's water is fresh and available for use. Low flow faucets, dual flush toilets and rain or snowmelt collection are some of the measures which reduce water consumption by more than 30%.



Materials and Resources

Construction/demolition wastes account for 40% of the solid waste stream in the U.S. By using recycled and renewable materials we reduce pollution and environmental impact.



Indoor Environmental Quality

Indoor environmental quality affects health and productivity. Fresh air and natural lighting create a healthy space. Using low volatile organic compound (VOC) paints and finishes reduces harmful toxic chemicals.



Sustainable Sites

Construction can have a harmful effect on local ecology. Choosing an already developed area, milling trees on-site from the building footprint, and controlling erosion/run-off, mitigates ecological impact.



This exhibit in the Tahoe Science Center highlights some of the green building practices.

Examples of the green building practices particular to this building include:

- Using 60% less energy vs. a similar building built to code
- Providing 10% of building energy from on-site renewable sources
- Using 65% less potable water use vs. a similar building built to code
- Diverting 86% of the construction waste from landfill disposal
- Using materials with high recycled content and low toxicity from regional and sustainable sources.
- Providing indoor environments with access to views and daylight that are ventilated with 100% outdoor air.

SUSTAINABLE SITES

Many of the best practices listed in the LEED site requirements are already mandated locally by the Tahoe Regional Planning Agency. These include stringent erosion control measures, stormwater infiltration and limitations on land coverage. This project included the following additional best practices related to site development.

Alternative Transportation: **Bike racks and showering/changing facilities** are provided at the building. These combined with **local bus and campus shuttle** stops provide occupants an array of alternative transportation options.

Exterior lighting is directed down and/or to the sides, **preventing light pollution** in the night sky.

WATER EFFICIENCY

Landscaping: In addition to local requirements for low water use landscaping, the landscaping here is designed with **native plants to go without irrigation** after being established with temporary irrigation for the first 3 years. Once established, native plants require no irrigation or fertilization and are resistant to most pests and diseases.

Efficient Fixtures: **Low flow faucets** with automatic sensors powered by batteries that are recharged by small solar cells receiving energy from the bathroom ceiling lights. **Low flow showers** use a nozzle design that increases the velocity to provide similar shower sensation with only 60% of the water. **Dual flush toilets** have two different buttons which use 0.8 and 1.6 gallons of water, depending on the flush. This half flush/full flush technology can reduce water usage by up to 67% compared with the traditional toilet that uses 2.9 gallons in a single flush.

Alternative Water Sources: **Rainwater and snowmelt** from the roof are collected in a tank in the basement, filtered, sanitized and pumped to flush the toilets.

ENERGY AND ATMOSPHERE

The TCES is one of the most energy efficient laboratories in the world. To achieve this level of performance, a comprehensive approach was needed that included:

Demand Reduction

- Understand the needs: Research and quantify occupant needs
- Passive strategies: Incorporate passive strategies including high performance building envelope, daylighting, solar heating, natural ventilation and cooling
- Design: Choose high efficiency designs and details
- Equipment: Choose efficient equipment
- Controls: Create control strategies that optimize equipment operational efficiencies

Alternative Sources

- Capture waste energy
- Capture renewable energy

It can be especially difficult to get a lab building certified by LEED because of its energy demands. Like most buildings, the TCES building uses energy for heating and cooling, ventilation, hot water, lighting and equipment. Unlike most buildings, it also uses energy to sterilize lab utensils, purify lab grade water, and to pump and filter rainwater on site.

During the planning of the TCES building, monitoring of the equipment used in existing university laboratory space identified that typical lab cooling requirements would result in oversized cooling equipment for the actual cooling needs of the occupants. By validating a reduced cooling demand, smaller and more efficient cooling systems were possible.

Passive Systems

Well-insulated building skin shell including the walls, ceiling, and basement walls has a high resistance to heat flow. The windows are insulated glass with a low-e coating (reduces heat transfer across the glass) and argon gas in between the panes of glass.

Free **day light** enters atrium skylights and perimeter room windows, prompting photo sensors to turn off the electric lights when enough day light is present.

Ventilation

100% outside air is filtered, de-humidified or humidified (depending on the season) and delivered to the rooms via **personally adjustable floor level outlets** in the offices, sidewall outlets in the classroom spaces and ceiling mounted induction diffusers, or “chilled beams” which provide supplemental heating or cooling (see Cooling below). The use of water-based supplemental cooling and heating allows the volume of air to be dramatically reduced (less air is needed to deliver heating/cooling) which allows the use of 100% outside air in lieu of re-circulated air (see Indoor Environmental Quality below).

Carbon dioxide sensors in classrooms and conference rooms monitor the rooms and increase the amount of outside air delivered to these rooms when the number of occupants increases.

Heating System

Heat is provided primarily from two 93.5% efficient natural gas-fired **condensing boilers** (vs. 80% efficiency for standard boilers). Additional “waste” **heat is recovered** from the laboratory exhaust stream and the casing and flue of the natural gas-fired co-generation microturbine (see Alternative Sources below). The heat is added to the incoming outside air and additional heating is delivered to spaces through **radiant floors** in the lobby, **radiant ceiling panels** in offices and induction coils in the laboratories.

Hot Water

Domestic hot water is pre-heated by **solar hot water panels** on the outdoor Trex enclosure, stored in a hot water storage tank in the basement and then heated to final temperature by the 97% efficient natural gas-fired water heater and circulated throughout the building.

Cooling

Cooling is provided by chilling water outside with “free cooling” through evaporation during nighttime hours via a cooling tower. This water is collected into two 25,000-gallon underground tanks. This cold water adds cooling to the incoming outside air and additional cooling is delivered to spaces through **radiant floors** in the lobby, **radiant ceiling panels** in offices and induction coils in the laboratories. This strategy eliminates the use of refrigerants (and their associated environmental impacts on global warming and ozone depletion) and is extremely efficient (refrigerant cycles are usually only 30% efficient).

Lighting

After making use of **daylighting** (as described under Passive Systems above), diffusing, **light-colored walls, ceilings, and laboratory counter tops** were chosen to allow lighting power to be reduced while improving visual acuity. **High-efficiency light fixtures** (that direct light downward and upward to reflect off of the ceilings) are **controlled by sensors** that dim the lights when daylight is present or turn the lights off when rooms are unoccupied.

Fume Hoods

Because of the huge volume of air flow through laboratory fume hoods, large amounts of heat would normally be lost through the roof vent. In order to diminish this heat loss, the TCES lab hoods have variable flow, almost completely stopping air flow when closed and out of use. Other TCES hoods turn off completely or recycle air within a room.

Power Generation

Electricity is generated on site by a microturbine and solar photovoltaic shingles. The **gas-fired microturbine** can generate approximately 21 kw of electricity (40% of the average building demand).

Generation on-site eliminates typical utility transmission losses of 7.2% and allows the capture of waste heat from combustion to heat the building's living spaces. This table shows the percentage of energy each source produces for TCES in both the summer and winter seasons.

TCES Energy Source	Winter	Summer
Utility	54%	48%
Photo Voltaic (PV)	2%	12%
CoGen	44%	40%
Total	100%	100%

The **solar shingles** cover the southeast facing roof with a total capacity of 20kw (Direct Current rating). This is fed to inverters in the basement that convert the Direct Current electricity into Alternating Current that can be fed to the building electrical service and is predicted to provide more than 10% of the building's annual energy cost, avoiding the use of the most inefficiently produced utility, electricity.

Operation

This building has undergone enhanced **commissioning**, a methodical process to ensure that the building functions as intended and will be checked regularly through ongoing measurement and verification. This is extremely important because of the level of complexity and connectedness of many of the building's systems.

MATERIALS

The TCES has recycling stations on each floor. During construction, over **85% of the construction debris was sorted and recycled** on site or shipped to a recycler instead of the landfill.

Materials re-used from site clearing:

- Mulch
- Landscaping rock
- Wood trim (milled from trees cleared from building site)

The new materials included in the building were selected for high levels of post-consumer and post-industrial recycled content resulting in over **25% of the construction material (on a cost basis) being recycled.**

Materials containing recycled content (not a complete list):

- Trex synthetic lumber (wood pulp)
- Concrete (fly ash from power plants)
- Structural Steel (cars)
- Wall Insulation (denim scraps)
- Carpet tile (soda bottles)

In order to reduce the environmental impacts of excessive transportation of construction materials, regional materials were selected whenever possible. On a cost basis, over 46% of the materials were manufactured within 500 miles and over 33% had their raw materials extracted within 500 miles.

Finally, to ensure that the building supported healthy forestry practices, over 52% of the wood materials used on the project were harvested from sustainably managed forests certified by the Forest Stewardship Council.

INDOOR ENVIRONMENTAL QUALITY

Americans spend on average 90% of their time indoors, where levels of pollutants may run two to five times - and occasionally more than 100 times - higher than outdoors, according to the U.S. Environmental Protection Agency. Hazardous pollutants may include carbon monoxide, radon, formaldehyde, mold, dirt and dust, pet dander, and residue from tobacco smoke and candles. In addition to standard best practices like restrictions on smoking indoors, other factors were taken into consideration to attain high indoor environmental quality.

High indoor air quality was targeted in the design with higher than typical ventilation rates and good design details that ensure delivery of that ventilation to the occupants. This quality was supported during construction by using products with no or low levels of volatile organic compounds, keeping the ductwork sealed during construction, and flushing the building with outside air prior to occupancy.

Lighting design was also emphasized. Over 90% of floor areas have direct views outdoors and all rooms have some natural lighting. This exposure to outside conditions can also enhance occupant health. Electric lights are low-glare and adjustable to occupant desires.

Careful consideration of occupant needs to adjust their environment to optimize comfort resulted in a combination of operable windows, individually adjustable floor diffusers in the offices, thermostats and zoned light switches in each of the work areas.

Sources:

- Bill Starr, UC Davis Architects & Engineers, communication 2009
- Architecture 2030 (www.architecture2030.org)
- US Green Building Council, 2009 LEED Reference Guide for Green Building Design and Construction
- US Green Building Council, The Green Home Guide